ZDMP: Zero Defects Manufacturing Platform

WP2: Business Challenge: Vision, Market, Use Cases, and Interlinking

D2.3 - Industry Scenarios and Use Cases - Vs: 1.1.1

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Abstract

The Industry Scenarios and Use Cases deliverable is a reference document focused on defining the top-level requirements associated to the industrial pilots that will be the validation scenarios of the ZDMP project. It also serves as the reference for guidance of which applications will be developed for project pilots.

Grant Agreement: 825631

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History

See Annex B.

Status

This deliverable is subject to final acceptance by the European Commission.

Further Information

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Disclaimer

Project Partners:

For full details of partners go to www.zdmp.eu/partners

Executive Summary

This document, “Industry Scenarios and Use Cases”, aims to characterise the different industrial scenarios addressed in ZDMP Platform. Task 2.3 activities are investigating the existing state-of-the-art of methodologies, architectures, technologies, and solutions currently applied in the four sectors addressed in ZDMP.
For each pilot scenario, the current state has been analysed pointing out where the ZDMP platform and the applications that run on top of it can affect it the most. Prioritization of the functionalities and a high level description of how the apps should work/interact have been drawn from the analysis in order to create a first set of requirements to be used as input for the RTD WPs (WP4, WP5, and WP6) and zero-defects applications development (WP7 and WP8). These general specifications also serve to prepare detailed specifications of each industrial pilot to be implemented in WP9, WP10 and WP11.

The use cases described in the ZDMP Description of Action (DOA) document acts as the foundation of this document.

The existing scenarios and solutions to be formulated in ZDMP scope are described in D2.3 following a common methodology for all the industrial sectors. The document is thus, organised under the following concepts:

- **Industrial Scenarios Characterisation:** ZDMP aims to formulate solutions that enhance manufacturing industries capabilities across targeted sectors. It is thus necessary to provide a generic understanding of manufacturing domains characteristics and needs and to identify the necessary strategies to be followed by the targeted industries.
- **User Scenarios:** In the scope of ZDMP, participating industrial pilots are the end users of the project platform and applications. To build such applications, pilots’ scenarios need to be described following a standard methodology in which objectives, processes, actors, and possible sets of data need to be defined.
- **Scenarios Classification and Analysis:** User scenarios that are addressed by ZDMP capture the needs of different industrial sectors and process domains. The scenarios described provide the guidelines to develop the application for each pilot. To build a global understanding, the scenarios classification and analysis are made based on classification standards such as Global Industry Classification Standard (GICS) and Supply Chain Management Processes.

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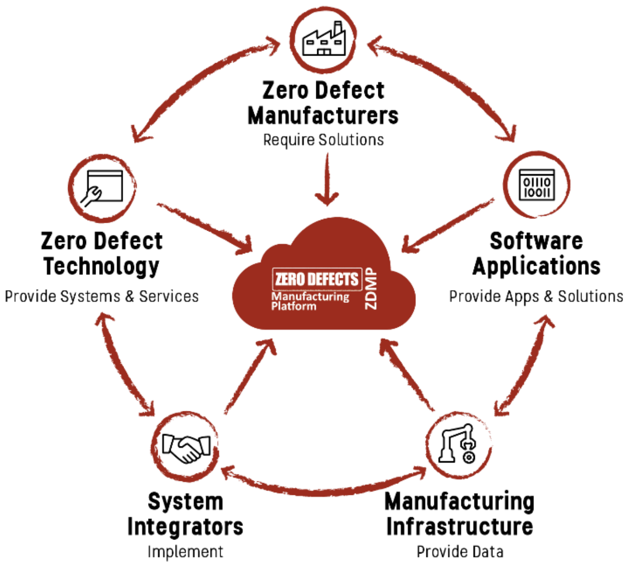
0 Introduction

0.1 ZDMP Project Overview

ZDMP – Zero Defects Manufacturing Platform – is a project funded by the H2020 Framework Programme of the European Commission under Grant Agreement 825631 and conducted from January 2019 until December 2022. It engages 30 partners (Users, Technology Providers, Consultants and Research Institutes) from 11 countries with a total budget of circa 16.2M€. Further information can be found at www.zdmp.eu.

In the last five years, many industrial production entities in Europe have started strategic work towards a digital transformation into the fourth industrial revolution termed Industry 4.0. Based on this new paradigm, companies must embrace a new technological infrastructure, which should be easy to implement for their business and easy to implement with other businesses across all their machines, equipment, and systems. The concept of zero-defects in the management of quality is one of the main benefits deriving from the implementation of Industry 4.0, both in the digitalisation of production processes and digitalisation of the product quality.



To remain competitive and keep its leading manufacturing position, European industry is required to produce high quality products at a low cost, in the most efficient way. Today, manufacturing industry is undergoing a substantial transformation due to the proliferation of new digital and ICT solutions, which are applied along the production process chain and are helping to make production more efficient, as in the case of smart factories. The goal of the ZDMP Project is to develop and establish a digital platform for connected smart factories, allowing to achieve excellence in manufacturing through zero-defect processes and zero-defect products.

ZDMP aims at providing such an extendable platform for supporting factories with a high interoperability level, to cope with the concept of connected factories to reach the goal of zero-defect production. In this context, ZDMP will allow end-users to connect their systems (i.e. shop-floor and Enterprise Resource Planning systems) to benefit from the features of the platform. These benefits include product and production quality assurance amongst others. For this, the platform provides the tools to allow following each step of production, using data acquisition to automatically determine the functioning of each step regarding the quality of the process and product. With this, it is possible to follow production order status and optimize the overall processes regarding time constraints and product quality, achieving the zero defects.

0.2 Deliverable Purpose and Scope

The purpose of this document "Industry Scenarios and Use Cases" is to take ZDMP pilots' descriptions from DOA, and further describe and characterise them. A comparative analysis of the status of the main manufacturing environments is performed, with special focus on supporting collaboration in the supply chain and classifying the different industrial scenarios that address ZDMP Platform and its applications.

Specifically, the DOA states the following regarding this Deliverable:

O2.3 To collect the high-level industry sector scenarios, Use Cases, and KPIs of the final industry users to address their specific zero defect problems and to define the generic KPIs to measure the improvements after applying ZDMP

T2.3	**Industry Sector Scenarios, Use Cases, and KPIs**			**FIDIA**	**M1-4**
D2.3	Industry Scenarios and Use Cases	R	PU	4	RDI1

This task will provide the identification and general definition of the different Use Cases belonging to each industrial pilot that will be used as validation scenarios of the ZDMP project. Specific zero-defect problems and top-level requirements associated with each Use Case will be addressed by obtaining a set of general specifications to be used for a better understanding of industrial pilots' needs as well as a first input for the RTD WPs related to ZDMP (WP4, WP5, and WP6) and zero-defects applications development (WP7 and WP8). These general specifications will also serve to prepare detailed specifications of each industrial pilot to be implemented in WP9, WP10 and WP11. Starting with the KPIs provided in this document, a list of specific KPIs will be defined for each use case including the procedure to measure current

The characterisation of the pilot Industrial Scenarios represents the starting point of innovative solutions that ZDMP project aims to develop. The deliverable document is thus a report that includes the characterisation of the main industrial scenarios, with particular emphasis on the pilots' industrial sectors and act as the main input of WP9 and WP10 – ZDMP Traditional and Extended Sector Cases.

0.3 Target Audience

Whilst primarily aimed at the project partners, this public deliverable can be useful for the wider scientific and industrial community. This includes other publicly funded projects, which may be interested in collaboration activities.

0.4 Deliverable Context

This deliverable will be used as input for the following activities:

- **Task 3.3**: Business Models and Business Case Development
- **Task 4.1**: Requirements Analysis
- **Task 4.2**: User Mock-ups
- **Task 9.1**: Traditional: Implementation Definition, Plan, KPI Validation/Measurement Criteria
- **Task 10.1**: Extended: Implementation Definition, Plan, KPI Validation/Measurement Criteria

It is not the purpose of this deliverable to describe the technical solutions envisaged for each use-case, but only to describe each application scenarios, its challenges and to suggest how possible ZD solutions should work, from the users' perspective.

0.5 Document Structure

This deliverable is broken down into the following sections:

- **Section 0:** Introduction: Provides an introduction to this deliverable, including a general overview of the project and an outline of its purpose, scope, context, status, and target audience
- **Section 1**: **Industrial Scenarios Characterization:** Provides a description of the current industrial situation and the technological advances beneficial of ZDMP
- **Section 2: User Scenarios Description**: Provides a detailed description of each ZDMP pilot, describing the "AS-IS" scenario, the "TO-BE" scenario and every application that will be developed in ZDMP for improving the "AS-IS" situation of the industrial pilot partners
- **Section 3: User Scenarios Classification and Analysis**: Provides an analysis of the user scenarios and a list of applications that address a set of problems identified within the presented industrial sectors
- **Section 4: Conclusions**: Provides a summary of the document, emphasising the most important aspects of user scenario characterisation

- **Annexes:**
  - **Annex A:** Document History
  - **Annex B:** References

0.6 Document Status

This document is listed in the Description of Action as "public" since it provides general information about the goals and scope of ZDMP and can therefore be used by external parties in order to receive insight into the project activities.

0.7 Document Dependencies

This document has no preceding documents.

0.8 Glossary and Abbreviations

A definition of common terms related to ZDMP, as well as a list of abbreviations, is available at www.zdmp.eu/glossary.

0.9 External Annexes and Supporting Documents

- None

0.10 Reading Notes

- None

0.11 Document Updates

Following the M9 Review comments the original document (v1.0.) was requested to be resubmitted (v1.1) and the issues raised were addressed as follows:

<table>
<tr><th>Issue</th><th>How/Where addressed</th></tr>
<tr><td>The consortium should provide a clear method to perform evaluation of the results of the project. A list of three or four Key Performance Indicators should be prepared for each use case.</td><td>Sections 2.X.2.3 now describe the key performance indicators for each use case. The tables list three or four KPIs on the selected manufacturing scenario. The previous and now removed Sections 2.X.1.4 which previously did include some criteria have been merged with the KPIs sections for clarity and coherence</td></tr>
<tr><td>The description of these KPIs should include the results that should be achieved, the metrics that will be measured and the process to measure them. These should be agreed with the consortium and in line with the objectives described in the DOA.</td><td rowspan="2">Clear quantitative metrics are largely provided for every KPI and have been revised for every use case. The changes include:
• Specification of the baseline
• Use of the same units for measurement of every KPI (time, cost, length, weight, etc)
• Use of both percentages of improvement and numerical values (number of parts/costs/time) whenever possible
• Examples of impact on specific production lines / application cases whenever the KPI baseline value is case-specific
• A brief description further specifies the KPI where the name may be unclear and provides general information on its achievement.
A new paragraph in Section 2 explains the methodology for the collection of the baseline value for the KPIs and further detail the application of the same measuring systems for the evaluation of the KPIs after the introduction of the ZDMP solutions.
The actual measuring processes/methodology and the experimental set up are subject of Deliverables 9.1 and 10.1 due in M18.</td></tr>
<tr><td>KPI for multiple Use Cases (e.g. Fig. 70) are unacceptably generic and lack baselines.

All KPIs need to be measurable and need to include a baseline. In cases where these values are product or line specific, a distinct exemplary product/line shall be selected.</td></tr>
<tr><td>Revise tables where sometimes “criteria” and sometimes KPI is used for the same item.</td><td>The no longer existing Sections 2.X.1.4 previously including the criteria descriptions have been merged with the KPIs sections for clarity and coherence.</td></tr>
</table>

In addition, the following comments were made which will be addressed in M18 Deliverables:

Issue	Comment
The description of these KPIs should include (…) the process to measure them.	The measuring process will be described in detail in Deliverables 9.1 and 10.1 due in M18 as per plan/DOA, together with the description of the experimental set up and the finalization of the KPIs.

1 Industrial Scenarios Characterization

The main objective of ZDMP is to develop a Smart, SME Friendly, Open, Zero-Defect Manufacturing Reference Platform, Apps, SDK, and Marketplace for product and Process Quality in any factory. Targeting the entire European Manufacturing Domain, the selection of an appropriate and representative collection of industrial scenarios to guide ZDMP development is no simple task. ZDMP considers use cases in quite different manufacturing domains, trying to answer to common needs and similar problems. Despite sectors such as automotive and construction being very different, they have in common, for example, the necessity to track products, the will for an easier communication across their value chain and the aim to detect quality issues at the earliest possible stages of production.

This chapter aims to provide an overview on the manufacturing sector, on its evolution in Europe, on its challenges and on how ZDMP technologies can support its advancement.

1.1 Industry 4.0

The Fourth Industrial Revolution, commonly known as Industry 4.0, appears to be changing the way businesses function and, by extension, their way of competing. Organizations must decide how and where to invest in these new technologies and identify which ones might best meet their needs. Without a full understanding of the changes and opportunities Industry 4.0 brings, companies risk to lose ground and market share.

In the Industry 4.0 paradigm, the integration of digital information from many different sources and locations can drive the physical act of doing business, in an ongoing cycle. Throughout this cycle (Figure 1), real-time access to data and intelligence is driven by the continuous and cyclical flow of information and actions between the physical and digital worlds [CS18].

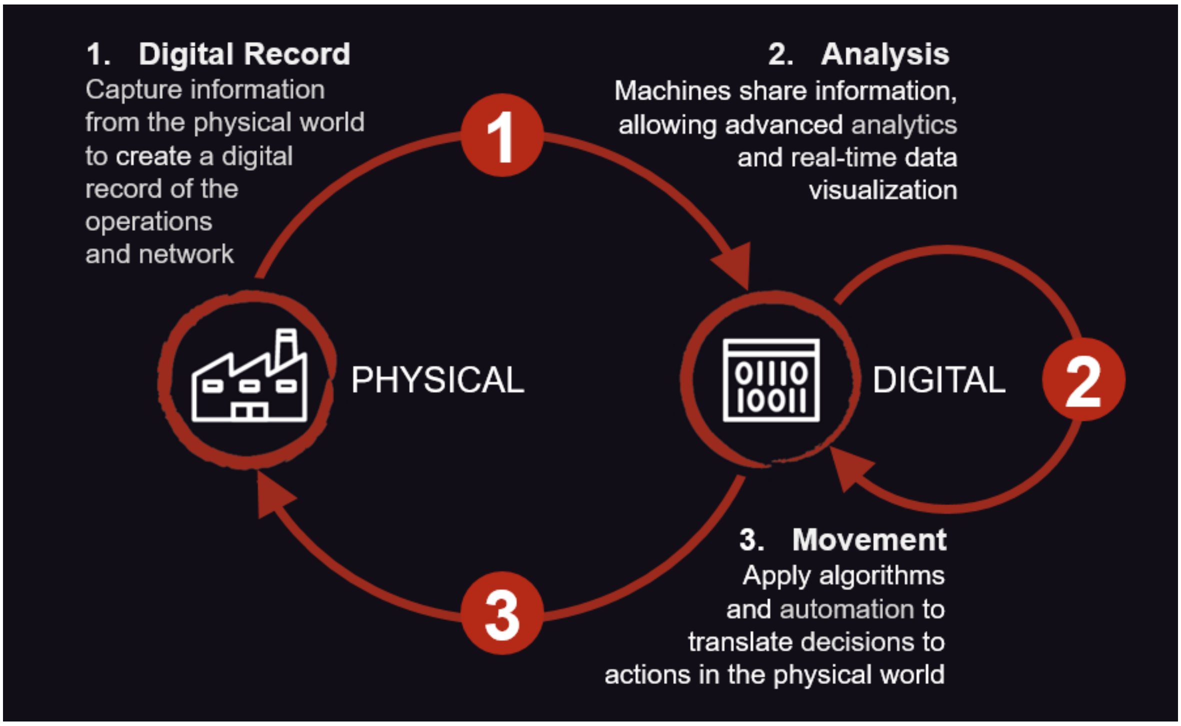


Figure 1: Physical-to-digital-to-physical loop. Source: Centre for Integrated Research Deloitte

This flow occurs through an iterative series of three steps, a physical-to-digital-to-physical loop:

- **Physical to digital**: Capture information from the physical world and create a digital record from physical data
- **Digital to digital**: Share information and uncover meaningful insights using advanced analytics, scenario analysis, and artificial intelligence
- **Digital to physical**: Apply algorithms to translate digital-world decisions to effective data, to spur action and change in the physical world

To achieve this process, Industry 4.0 combines relevant physical and digital technologies, including analytics, robotics, high-performance computing, artificial intelligence, and cognitive technologies. The digitization of operations, manufacturing, supply networks, and products enables companies to combine information from humans, machines, analytics, and predictive insights to make better, more holistic decisions [MUS18].

Industry 4.0 concepts are widely applicable and can affect the entire society and the way we live. Its primary focus is however, as the name states, on industry. Within the industrial domain, the sector most ready to embrace such changes and to profit from them the most is manufacturing.

1.2 Manufacturing Domain

Innovation within manufacturing was spurred by waves of transformations in major sectors supported by R&D investments from manufacturing companies and public funds. This transformation produced high-value manufactured goods in regions across the globe whilst investing in technological innovation. Recently, major national and international organisations, along with consultancy companies, have been measuring the effects of the application of the Fourth Industrial Revolution technologies to selected major manufacturing sectors worldwide.

Manufacturing and Industrial Technologies are major drivers of societal wealth around the world. Without doubt, manufacturing has become a major driver of the global economy in terms of jobs as well as overall wealth. Moreover, the manufacturing sector is important because of its major role in driving productivity and innovation. An hour of work in manufacturing generates nearly 32€ of added value. Manufacturing is responsible for 64% of private sector R&D expenditure and for 49% of innovation expenditure [DP18].

Among the most influencing technologies now driving innovation in the manufacturing sector, there are digital and cognitive technologies, which are moving production focus into connection with the supply chain and data-driven decision making. Industry 4.0 technologies are becoming the most important elements of advanced manufacturing. They combine Industrial Internet of Things (IIoT), connected intelligent devices, and data analytics in tools that are used by manufacturers to monitor, collect, exchange, analyse, and deliver valuable new insights about their products and processes. In order to be functional and efficient, this new model requires quality, responsiveness, and maximal availability.

Poor quality can cost manufacturers from 5% to 40% of sales [SD18]. Further, suboptimal manufacturing quality imposes significant downstream costs to almost every aspect of an organisation including underutilisation of assets, added scrap and rework expenses, warranty costs, reputation, and lost sales.

Equipment and plant downtimes cost manufacturers an inordinate amount of money. Poor maintenance strategies can reduce plant capacity by 5% to 20% [CDC+17]. Therefore, predictive maintenance is also becoming an imperative. This signals a change in the manufacturing industry for higher quality goods and services, which in turn adds more wealth and innovation to society.

Increasing product quality, reducing rework and scrap parts, improving maintenance strategies and reducing equipment downtime, is subordinated to the ability of industry to collect and analyse all kinds of manufacturing data in a cost-efficient manner. All these objectives are targeted in the so-called zero-defect manufacturing strategy.

1.3 Zero Defect Manufacturing Strategy

As described in previous sections, modern manufacturing is driven by rapid technological changes. High-value manufacturing processes are increasingly moving towards flexible, intelligent production systems. With the rise of product customisation, industries have shifted to manufacturing methods based on lean practices and customer demands. Setting aside the increased necessity for adaptability in both production and management processes, it also becomes much more challenging to apply systematic methodologies for monitoring and preventing the occurrence of defects in production [Wan13].

A Zero Defects Manufacturing (ZDM) Strategy has a goal to decrease and mitigate failures within manufacturing processes and “to do things right first time.” In other words, it aims to prevent or, when impossible, to detect and discard defective parts during production. Zero Defect Manufacturing can be product oriented or the process/machinery oriented. Product oriented ZDM analyses the defects on actual manufactured parts and tries to find a solution whereas the process/machine oriented ZDM studies the defects of the manufacturing equipment or process and infers the quality of the produced parts.

ZDM consists of four strategies: Detect, repair, predict, and prevent. When a defect is detected recovery actions can be undertaken and the data gathered can populate specifically designed algorithms for defect prediction and therefore prevention [TAG+18].

While the advantages of the Zero Defect Manufacturing Strategy are well known in every manufacturing sector, its implementation is not necessarily widespread in the operational environment. For example, the ZDM concept requires a huge amount of data. The generation of such data is limited by the scarce digitalization of the production lines, the need for standardized formats and the collection and manipulation of data is impeded by the missing digital expertise and computational power of manufacturing companies.

The Zero Defects Manufacturing Platform answers the needs for digital skills and computational power that are missing for a wide application of all zero-defect oriented technologies.

1.4 Technical Advancement ZDMP

ZDMP provides an extendable platform for supporting factories with a high interoperability level to cope with the concept of connected factories to reach the zero-defects goal. In this context, ZDMP will allow end-users to connect their systems (ie shop floor and ERP Systems) to benefit from the features of the platform. These benefits include products and production quality assurance. On the other hand, the ZDMP Platform will provide the possibility to extend its features using a dedicated application store where these applications can be added as extensions to the platform according to their needs. Users can also request new applications and software / hardware developers can use the ZDMP SDK (Software Development Kit) to build new Apps for them quickly using the projects toolkit and platform components.

The whole vision of ZDMP project is described in detail in D2.1 – Vision Consensus, which provides a clear definition of what the project wants to achieve. This section presents a high-level description of the technical advancement ZDMP proposes and some of the technologies that will be central for the use-cases realization.

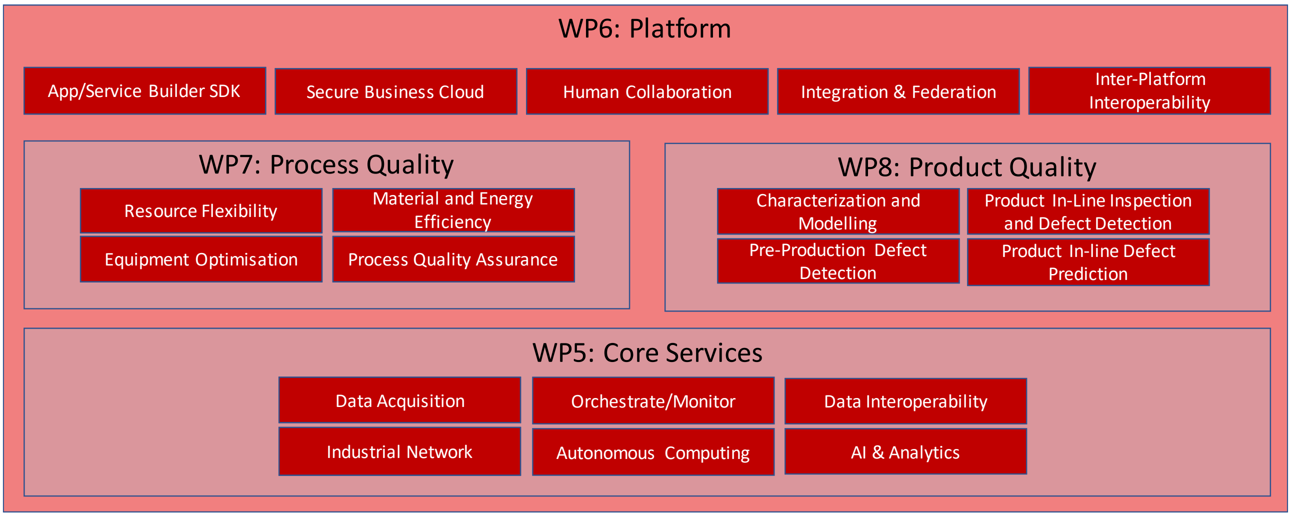


Figure 2: Concept and features developed in ZDMP

Figure 2 shows the core services and features developed in ZDMP. ZDMP use-cases rely on these components for building the zApps, zero-defect-oriented applications. As specified in the Vision document the core services and features are:

- **Core Services (WP5):**
  - **Data Acquisition** comprises of collecting data from factories shop floor, ERP systems, and partners to assist, detect, and monitor the production process in real-time manner. This creates a challenge in the interoperability area where security and reliability are a main concern. Thus, ZDMP will offer the end users a set of applications to choose depending on the functionality, used communication protocol, and data source types
  - **Data Analytics** is considered as a main pillar in the ZDMP architecture. In this sense, the user will benefit from the reasoning applications that are offered by the platform. Additionally, and intrinsic to this feature, Big Data management will be employed to detect and / or predict any defects in the production process and parts that leads to delay or inconsistency in the delivery of the further products
  - **Resource Orchestration** is provided to act for avoiding any defects in the production process. In addition, assessment will be provided by the platform on product quality assurance in case there is misalignment with the product quality standards. Further, the orchestration takes the human into account where collaboration is needed in manual production systems

- **Platform and Application (WP6)** A “Store” (marketplace) will allow high-level of connectivity between the parties (manufacturers, customers, and suppliers) in the supply chain. As a basic requirement, ZDMP will ensure the required security and privacy for the factories to eliminate any defects in the platform functionalities. On the other hand, having an applications store will allow end users to choose the necessary applications for their own situations. Moreover, they or others can develop their own applications and share them with their partners using the platforms SDK features.

- **Process and Product Quality (WP7 and WP8).** These will benefit from the AI applications / algorithms that are developed and employed in the ZDMP Platform. This feature will use the collected and analysed data regarding both Product and Process (real –time data from the shop floor and ERP data) to interact with the manufacturing systems. This interaction includes orchestrating the factory resources and supporting the factory workers with solutions for possible problems that can arise.

Technical advancements in ZDMP will provide to the manufacturing domain:

- **Quality inspection technologies**: Pre-production, in-line inspection, and final inspection tools will be made available in the platform. These tools will gather data with non-destructive methods at various stages of the manufacturing processes
- **Quality inspection analytics:** Analysis of the data gathered by the inspection tools to provide results influencing, for example, predictive maintenance systems and processes
- **Self-learning systems:** Self-Learning systems using algorithms that can learn from experience to improve their performance. The ability to learn and automatically adapt to current conditions without human intervention can enhance different manufacturing equipment capabilities, such as self-configuration, self-optimization, and self-healing, and allows the system to adapt the process dynamically to avoid error propagation and assure quality
- **Industrial IIoT:** The ZDMP platform provides a high degree of interconnection between the elements that form part of the industrial system and the surrounding environment (customers, suppliers, markets, etc) as well as the implementation of machine-to-machine communication technologies
- **Supply Chain Shared Access**: The ZDMP platform offers the chance to different actors of the supply chain to have access to all or a part of the data, results, and functionalities, making the connection between different companies easier, faster, and more secure
- **Large Scale Data Collection**: Data can be gathered from many sources and from many different companies. On one side the equipment manufacturers have unprecedented access to data coming from their equipment. On the other side the manufacturing companies using that equipment can profit of the improved accuracy and resulting higher quality of their equipment, together with new services, such as predictive maintenance or parameters optimization, that require much more data than they alone produce
- **Scheduling and tracking**: The ZDMP platform allows tracing materials and products during different processes and at different stages of the supply chain

Beyond the specific technologies, ZDMP offers a platform and functional blocks, specific for the zero-defect manufacturing applications, making simpler, more secure and more reliable the building, selling, and using apps for manufacturing companies.

2 User Scenarios Description

In this section, ZDMP project's use cases are described in detail. The interactions between the different domains considered in the ZDMP use-cases are modelled in Figure 3. The two production lines considered in ZDMP are assembly and provision.

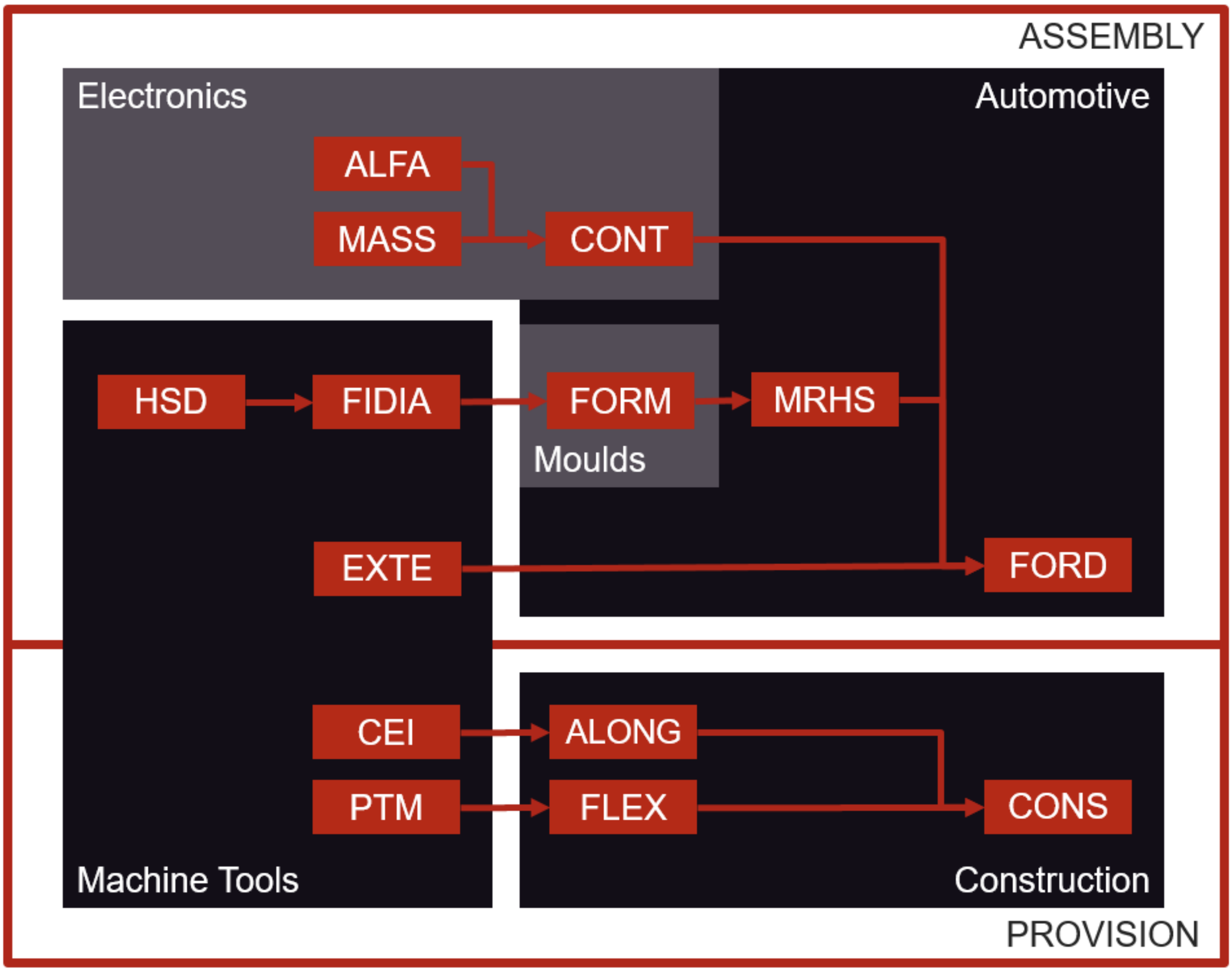


Figure 3: Manufacturing lines and supply chain of the actors participating in ZDMP

The table of Figure 4 (below) identifies a summary of the use cases that will be implemented and shows in which section of Figure 3 each use-case relates to. One demonstrator will be devoted to cross domain validation, which will be further expanded in D11.1 and D11.2.

The description of each use case is structured in to the following sub-sections:

- **Current situation** (As-Is scenario): Presents and analyses the current situation of the use case. It introduces the companies involved, describing their current business processes and the main problems they are facing.
- **Desired scenario** (To-Be scenario): Analyses the workflow expected after the implementation of the new platform, identifies the requirements of the first applications to be developed during the course of the project, describes the possible solutions in the form of zero-defects applications (zApps), and their quantitative / qualitative impacts measured in KPIs.

Each scenario includes a figure representing the workflow of the targeted use-case. The As-Is figure describes the flow of products, data, and information before ZDMP. A red **Z** highlights which is the area of the current workflow that the introduction of ZDMP solutions will impact upon. The To-Be figure represents the workflow after the introduction of ZDMP solutions. The envisaged zApps are represented in the data or product flow with a brief explanation of their impact.

The subsection “Candidate Solutions - zApps” describes possible ZDMP Applications (zApps) that, from the users’ point of view, would solve the targeted problem. Each application description includes its objective, the actors involved, the process description, the data sets, and the expected behaviour. An term has been created and assigned to each application together with a reference number (eg zA2.1). These terms and reference numbers will be used throughout the documentation of the project to refer to the applications in the pilot use cases.

For each use-case a set of KPIs is defined, providing clear quantitative metrics. This includes:

- Specification of the baseline
- Specification of the units for measurement of every KPI
- Use of both percentages of improvement and numerical values whenever possible
- Examples of impact on specific production lines / application cases whenever the KPI baseline value is case-specific

The baseline values for the KPIs have been collected with the following methods:

- Automatic production parameters: Several end-users have solid systems to collect data on production quotas to verify the reach of the company goals
- Historical data: In some cases, data are collected and registered manually, so gathering of historical data is necessary to have the relevant statistics
- Estimation through experience: Parameters such as time required for specific phases of the work or intervention times are not easily collectable. In this case the current baseline values are estimated

The methodology for the evaluation of the KPIs after the introduction of ZDMP solutions will involve gathering data from new production batches/operations and compare it with the baseline. In those cases where the baseline value is not deriving from actual measurements, an experimental set up will be exploited to evaluate the performances with and without ZDMP solution.

The experimental set ups and the methodologies for their measurement will be further detailed in the first deliverable of WPs 9 and 10.

In summary, this section:

- Proposes a set of zApps
- Describes their interaction and functioning from the user perspective
- Defines methods to measure their performances and the effects on production
- Proposes names and functionalities, in relation to the existing facilities, data types, platforms and constraints

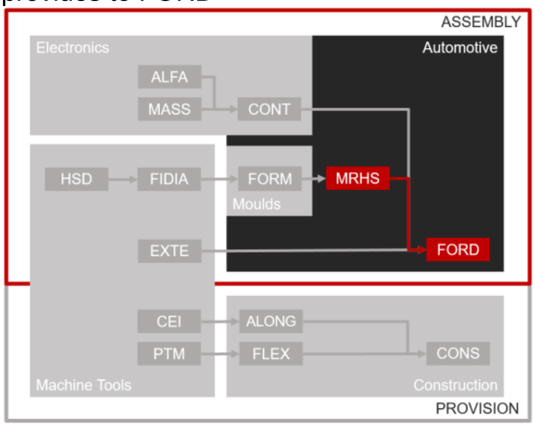
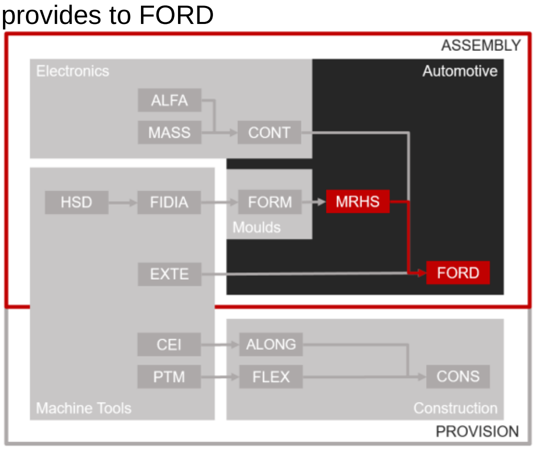
This section does not:

- Describe the technological implementation of the zApps – see deliverables of WP4-8

- Set any technological requirements: Formats, sizes, exchange protocols, sources, storage types and databases specific are explicitly stated only when restricted by company policies or compatibility issues – again see deliverables of WP4-8

In addition to this deliverable, the user scenario Description, the zApps description, and the KPIs will be further expanded in the following deliverables:

- **D4.3** User Mock-ups: description of the expected user interfaces of the zApps and their functionalities
- **D9.1** Traditional: Implementation Definition, Planning, and KPI Validation/Measurement Criteria: Detailed description of the implementation of the zApps and their KPIs in the “traditional” use-cases
- **D10.1** Extended: Implementation Definition, Planning, and KPI Validation/Measurement Criteria: Detailed description of the implementation of the zApps and their KPIs in the “extended” use-cases

Sector		ID	Titles	
Traditional	**Automotive**	**UC1.1**	Engine block manufacturing: Defects detection and prediction in aluminium injection operations	MRHS manufactures engine blocks and provides to FORD 
		UC1.2	Engine block manufacturing: Defects detection and prediction in machining operations	MRHS manufactures engine blocks and provides to FORD 
		UC1.3	Engine block manufacturing: Defects reduction by the optimization of the machining process	EXTE produces a turkey system used by FORD in production

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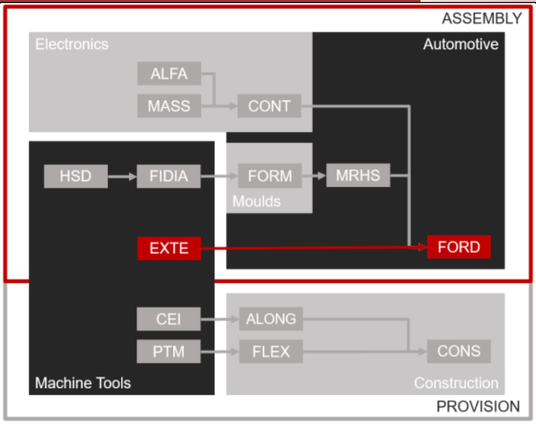
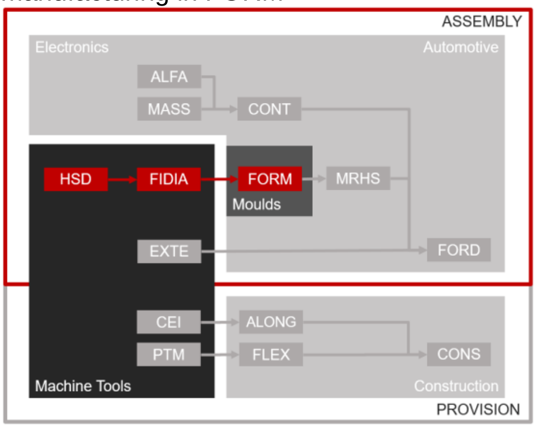
<tr><td></td><td></td><td></td><td></td><td>
</td></tr>
<tr><td></td><td>Machine Tools</td><td>UC2.1</td><td>Moulds manufacturing: Process alert system for machine tool failure prevention</td><td>HSD manufactures electro spindles, mounted on FIDIA high speed milling machines, which are used for mould manufacturing in FORM

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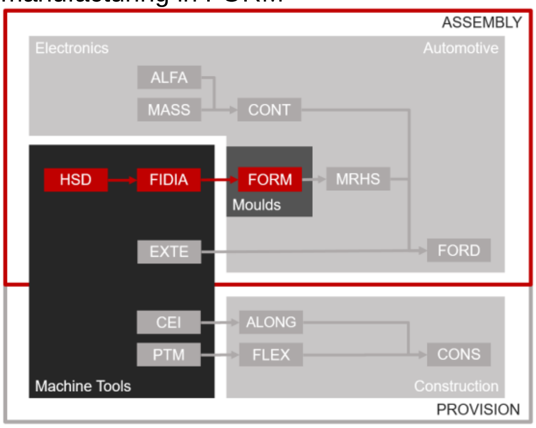
<tr><td></td><td></td><td>UC2.2</td><td>Moulds manufacturing: Smart process parameter tuning</td><td>HSD manufactures electro spindles, mounted on FIDIA high speed milling machines, which are used for mould manufacturing in FORM

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<tr><td></td><td></td><td>UC2.3</td><td>Moulds manufacturing: in-line 3D modelling</td><td>FIDIA produces high speed milling machines and the CNC, used for mould manufacturing in FORM</td></tr>
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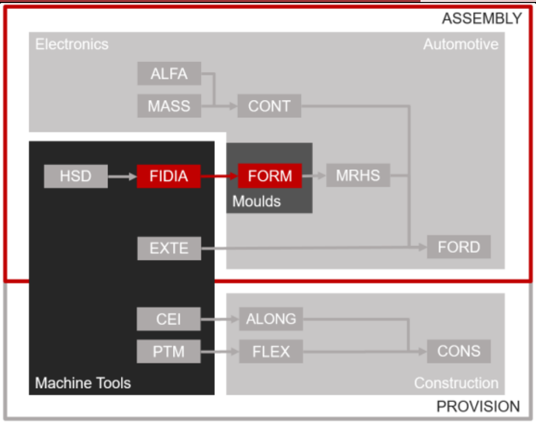
<tr><td></td><td></td><td></td><td></td><td>
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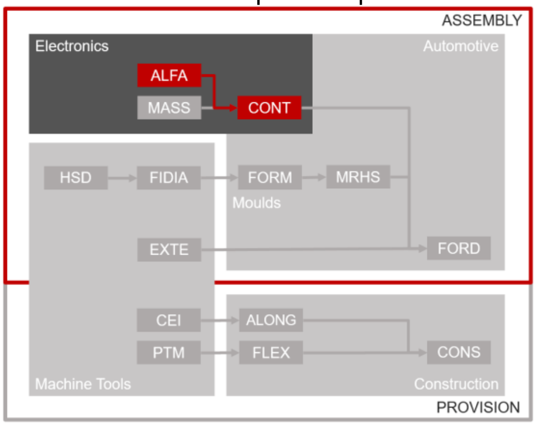
<tr><td rowspan="3">Extended</td><td rowspan="3">Electronics</td><td>UC3.1</td><td>Electronic products manufacturing: Component inspection</td><td>ALFA makes x-ray solutions exploited in CONT electronic components production line

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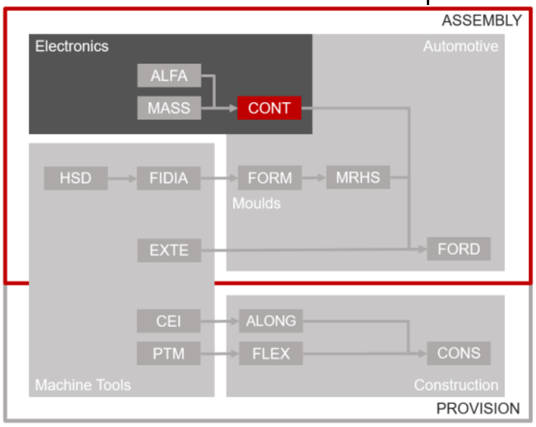
<tr><td>UC3.2</td><td>Assembly line: AI-supported optical defects detection</td><td>CONT manufactures electronic components

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<tr><td>UC3.3</td><td>Assembly line: monitoring and control system</td><td>MASS makes production equipment used in CONT electronic components production line</td></tr>
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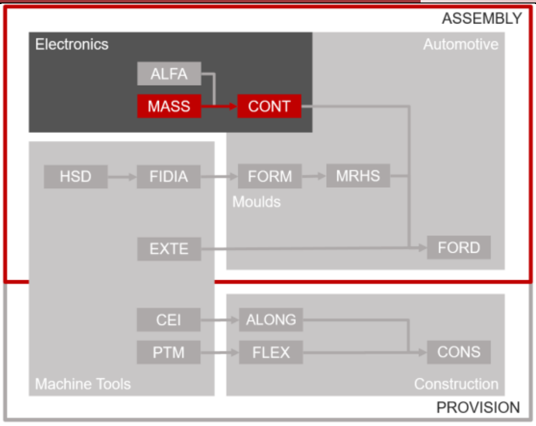
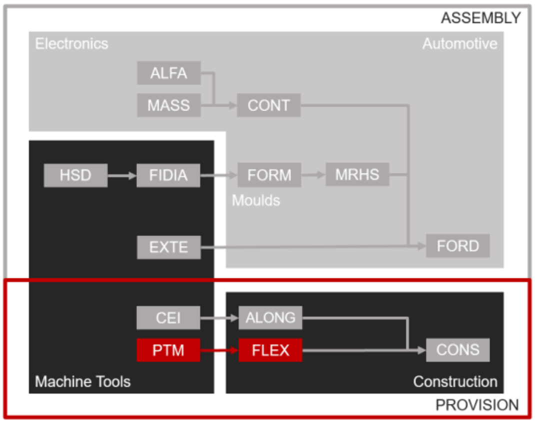
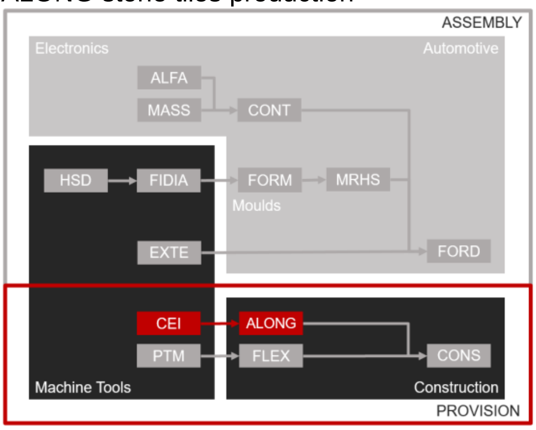
				
	Construction	**UC4.1**	Steel tubes: production monitor	PTM makes steel cutting equipment used in FLEX steel tubes production line 
		UC4.2	Stone tiles: equipment wear detection	CEI makes stone cutting machines used in ALONG stone tiles production 
		UC4.3	Construction supply chain: quality control at construction site	FLEX provides steel tubes and ALONG provides stone tiles to the construction sites managed by CONS

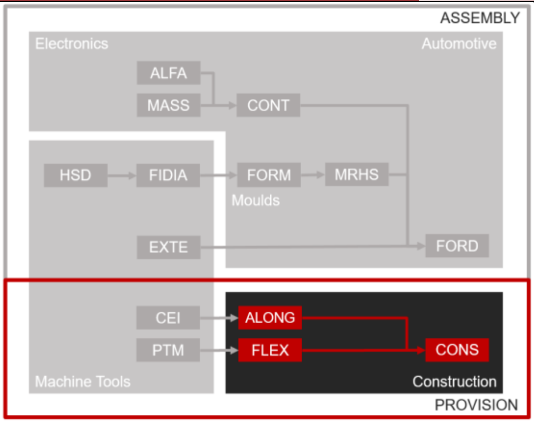
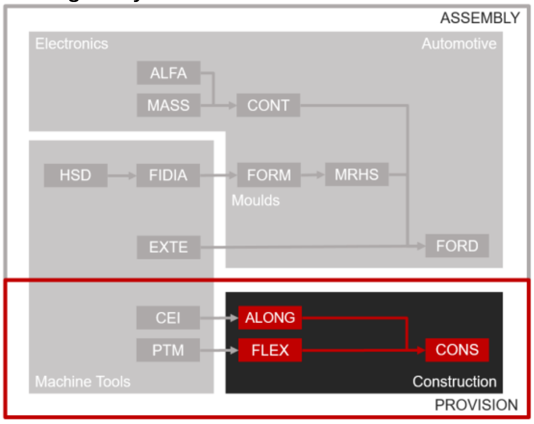
				
		UC4.4	Construction supply chain: quality traceability	FLEX provides steel tubes and ALONG provides stone tiles to the construction sites managed by CONS 

Figure 4: List of ZDMP Use Cases divided by sector

zApp name	ID	Description
zAnomalyDetector	zA1.1	This is the AI and Advanced Analytics Module. The objective of zAnomalyDetector is to ingest real time data from multiple sources (and elaborate a multivariate analysis to detect system anomalies. When the system detects such an anomaly, it will generate notifications to the zAlarm, to alert the operator or the shop floor manager.
zDigitalTwin	zA1.2	This objective of this zApp is to ingest real time data from multiple sources and elaborate a simulation of the observed system. The model can optimize the system parameters and produce recommendations on those to achieve a certain objective (defined by user).
zAlarm	zA1.3	The objective of this app is to alert users in real-time in case of incidents or abnormal situations eg machine downtimes. Service technicians can receive notifications with related information (machine, location, type of error, required tools…) on their smart wearable.
zMachineMonitor	zA2.1	The objective of zMachineMonitor is to automatically gather and store both equipment and machining process data. It is also able to monitor the task to detect sudden or abrupt changes that can lead to a premature failure and that needs to be taken care of by the operator quickly. When the system detects such an event, it will generate notifications to alert the operator or the shop floor manager. This data is temporal series of values read by the machine numerical control.

zMachineAnalytics	zA2.2	The objective of zMachineAnalytics is to automatically detect equipment or process deviation from standard working conditions that can lead to near failure events using data analysis algorithms. It will work on data already stored in a database by the zMachineMonitor zApp to identify degradation trends of the machine or components.
zParameterMonitor	zA2.3	The objective of zParameterMonitor is to automatically gather and store all parameters data and operators' feedback. The objective and the functioning of this zApp is similar to zA2.1, but in this case it might need a much simpler UI.
zParameterAnalytics	zA2.4	The objective of zParameterAnalytics is, given a condition (e.g. type of machine, environmental variables, etc), to automatically detect which parameter combination provides the best results. It triggers the appropriate response to all new production requests and provides the machine operators a suggestion upon which parameters to use for their current situation.
z3DScannerDriver	zA2.5	The objective of *z3DScannerDriver* is just to make the upload of the cloud of points to the ZDMP platform more easy/automatic and then to trigger the conversion. This is an auxiliary application requiring the authorization of the operator, which should substitute the manual upload. If the format of the cloud of points generated by the Scanner is proprietary or not suitable as input for the z3DGenerator, a format conversion or adaption should be considered within the z3DScannerDriver.
z3DGenerator	zA2.6	The objective of z3DGenerator is to clean the cloud of points, convert it in 3D format and if needed simplify it also in term of memory occupation. The output should be a 3D .stl file.
zXRAYMonitor	zA3.1	The objective of zA3.1 XRAYMonitor is to automatically start the correct inspection program from the library, depending on the sample under testing and to make the comparison of the XRAY/CT information and the sample drawing & specification. For each type of material / sample, a set of special characteristics in the XRAY/CT library will be generated, measured, and controlled with the dedicated software. The application will generate for each measurement an output, which will be the input to the database of zA3.2, which will store the measured values and defined parameters for each sample under testing.
zXRAYAnalytics	zA3.2	The objective of zA3.2 XRAYAnalytics is to have a database of the inspected parts and the measurement results. This allows comparing new measurement results for the specific part to the measurement results from previous analyses and generates statistical analysis and the deviation overview, trend line of measurements, including graphical representation. The direct results will be to have a preventive approach for the analysed set of material and to discover the defect or predict issues at the component supplier before it had occurred. In case of deviations, the application will send alerts in a mail format to the involved parties.
zFeedbackMFT	zA3.3	The objective of zA3.3 application is to assure the interface with MFT, collect images and operator optical inspection decision and leaked parts information. The collected information will be stored in a database and used by a Z3.4 application.
zArtificial IntelligenceMFT	zA3.4	The objective of zA3.4 is to apply the artificial intelligence algorithm for Manual Final Test, tests and to inform the operator for optical inspection test results.
zFeedbackAFT	zA3.5	The objective of zA3.5 application is to assure the interface with AFT, correlate the test image, test results, and quality of test result. The collected information will be stored in database and used by zA3.6

		application to improve the testing program.
zArtificial IntelligenceAFT	zA3.6	The objective of zA3.6 is to apply the artificial intelligence algorithms for Automatic Final Test testing and to provide manual and automatic improvement of the testing program.
zDriver	zA3.7	The objective of the zA3.7 application is to assure the interface with the equipment and the line server database. Communication is assured based on client server protocol on a predefined set of parameters with extensible data table
zLineData	zA3.8	The objective of zA3.8 is to store the received information from the driver in the database and to perform the strategic KPI calculations.
zVisualManager	zA3.9	The application zA3.9, is a WEB application that displays in web pages the specific information in collaboration with other applications (zA4.4-zA4.9).
zProductVersionControl	zA3.10	Application zA3.10 is responsible to assure that the produced part has used the right material version and the right equipment program for the mentioned product serial number. Additionally, the application automatizes the changeover process to avoid the change over time and quality risks.
zAutomaticCall	zA3.11	The application zA3.11 monitors the status of the equipment and if the equipment breakdown is larger than the specified time, it will automatically call the right phone number for the intervention. Additionally, it provides the details regarding the equipment maintenance plan details, corrective intervention history, and based on historical data provide a predictive view.
zPowerManager	zA3.12	Application zA3.12 handles the power management actions to reduce the total energy consumption of the assembly line. For example, if the production lot is finished, the data from the production plan may allow putting the equipment into a power save mode until needed again.
zCycleTimeManager	zA3.13	The application zA3.13 reads the production check-in and checkout timing and evaluates the KPI production (OEE cycle tine, breakdown)
zAutomaticMaterialOrdering	zA3.14	The application zA3.14 manages the current material stock in the line information and requests automatically materials to logistic.
zDataArchiveControl	zA3.15	Data Control and Archive application manages all the archiving data operations (archive, restore, clean database)
zSteelSheetWidthMonitor	zA4.1	The goal of zSteelSheetWidthMonitor is to automatically detect the width of the steel sheet to detect if the width of the sheet varies over time. In a situation that the width changes, the tube will be defective. When this problem is detected in time, tube waste is avoided.
zHorizontalWeldDetection	zA4.2	The goal of zHorizontalWeldDetection is to automatically detect the horizontal weld of the steel sheet; this welding is made to connect the different steel coils to each other for production to continue uninterrupted. By detecting this defective welding the operator can be warned to remove the tube that will contain the weld as this tube will need to be scrapped.
zVerticalWeldMonitor	zA4.3	The goal of zVerticalWeldMonitor is to automatically detect the quality of the vertical weld of the steel sheet. In a situation where the vertical welding has a defect, it will cause the final product to be defective. Thus, it is necessary to readjust the machine every time that this happens, and it is also necessary to warn the operator.
zShapeTubeMonitor	zA4.4	The goal of zShapeTubeMonitor is to automatically detect the conformity of the tube shape. It is necessary to detect if the shape of the tube is within the conformity, in case it is not necessary to warn the operator, to

		proceed with the reconfiguration of the machine.
zWiresMonitoring	zA4.5	The goal of zWiresMonitor is to detect automatically broken cables or irregular movements of cables and the alignment of the cable, in first step of stone cutting. When a stone is being cut, the cables, responsible for this work, can break or move irregularly, creating defects in the stone. To solve these problems, the zCableMonitor intends to implement sensors capable to detect when a cable is broken or moving irregularly.
zThicknessMonitor	zA4.6	The main goal of zThicknessMonitor is to automatically detect defects in the thickness of stone slabs. For a correct polishing, the stone slabs need to be in a certain size range. To verify compliance, this zApp allows real-time analysis of the thickness of stone slabs.
zDetectDefects	zA4.7	The objective of zDetectDefects is to automatically assign sheets stone moulds to stone slabs.
zWornOutBladeDectection	zA4.8	The goal of zWornOutBladeDetection is to automatically detect worn blades during the stone slabs cutting.
zTilesCorformity	zA4.9	The goal of zTilesConformity is to validate the conformity of the final product before it goes to packaging. This zApp will be the last step in the stone cutting process and will act as a validator of stone cutting procedures.
zRemoteQC	zA4.10	The objective of zRemoteQC is to allow access to and easy archiving of documentary evidence of compliance regarding material including their specifications. This facilitates the documentation assessment and the detection of potential errors, even before the supplies leave the manufacturing facility. It will also allow the access to production quality control records of the corresponding material lots, if the user chooses to do so.
zRescheduler	zA4.11	The objective of zRescheduler is to allow a quick adjustment of works schedule in case of delays in supplies, thus reducing productivity losses that normally would occur due to the Supervisor taking time from other activities to redo the schedule.
zMaterialTracker	zA4.12	The objective of zMaterialTracker is to allow the recording of the use of a specific material at a specific location, and based on that, to allow access to all the documentation related to that specific material, be it construction records, quality control records, shipment records or production control records. The zApp will interact and access information stored by zApp4.1
zMaterialID	zA4.13	The purpose of zMaterialID is to create an identification system capable of creating a unique identifier for different materials and corresponding quality control information. Through this identifier the materials will be traceable throughout the production process

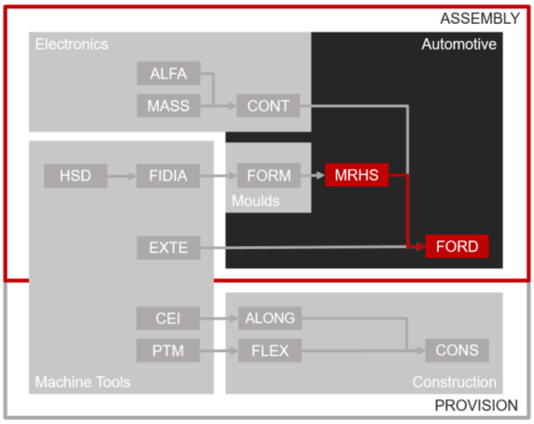
2.1 UC1.1: Engine block manufacturing: Defects detection and prediction in aluminium injection operations

Figure 5: Picture of a casting cell

2.1.1 As-Is: Analysis of the Current Situation

2.1.1.1 Partners Roles

This use case involves industrial partners: MRHS and FORD



- **MRHS**: Located in Madrid is a leading manufacturer of aluminium cylinder blocks produced by high pressure die casting process
- **FORD**: Ford Valencia Engine Plant is finishing the rough Cylinder Blocks received from MRHS to produce the 2.0 & 2.3L engines. Those engines are assembled in Ford Vehicle operations plants worldwide

2.1.1.2 Business Process Model

The “As-Is” business process model is shown in Figure 6. MRHS produces an aluminium cylinder block for FORD Valencia Engine Plant (VEP) by high-pressure die casting (HPDC).

The process “As-Is” could be improved and benefit from a zero defect manufacturing approach. The red ‘Z’ in this and future diagrams represents the ZDMP Applications that, if developed, will allow such improvements.

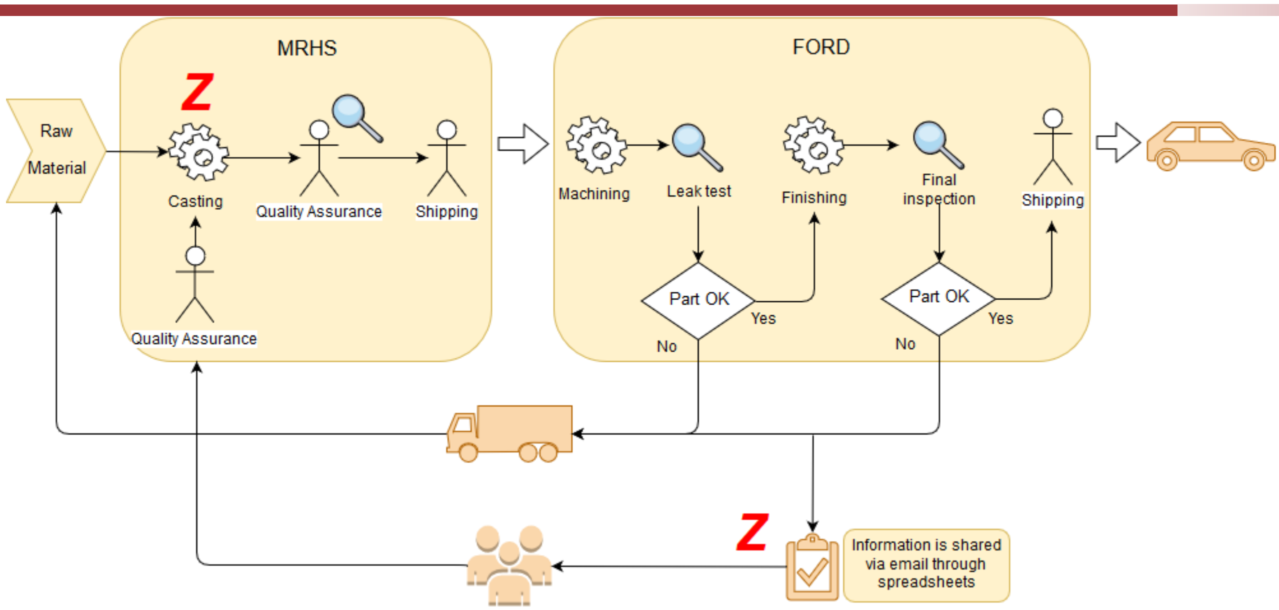


Figure 6: Business process model diagram “As-Is”

Figure 7: Picture of an engine block

The engine block is manufactured in two steps: First it is cast and pre-machined by MRHS, then sent to FORD, who oversees the finishing operation. During the casting process, parts are marked with a unique serial number. Casting process data is related to this unique serial number (traceability number).

During the final machining of the block, a variety of defects can appear. These defects can be categorized mainly as porosity and leakage. Both types of defects can be detected with high accuracy level at FORD premises. Leakages are analysed in a dedicated Leak Test Station and visual porosity is detected during the final inspection stage with automated cameras recording and storing information in a database. Every week, FORD sends quality results back to MRHS, containing information on how many parts were not compliant with the requirements. Based on these quality results, corrective actions (adjustment of process parameters) can be taken by MRHS.

A better and quicker corrective action could be undertaken if the quantitative and qualitative data is transmitted in (almost) real time. Defects found during the final inspection step would need further analysis in order for MRHS to be able to find correlations with the casting parameters and make adjustments.

Additionally, a comprehensive collection of the process data from both the supplier (MRHS) and the manufacturer (FORD) would enable the use of algorithms to predict quality results in advance.

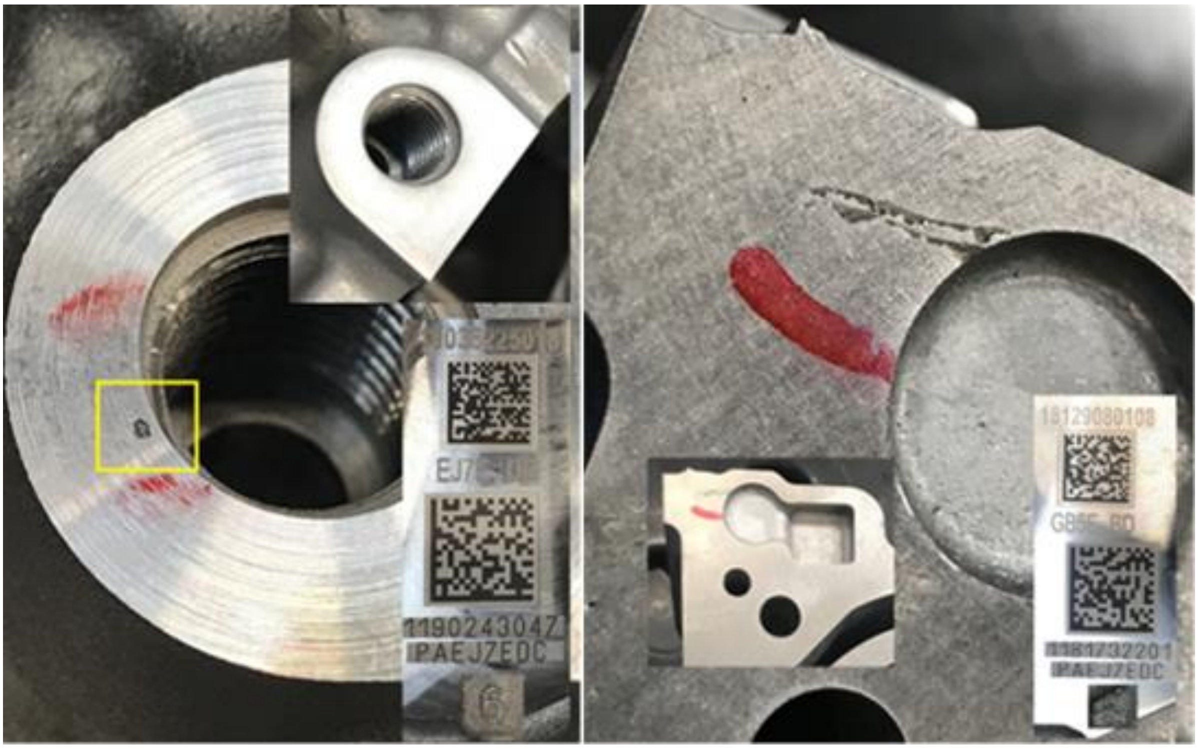


Figure 8: Manually generated pictures of typical defects, including traceability numbers

2.1.1.3 Zero Defect Key Issues

The production of parts by High Pressure Casting involves a number of variables that can directly affect the final quality of the products. The process control can detect when a parameter deviates from a predetermined tolerance. However, the effect of each variable or the interaction between different process parameters on the final quality of the product is difficult to analyse. In regard to porosity, a high-quality feedback is therefore critical to make process adjustments. Currently, the quality feedback that the Valencia Engine Plant can provide to MRHS is based on an automated quality control machine working at the VEP. When the part is rejected by the quality control machine at VEP, the piece is sent to a manual inspection stage where an operator must confirm the assessment. If the rejection is confirmed, another picture is taken and identified with the traceability number on the part.

The expectation is that the ZDMP platform should provide predictions of the quality results expected at MRHS and Ford VEP. This would be based on historical process data from MRHS, and quality data from both MRHS and Ford, and should provide recommendations on process adjustments to improve quality results.

2.1.2 To-Be: Analysis of the Expected Scenarios

2.1.2.1 Target Business Process Model and Partners Roles

MRHS, together with the other participants of ZDMP, aims to achieve scrap reduction and an OEE improvement. To achieve this goal, MRHS needs to collect and analyse a large amount of data from their production equipment and to compare it with the quality detected during FORD's finishing operation.

The changes to the process expected after the introduction of ZDMP are shown in Figure 9. The ZDMP platform collects data from both MRHS and FORD processes. MRHS already has access to process data from PLCs, sensors, flow meters, and other data available in MRHS systems, some of which are batch related and are recorded manually. Additional sensors may be needed to provide better results. The main types of data registered are integer, real, text streams, chart (character), and Boolean (true / false). All data is uploaded automatically in a MySQL database, and a backup is made in a SQL server. All the data currently managed in this internal database and can be provided to (or read by) the platform. The data can be adjusted to different formats (Excel, CSV, Database, etc), although MySQL is the preferable option. The volume of data is considered limited; possibly about 1.000 parameters per part, to be uploaded at production time. Every production cycle lasts approximately 2 minutes, which would result in an upload every 2 minutes. The location and security of the platform is highly relevant to this use-case, since the data to be managed is highly sensitive and confidential. Once data is uploaded, a function should then be able to detect any anomaly. The desired alert time is, at least, daily, while the ideal scenario would be to receive results as close to real time as possible.

This scenario will make use of the zApp Multivariate Anomaly detector (zA1.1) in MRHS premises to raise alerts on the current production. In addition, the zApp zDigitalTwin (zA1.2) uses process parameters and quality results from FORD Valencia Engine Plant and MRHS to raise alerts on current production, and to give a prediction of the expected quality results. The algorithms will therefore need a training phase based on quality data coming from both MRHS and FORD. This information will enable MRHS to adjust the manufacturing process parameters.

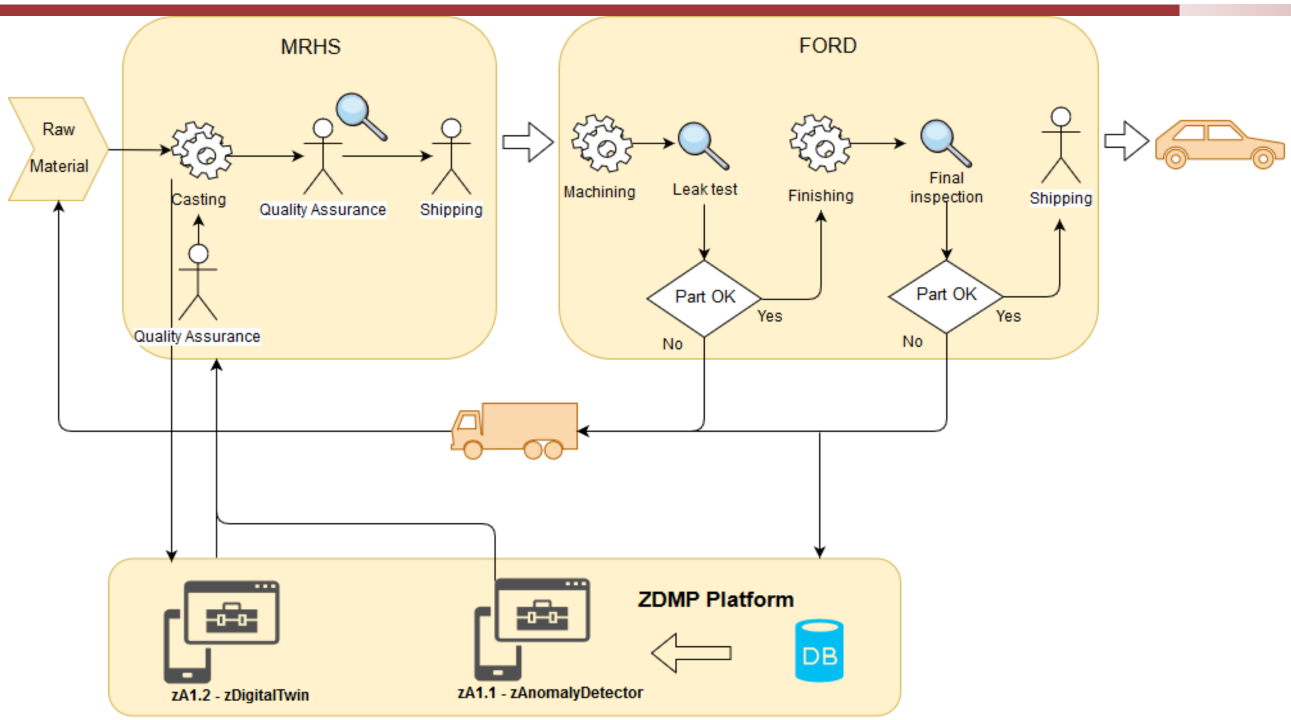


Figure 9: Business process model diagram "To-Be"

2.1.2.2 Candidate Solutions - zApps

The companies participating in this use case wish to reduce costs and reduce the number of waste parts generated. The goal is to advance from a scenario in which monitoring is a slow process and the collaboration is scarce; to a scenario where, using digital platforms, data processing, monitoring, and reacting are agile and collaborative processes. This scenario will make use of the ZDMP platform through the Apps described in Figure 10.

zApp name	ID	Description	Timing
zAnomalyDetector	zA1.1	The objective of zAnomalyDetector is to ingest real time data from multiple sources (MRHS machine sensors, process and / or product results) and elaborate a multivariate analysis to detect system anomalies. Data will be gathered and collected in ZDMP and will be combined with the porosities validation test results conducted in Ford to detect correlations. The main result will be a percentage of rejection possibility of a set of blocks.	Minimum: daily Desired: every cycle (120 s)
zDigitalTwin	zA1.2	This objective of this app is to ingest real time data from multiple sources and elaborate a simulation of the observed system. The model can optimize the system parameters and produce recommendations on those to achieve a certain objective (defined by user).	Not applicable (Simulation)

Figure 10: zApps selected for the Use Case

After a preliminary analysis, the WP7 and WP8 tasks relevant to develop the zApps for this UC are:

- T8.2 Pre-Production: Product Quality Prediction
- T8.4 Production: Supervision

2.1.2.3 Expected Impact on KPIs

The expected impacts are to improve quality results at MRHS (ie decrease internal scrap at MRHS), improve the quality results at Valencia Engine Plant (external scrap), and to reduce the reworks at Ford.

With respect to the selected KPIs the expected improvements are:

KPI	Description	Current Value	Target Value
Reduction of scrap parts at MRHS	Number of bad parts vs total number of parts produced. Bad parts are those out of tolerance in porosity or leak test according Ford Specification detected at MRHS's premises. Scrap parts due to human errors are not considered.	6.5% about 18.200 parts per year	5% 2.800 units reduction, with corresponding savings for 125.000 € per year
Reduction of scrap parts at FORD	Number of bad parts vs total number of parts produced. Bad parts are those out of tolerance in porosity or leak test according Ford Specification detected at FORD's premises. Scrap parts due to human errors are not considered.	4.500 parts per year	3.500 parts per year 280 units reduction, with corresponding savings for 32.000 € per year
Reduction of re-work parts at FORD	Number of reworked parts vs total number of parts delivered. Ford´s specifications allow repairing certain porosities at defined locations.	0.8% About 2.250 parts per year	0.4% 1.120 units reduction, with corresponding savings for 2.200 € per year (rework direct costs only)

Figure 11: KPI: Expected improvements

2.2 UC1.2: Engine block manufacturing: Defects detection and prediction in machining operations

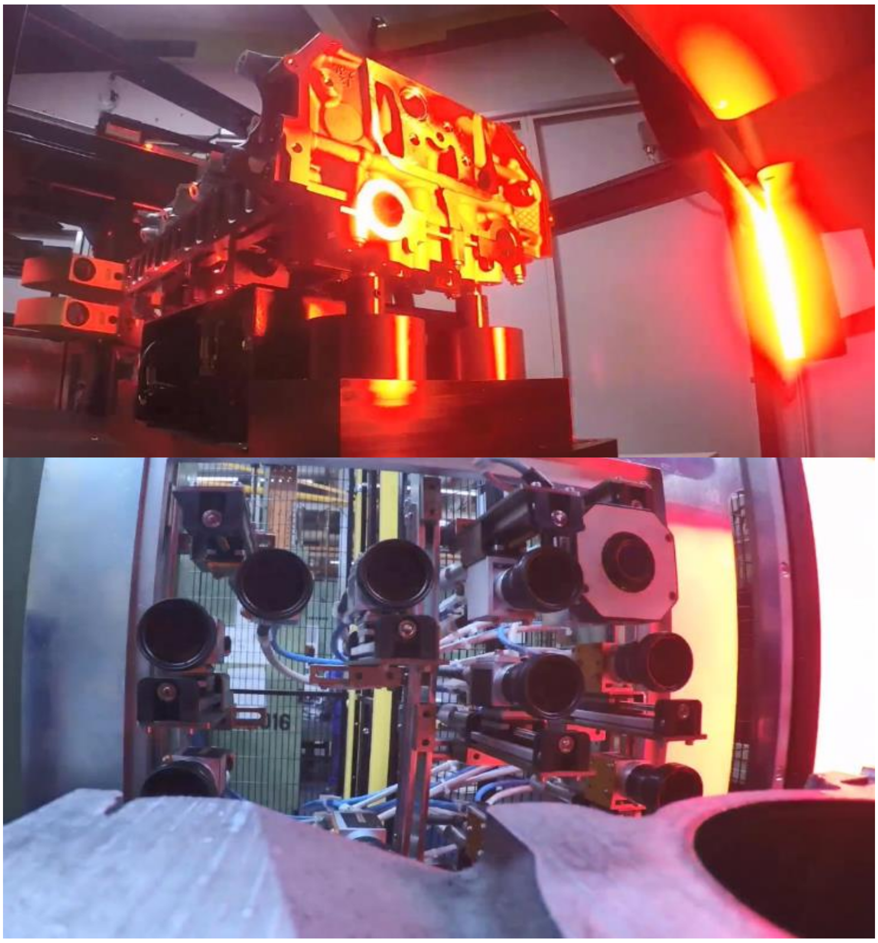


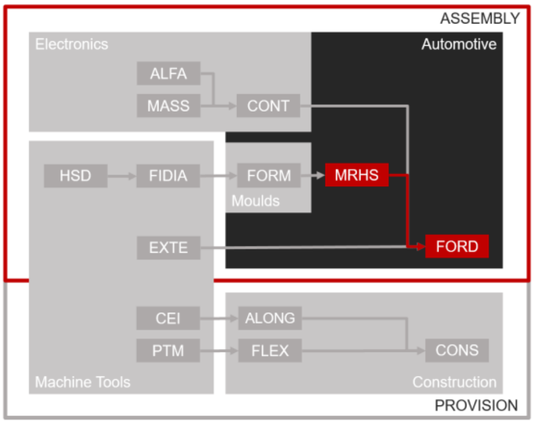
Figure 12: Ford final quality control operation based on artificial vision

2.2.1 As-Is: Analysis of the Current Situation

2.2.1.1 Partners Roles

This use case involves industrial partners: MRHS and FORD

- **MRHS**: Located in Madrid is a leading manufacturer of aluminium cylinder blocks produced by a high pressure die casting process
- **FORD**: Ford Valencia Engine Plant is finishing the rough Cylinder Blocks received from MRHS to produce the 2.0 & 2.3L engines. Those engines are assembled in Ford Vehicle operations plants worldwide



2.2.1.2 Business Process Model

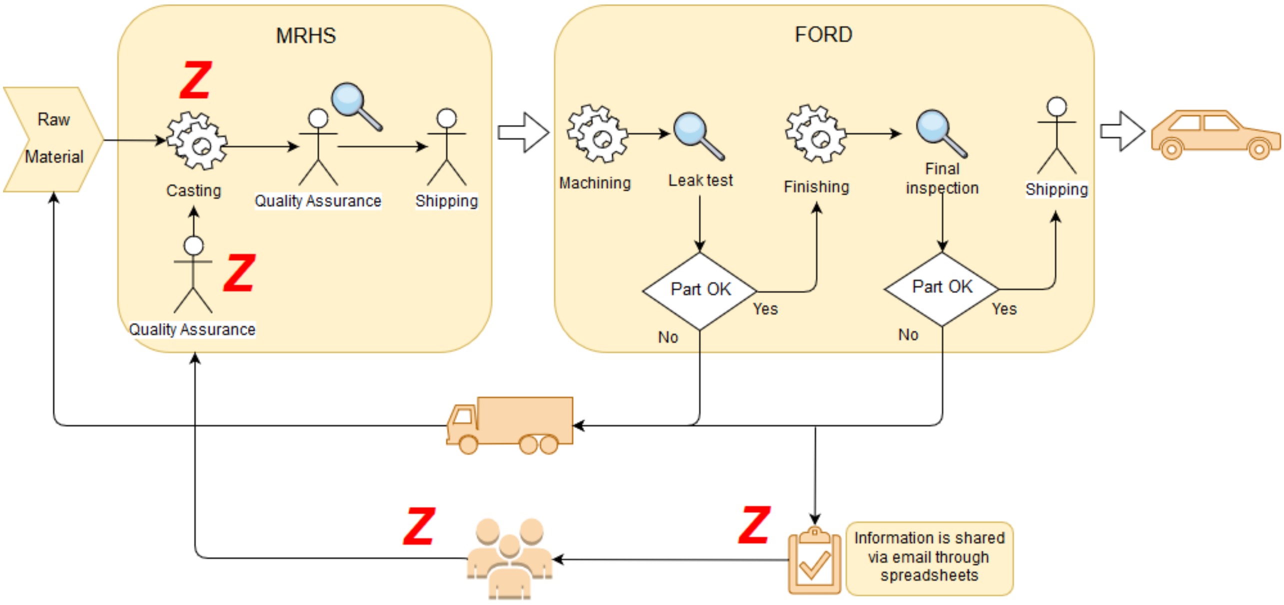


Figure 13: Business process model diagram “As-Is”

FORD manufactures the cylinder block rough parts received from MRHS. Some of these parts have “hidden” porosities, a problem that arises only after the engine block is manufactured. Defective engine blocks can be detected at specific control points in the manufacturing process, but only after a part of the machining operation are completed. This makes the process overly expensive and inefficient since it implies that resources and time are invested in defective engine blocks that are eventually discarded.

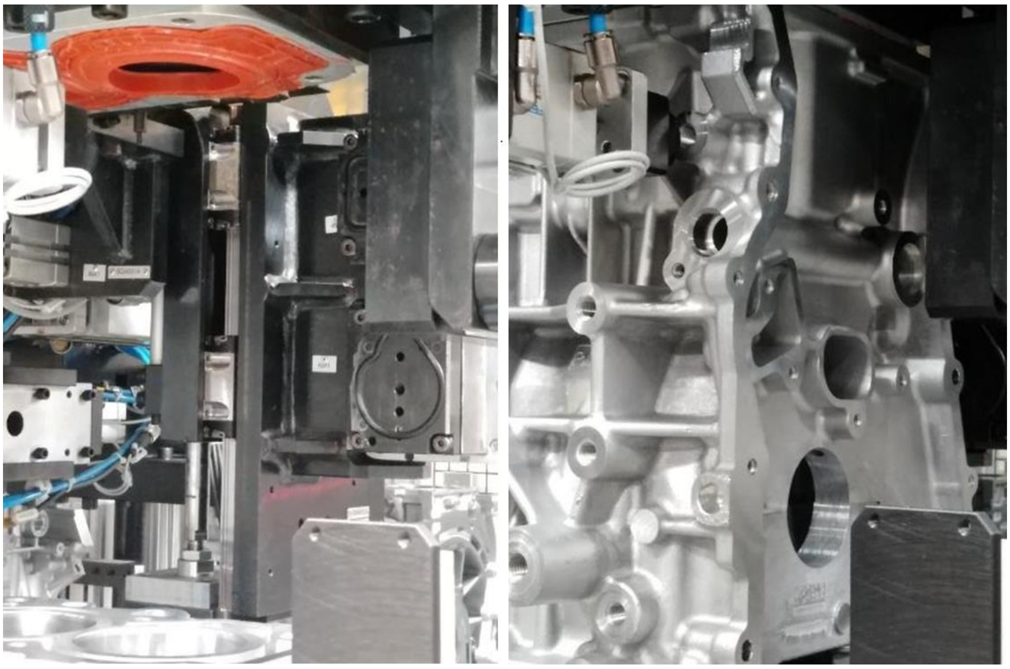


Figure 14: Ford Leak test operation

To prevent that the porosity defect reaches the final customer, several quality control operations are in place in the cylinder block line:

- Oil circuit leak test
- Coolant circuit leak test
- Surface porosity check with artificial vision

The two leak test operations (OP65: Oil circuit, OP145: Coolant circuit, Figure 14) are implemented. A machine seals all the orifices of the relevant circuit but one, where compressed air is introduced with a wait until the pressure is stabilized and then a check is made for several seconds that the leak flow is under the permitted limit. If the result of this test is satisfactory, the machine adds a mark on the part and releases it for the next operation. Each test is only possible after some manufacturing processes. For instance, it is not possible to check that there are no porosities in the lubrication circuit before machining the connection point which links the lubrication gallery with the oil pressure sensor. Currently the leak test operations do not have any high frequency data acquisition system.
Artificial vision is used during final quality control for surface quality check. It verifies that all the cylinder block machined surfaces are fulfilling Ford's engineering specification, considering the number and the size of the porosity, of which the allowed number depends on the area considered. This Quality Control takes 234 pictures per every part checked using 83 cameras. The total size of the 234 .jpg files stored in the NAS machine is about 50 MB per part (approximately 150GB per day). The result of this test is an OK / NOK part.

Parts rejected at any of these quality controls are sent back to MRHS to be reprocessed.

Ford Quality Control Department reports weekly to MRHS Quality control department the number of the parts rejected during the week. It uses an Excel file where MRHS are documenting the actions taken to reduce the porosity impact which, vice-versa, is shared with Ford.

2.2.1.3 Zero Defect Key Issues

Process variability of the aluminium injection procedures can affect the cylinder block mechanical properties such as in the case of porosity. This porosity can cause oil, coolant leaks from lubrication, or cooling engine galleries, to detect and prevent those leakages in the engines manufactured by Ford, there are two leak test operations at cylinder block line.

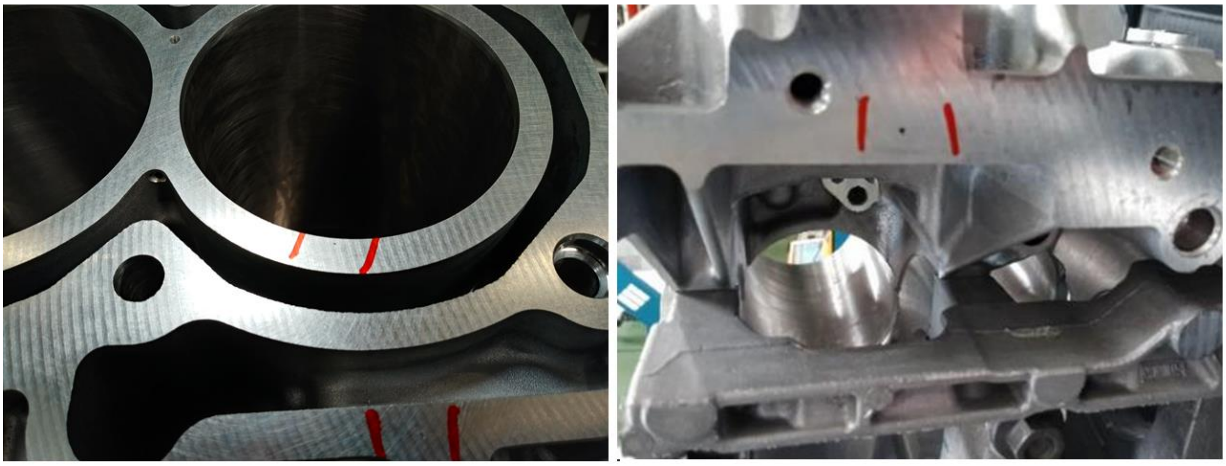


Figure 15: Typical porosity defects detected at Ford Final inspection operation.

Fluent communication between Ford inspection stations and MRHS casting processes would allow exchanging information on the defect in a faster and more efficient way to take the necessary corrective actions at MRHS.

2.2.2 To-Be: Analysis of the Expected Scenarios

2.2.2.1 Target Business Process Model and Partners Roles

The companies participating in the automotive use cases wish to reduce costs and reduce the number of scrap parts generated. The goal is to advance from a scenario in which monitoring is a slow process and the collaboration is scarce; to a scenario where, through the use of digital platforms and data processing, monitoring and reacting are agile and collaborative processes.

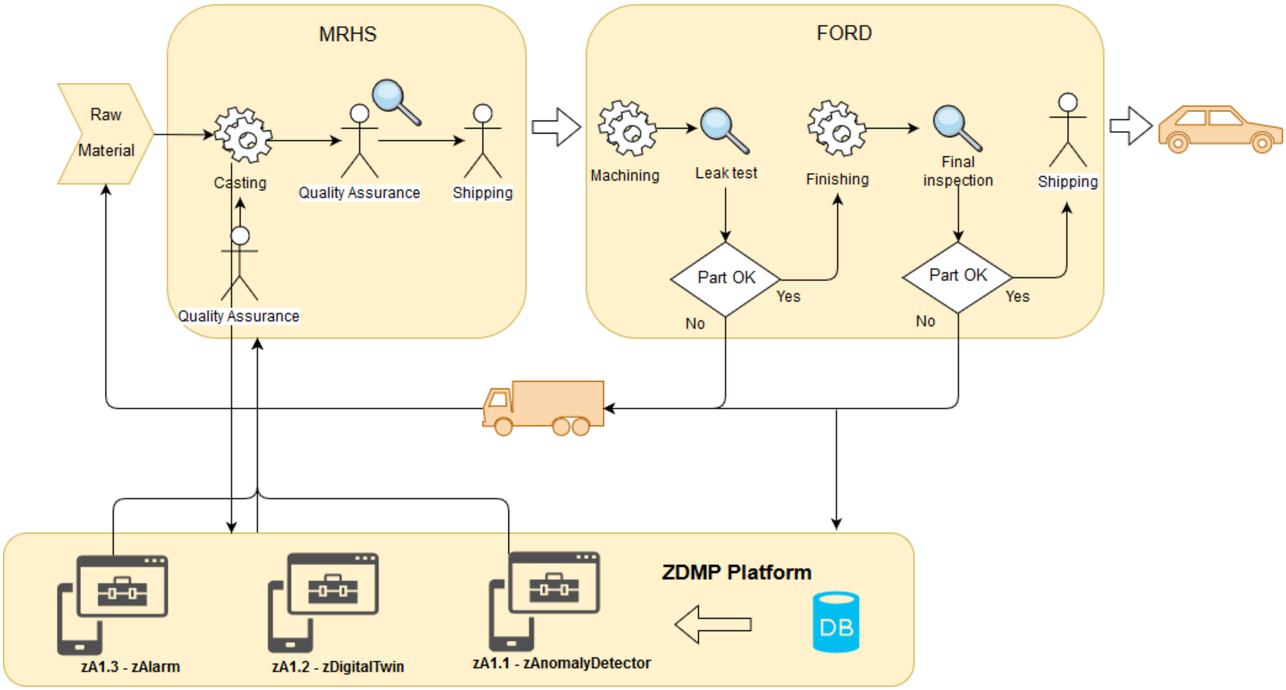


Figure 16: Business process model diagram "To-Be"

The flow diagram represented in Figure 17 helps to understand the proposed method for communication between Ford and MRHS plants through the ZDMP platform.

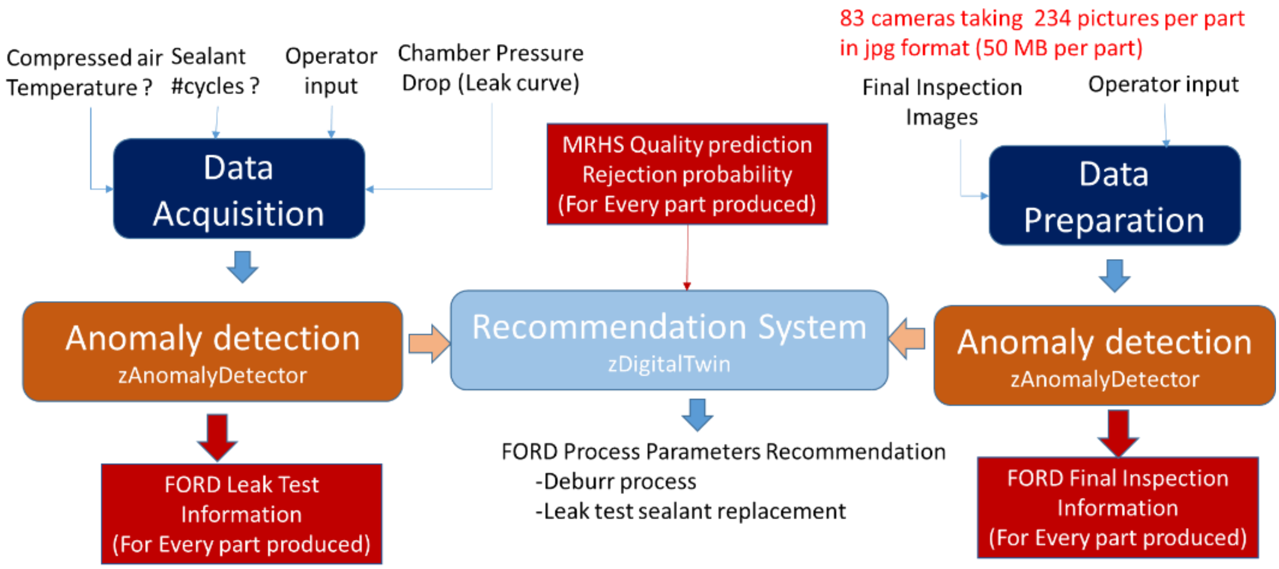


Figure 17: Diagram of the data flow between the proposed zApps

Due to Ford's IT requirements on data protection and confidentiality, this use-case makes use of a local instance of ZDMP platform and the proposed zApp for anomaly detection.

This application receives data directly from the Data acquisition service, which gathers the leak process data. The output of this application is the information necessary for MRHS to close the loop with the feedback of the leak results in Ford. When applied to the artificial vision operation, the Anomaly Detection application receives data from the Data preparation service, which processes the 50 MB of information produced by the 83 cameras installed in the Final inspection operation. The output is the information that is necessary to MRHS to close the loop with the feedback of the quantity and size of porosity in machined surfaces in Ford.

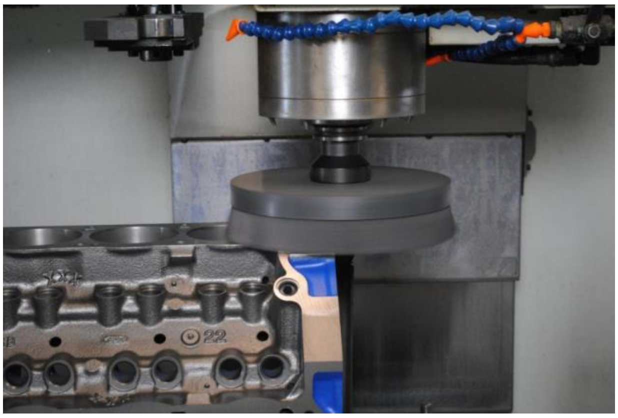


Figure 18: Typical brush deburr process

The output of both applications, in conjunction with the information of the MRHS quality prediction value calculated by the MRHS anomaly detection software, are serving as an input for the FORD Recommendation System. This information is exploited to alert the operator to take an urgent action. For example, in case of a known porosity, the operator can modify the deburr brush pressure, to minimize the porosity. Figure 18 shows a typical steel brush deburr process based on compensation table. The purpose of this process is to eliminate the burrs produced by worn milling tools to avoid mechanical problems in the engine. The compensation table is designed to consider the brush wear, calculated by analysing the variation of power consumption of the brush electrical motor. During every cycle, the brush power consumption is checked, and compensation command is raised if the minimum power value has not been reached. While eliminating burrs is an essential process, it can uncover pores, leading to leakages problems. To prevent this condition, the recommendation system, having data on both surface and porosity, can propose to the operator to modify the deburring parameters to minimize both effects. The algorithm model should be evaluated on request and updated if the error of the new model improves the model in production.

2.2.2.2 Candidate Solutions - zApps

This scenario will make use of the ZDMP platform through the following Apps running in MRHS and FORD premises. Some zApps are in-common with use-case 1.1.

zApp name	ID	Description	Timing
zAnomalyDetector	zA1.1	The objective of *zAnomalyDetector* is to ingest real time data from multiple sources (coming from Leak tests and Artificial Vision tests) and elaborate a multivariate analysis to detect system anomalies. Data will be gathered and collected in ZDMP and will be combined with the porosities validation test results conducted by MRHS to detect correlations. The main result will be a percentage of rejection possibility of a set of blocks during FORD machining process.	Maximum: 20 s (Machine cycle time) Desired: real-time.
zDigitalTwin	zA1.2	The objective of this app is to ingest real time data from multiple sources and elaborate a simulation of the observed system. The model can optimize the system parameters and produce recommendations on those to achieve a certain objective (defined by user).	Real time recommend ations
zAlarm	zA1.3	The objective of this zApp is to alert users in real-time in case of incidents or abnormal situations eg machine downtimes. Service technicians can get notifications with related information (machine, location, type of error, required tools…) on their smart wearable.	Real time

Figure 19: zApps selected for the Use Case

After a preliminary analysis of WP7 and WP8 tasks the apps relate to:

- T8.2 Pre-Production: Product Quality Prediction
- T8.3 Production: Non-Destructive Product Inspection
- T8.4 Production: Supervision

T5.1 Data Acquisition and IIoT and T5.2 Robust Industrial Network Support will implement part of the technologies needed to run zA1.3.

2.2.2.3 Expected Impact on KPIs

The expected impact is to improve the quality of the parts during the casting process. With respect to the selected KPIs the expected improvements are as follow.

KPI	Description	Current Value	Target Value
Ford Cylinder Block Line FTT	Percentage of units without defects or re-work needs form FORD’s cylinder block line	97,4%	98%
Cost reduction due to hidden porosity defects	Cost of the Ford resources including labour and energy to manufacture the parts sent to scrap due to “Hidden porosities”	32.000€	20% reduction

Reduction of Rejections per shift during Cylinder Block Tests	Percentage of rejected parts during Leak test operations that need to be reprocessed to confirm that the leak really exists and there is not any problem with the sealant.	OP65:2,5% OP145:0,05% OP150: 2,5%	OP65:2% OP145:0,02% OP150:2%

Figure 20: KPI: Expected improvements

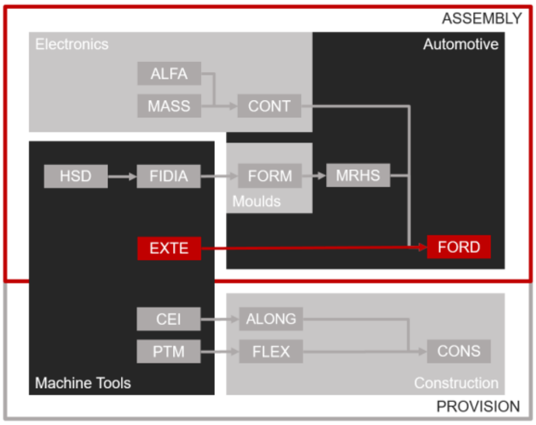
2.3 UC1.3: Engine block manufacturing: Defects reduction by optimization of the machining process

Figure 21: Transfer machining operation.

2.3.1 As-Is: Analysis of the Current Situation

2.3.1.1 Partners Roles

The partners involved in this use case are ETXE and FORD.



- **ETXE**: Located in Elgoibar (Spain), ETXE is a leading manufacturer of turnkey machining systems for high production lines
- **FORD**: Ford Valencia Engine Plant is producing engine blocks in its manufacturing plant of Valencia, using transfer lines and dedicated CNC machining centres, equipped with CNC controls and PLCs from different suppliers and years of construction

2.3.1.2 Business Process Model

The "As-Is" business model is shown in Figure 22. FORD manufactures the cylinder block in a production line, where different models of cylinder blocks can be manufactured. Rough parts enter the line and go through different machines, so that at the end of the line, the cylinder block is finished, checked, and ready for sending it to the assembly line. After each machining operation of the line, there is a quality checking point, where parts are verified with a defined frequency to ensure that the process is performing as per quality requirements.

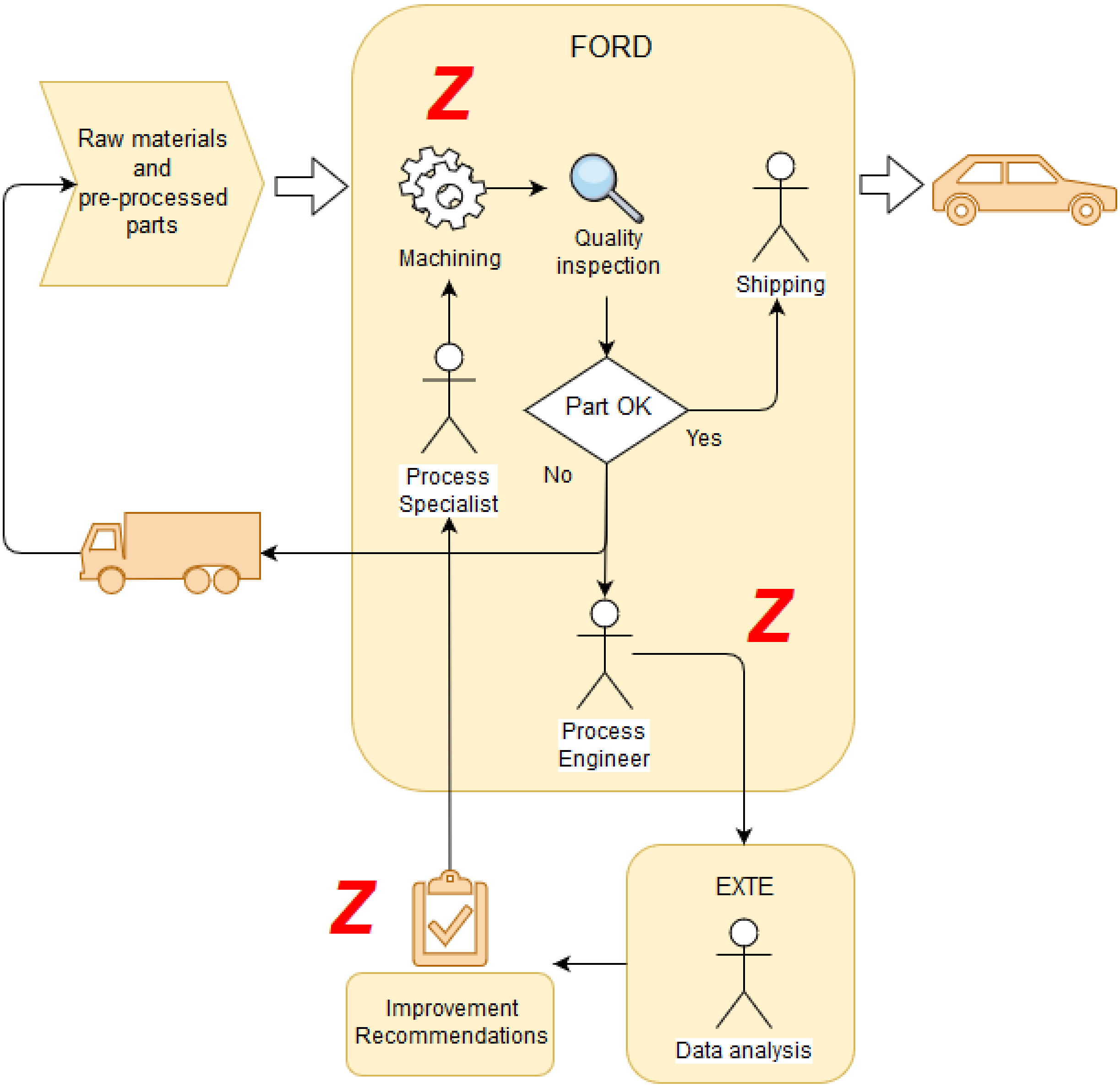


Figure 22: Business process model diagram "As-Is"

The machining process performed in each machine is different and depends on the model of cylinder block that is being produced. Normally it requires several machining technologies as milling, boring, drilling, tapping, etc.

Two key issues must be considered. On one hand the behaviour and stability of the cutting tools along the manufacturing process is critical for the reduction of machining defects along the production line. Unexpected tool breakages or wear are the responsible of many quality issues. On the other hand, the productivity of the whole line depends on the availability of each of the machines involved. In other words, it depends on the percentage of the production time that the machine is really in condition to produce good parts in the required cycle time. Preventive and corrective maintenance times reduce the productivity of the line.

When some of these cases occur and the productivity of the line is affected, a Ford process engineer contacts the machine builder to get recommendations for improving the machining process or the machine availability and recover the production capacity. For extracting this, data of the real process must be sent to the engineering department of the machine manufacturer. The information typically reaches the engineering department late and usually the quality of this data is not good enough to get good conclusions or it takes a long time to get them.

2.3.1.3 Zero Defects Key Issues

The aims of the present use-case are the reduction of:

- Quality issues related with the unexpected breakage or wear of the machining tools, optimizing the process conditions
- Corrective and preventive maintenance times which are unplanned and cause production loses

Figure 23: Typical machining process of an engine part in a CNC machine.

The cylinder block manufacturing line is equipped with ETXE-TAR CNC dedicated machining centres (Figure 23 shows an example of a CNC dedicated machining centre) and Cross Hüller transfer lines (Figure 21 shows an example of a machining station in a transfer line). Since it is the most critical machining station it is equipped with sensors for:

- Vibrations: Two sensors in each spindle
- Power consumption: Directly from servo regulator or by toroidal transformers
- Temperatures: Plant temperature, spindle heads temperatures, and lubrication oil temperature
- Lubrication oil: Flow, humidity, and presence of particles

Additionally, the industrial PC that controls the machine is capable of sharing additional information of the process such as:

- Process times: Total cycle time, station cycle time, etc.
- Machine status: blocked, starved, running, failure, warning, tool change, etc
- Cylinder block model in production

FORD captures all this data and stores it in its Cassandra database. Most of the variables recorded are associated to each produced part, such as the vibration signal or the power consumption during the manufacturing of that part, so the database is uploaded with a frequency of around 20 seconds.

The key issue for the success of the use case is to convert all this data in to knowledge that can be used for taking actions to improve the tooling behaviour and to minimize the time and resources needed for maintenance activities.

The reliability of these systems is very high, so there are very few failures in the data recorded.

2.3.2 To-Be: Analysis of the Expected Scenarios

2.3.2.1 Target Business Process Model and Partners Roles

A local instance of the ZDMP platform hosted at FORD premises can avoid problems of data protection and confidentiality, but the communication with ETXE-TAR needs to be granted.

As some data are already being registered, the first step is to define if any other signal / variable is needed for the later analysis. The existing exchanging data module, Cassandra, can transfer the data to the AI and Advance Data Analytics Module (zAnomalyDetector), included in the ZDMP platform. zAnomalyDetector analyses the data and determines the "normal" condition of the machine critical subsystems (performance of spindles and linear and rotary axes, for example) and the interaction of the tool with the material of the part being processed. Once the "normal condition" is established, the zAnomalyDetector monitors the trending of the data, evaluating when the subsystems and the machining process are drifting to a potential risky "abnormal" condition. As an output of this analysis, the module should also identify which is the subsystem that is responsible for the drift to the "abnormal" condition. Additionally, another zApp in the platform can send an alarm to operators or technicians informing about this "abnormal" condition (zAlarm).

Depending on the specific case, the platform can generate enough knowledge to automatically change some parameters of the process (cutting conditions …) to recover the production capacity. Alternatively, it sends its evaluation to ETXE-TAR where further analysis must be performed to decide concrete actions that should be taken to recover the "normal" condition of the whole system. For this purpose, the platform uses a Simulation Module (zDigitalTwin). The recommended actions by ETXE-TAR are also manually introduced into the platform, so that once the actions are implemented, the platform can evaluate their effectiveness and increase its own knowledge. Figure 24 shows the "To-Be" business model.

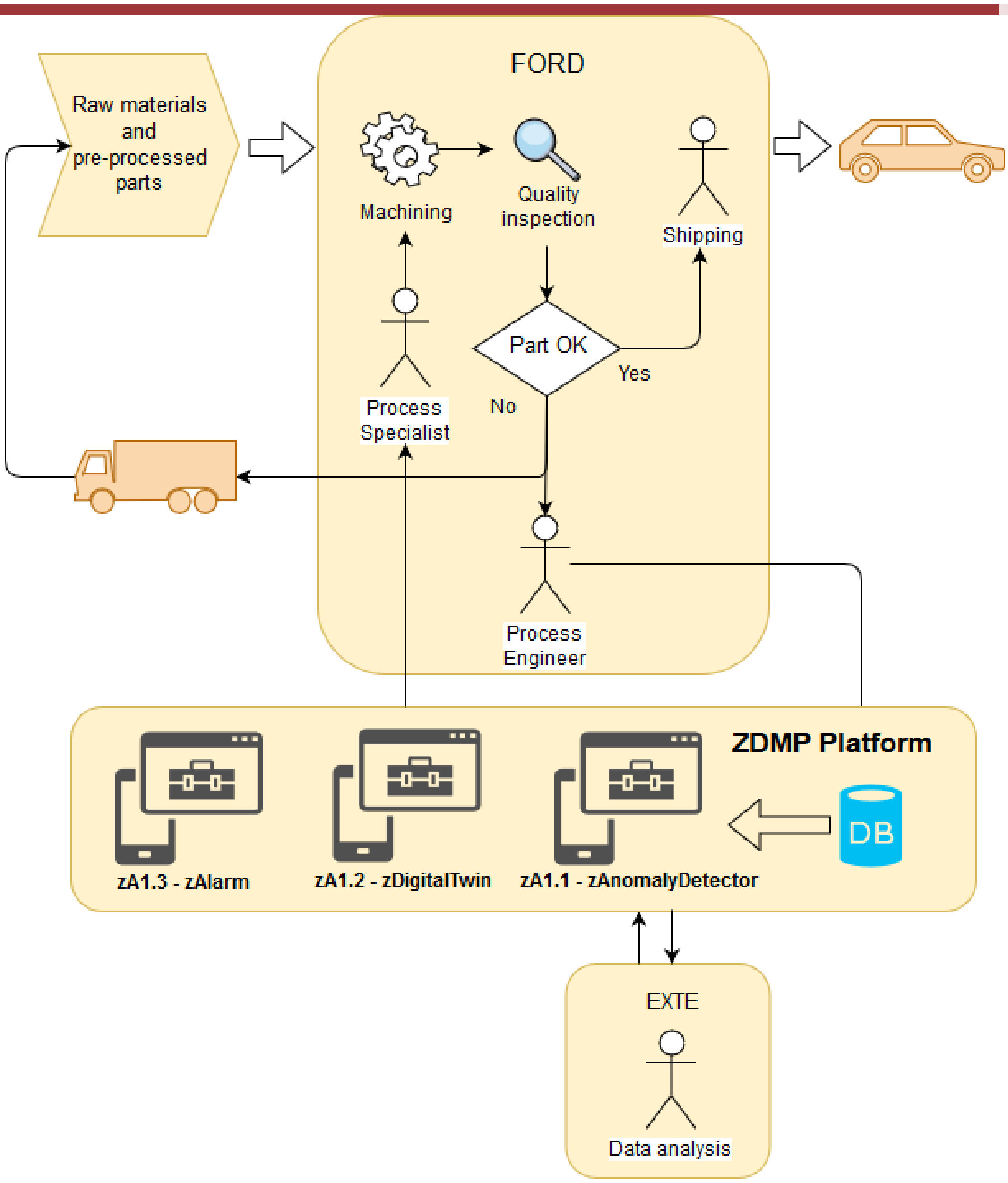


Figure 24: Business process model diagram "To-Be"

2.3.2.2 Candidate Solutions - zApps

This scenario will make use of the same zApps of UC1.1, customized to the specific equipment and process.

zApp name	ID	Description	Timing
zAnomalyDetector	zA1.1	This is the AI and Advance Analytics Module. The objective of zAnomalyDetector is to ingest real time data from multiple sources (Etxe -Tar machine tools sensors, etc.) and elaborate a multivariate analysis to detect system anomalies. When the system detects such an anomaly, it will generate notifications to alert the operator or the shop floor manager.	Minimum: Daily Desired: every 5 parts
zDigitalTwin	zA1.2	This objective of this zApp is to ingest real time data from multiple sources and elaborate a simulation of the	Real time with

		observed system. The model can optimize the system parameters and produce recommendations on those to achieve a certain objective (defined by user).	predefined time for predictions
zAlarm	zA1.3	The objective of this app is to alert users in real-time in case of incidents or abnormal situations eg machine downtimes. Service technicians can receive notifications with related information (machine, location, type of error, required tools…) on their smart wearable.	Real time

Figure 25: Table of ZDMP apps

After a preliminary analysis of the WP7 and WP8 technologies, the zApps are related to the following tasks:

- T8.2 Pre-Production: Product Quality Prediction
- T8.4 Production: Supervision

2.3.2.3 Expected Impact on KPIs

The expected impacts are:

- To improve overall product quality
- To improve the productivity reducing unplanned downtime and optimizing the maintenance activities

With respect to the selected KPI the expected improvements are:

KPI	Description	Current Value	Target Value
# Scrap parts per year	Number of parts that have been scrapped due to unexpected failures of the tools. Scrap parts due to human error are not considered.	Depending on the process For Block line OP20: 250 parts	5% reduction For Block line OP20: 235 parts
Tooling cost	Cost of tooling used in a given production process	35.000€	5% reduction
Machines unplanned downtime	A measure of the percentage of time that machines are not producing when they are supposed to, due to unscheduled tool changes	Depending on the process For Block line OP20: 3.5 % of usage time	15% reduction For Block line OP20: 3% of usage time
Reaction Time	The time needed to ETXE-TAR to react to a malfunctioning with and without on-line data access (with emails and spreadsheets data access as current method).	Specific to the problem. Currently the annual average is about 20h	50% reduction Corresponding to a new reaction average time of 10h

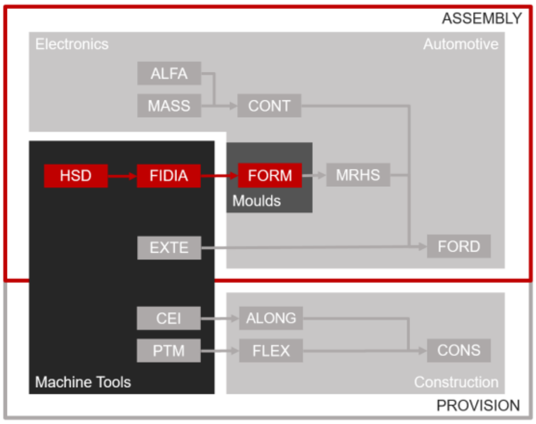
Figure 26: KPI: Expected improvements

2.4 UC2.1: Moulds manufacturing: Process alert system for machine tool failure prevention

Figure 27: Milling operation example

2.4.1 As-Is: Analysis of the Current Situation

2.4.1.1 Partners Roles



This use case involves industrial partners: HSD, FIDIA and FORM:

- **HSD**: Located in Italy, is one of the world's largest electro spindle manufacturers. HSD supplies the spindle data for the use case.
- **FIDIA**: LE located in Italy, FIDIA designs, manufactures, and sells Numerical Controls, High-Speed Milling Systems and Flexible Manufacturing System. FIDIA machines use HSD spindles.
- **FORM**: SME located in the Czech Republic, they are one of the leading maintenance and modification tool shops for large plastic injection moulds in Bohemia. FORM is the user of the machine tools FIDIA produces.

2.4.1.2 Business Process Model

The "As-Is" business process model is shown in Figure 28. FORM is producing moulds for plastic injection with a FIDIA machine that in turn is equipped with an HSD spindle. Typically, mould sizes are up to 3x3x1 meters and the machining process of a single mould can involve the use of several tools (different types and shapes) and typically takes up to 6 / 8 hours to be completed. The composition of the workpiece being machined could change every time and its physical and technological properties (such as stiffness, dimensions, etc). Moreover, physical and technological properties can also change within the same machining process. In fact, the same mould can be composed by different materials especially if it is built with different parts welded together.

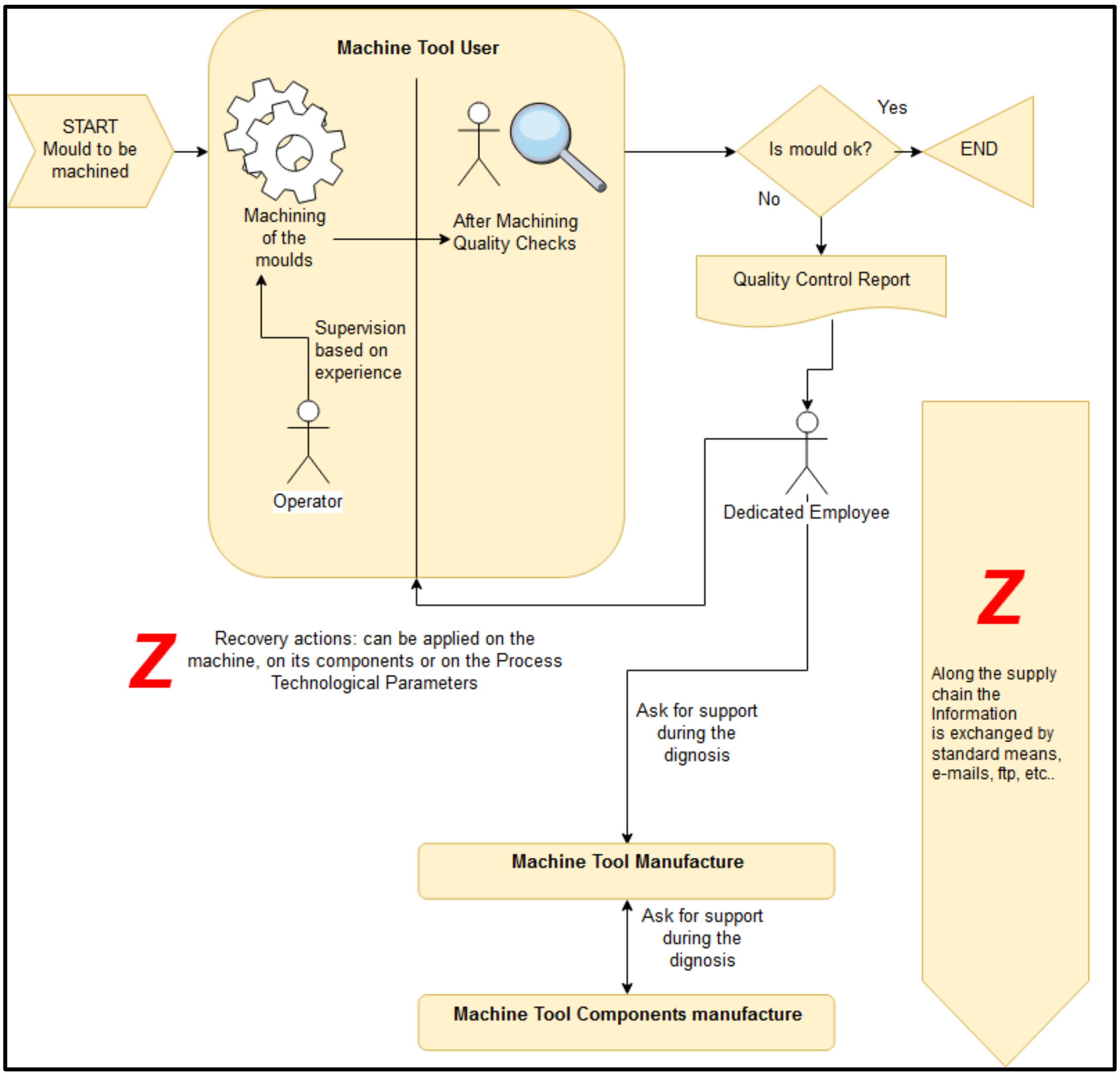


Figure 28: Business process model diagram "As-Is"

During the current machining operations, no monitoring of the health status of the machine tool and its components is currently performed. To assess the status of the equipment, FORM relies on the experience of the operator, for whom hidden malfunctions or non-blocking faults are extremely difficult to detect in time to stop the manufacturing operation. Post production quality control procedures are always performed on the parts after manufacturing or, in exceptional cases in between the machining phases, by stopping production. In both cases, the detection of non-conformities or out of tolerance issues occurs at an advanced stage of the process.

Especially in SMEs, where quality and maintenance need to cope with hard production deadlines and penalties from customers, intermediate stops are not acceptable as they reduce competitiveness.

Once the quality control detects a scrap part, a diagnostic process starts to understand what happened and why? The aim is to avoid repeating the problem. However, the problem is not always trivial and the Machine Tool User (FORM) can ask the Machine Tool Manufacturer (FIDIA) support in this assessment. In addition, if the diagnosis leads to the identification of a specific component as the cause of the defect. Then FIDIA can ask the Components Manufacturer (HSD) to intervene identify / solve the cause of the problem. For example, an unbalanced spindle can lead to an unacceptable surface quality.

All the information needed to carry out the diagnosis are exchanged manually by means of digital, but unsophisticated, means, such email, FTP, etc.

Recovery actions are put in place just after the problem has been identified and diagnosed by the quality control processes. Up to that point, the machining process is likely to continue with further parts. Moreover, the diagnosis is not immediate and often the involvement of the machine tool builders extends the time needed to act.

2.4.1.3 Zero Defect Key Issues

When machine tools, or one of their main components such as the spindle, suffer a major and unexpected failure the machining is likely to be stopped. Non-blocking malfunctions or performance degradation due to components wearing are not detected but they can lead to unfit and/or scrap parts. Moreover, the machining is not immediately interrupted and time for both machining and quality control is unnecessarily spent.

Figure 29: Moving components: Bearings, ball screw nuts, gears, and linear guides

Early diagnosis and prevention are thus key points and can become a significant advantage to improve quality and competitiveness. From a preliminary analysis performed at FORM, the most common failures seem to be related to the movement components and subsystems of the machine, such as spindle, racks and pinions, balls screw, bearings, gears, shafts, belts, guideways, etc. These components also have the major impact on the final quality of the products and in a Zero Defects strategy can be considered critical.

2.4.2 To-Be: Analysis of the Expected Scenarios

2.4.2.1 Target Business Process Model and Partners Roles

The target business process (Figure 30) foresees the Machine Tool User (FORM) adopting the platform hosted outside the company. This solution is ideal for an SME as it reduces the investment and maintenance cost of an internal platform including the related development of human skills.

A first zApp (zA2.1 - zMachineMonitor) running on the platform enables the continuous gathering of data from the machine and its components.

The objective of zMachineMonitor is to automatically gather and store both equipment and machining process data. It is also able to monitor the task to detect sudden or abrupt changes that can lead to a premature failure and that needs to be taken care of by the operator in a short time. When the system detects such an event, it generates notifications to alert the operator or the shop floor manager. This data is a temporal series of values read by the machine numerical control. Each machine parameter value is read periodically and stored as a temporal series. The data format can be binary or ASCII delivered in a format readable by a program such Json / Bson or XML.

Once the machine has produced this data (and in some cases it can cache them temporarily locally) they have to be transmitted to a central storage (Database). Depending on the acquisition frequency and the number of machine components, the size of data could range from 100KB to 10MB per hour of machining. Dependant on the amount of historic data needed by the zMachineAnalytics (zA2.2), older and not more useful data can be cleared to reduce space acquisition. A simpler, but faster, data analysis / comparison on the last data recorded (not the entire temporal series) needs to be carried out locally to detect sudden or abrupt changes that can lead to a premature failure.

Thanks to an UI, the operator can receive information on the machine health and process status. The central data storage should to be able to gather data from several zMachineMonitor zApp working on different machines of different customers, so it needs to be internally structured to keep record/track of all the data. The zMachineMonitor integrates a driver for connecting with the machine for reading parameters values and sending notification. Currently the driver must be programmed on top of a C++ API delivered by means of a shared library (.dll). It runs automatically and periodically, and it will need to be configured in advance for each machine. This is necessary because parameter types and availability changes based on the machines model. For coping with the time constraint, the zMachineMonitor should be deployed locally on the machine that is managed by a Widows based industrial PC.

A second zApp (zA2.2 - MachineAnalytics) running in background (possibly on the platform) periodically access the data (collected through zA2.1) to carry out analysis and try to estimate deviation or predict malfunctions (faults, non-conformity process parameters, etc). A dedicated UI delivers status and monitoring information to the Machine Tool User.

The objective of zMachineAnalytics is to automatically detect equipment or process deviation from standard working conditions that can lead to near failure events using data analysis algorithms. It will work on data already stored in a database by the zMachineMonitor zApp to identify degradation trends of the machine or components. The result of the analysis can be stored on the database itself and the zApp needs a User Interface accessible by: Machine Tool User, Machine Tool Manufacturer, or the Machine Tool Components Manufacturer. By means of this UI results are displayed allowing both deep diagnosis and analysis of the problem as well as trigger the appropriate mitigation actions.

This output will be used for implementing the feedback with recovery actions at the following levels:

- A first recovery loop is closed directly by the Machine Tool User (FORM) whose operators, by means of an UI, receive information on the machine health and process status. This will aid the decision upon which mitigation action to take. The reaction time of this recovery loop is in the range of days. In case the Machine Tool User does not fully understand the reason why the machine status has changed, they can ask help from the Machine Tool Builder (FIDIA) or Machine Tool Components Manufacturer (HSD), who can provide support by accessing the same data remotely. The UI of Machine Tool Builder or Machine Tool Components Manufacturer can be structured to access and compare the analysis performed in other similar machines / components coming from others Machine Tool Builder or Users.
- A second recovery loop is closed automatically by the machine and no Machine Tool User interaction is needed. In this case, the reaction time is shorter, 2/10 seconds, and the main objective is to pause the Equipment (Machine) because of a rapid deviation from the nominal condition. Once paused, the operator can decide what to do next thanks to the help of the same UI used for the first recovery loop.

Both first and second loops are intended to detect, and react, preventing further failures or Machine Tool performance changes.

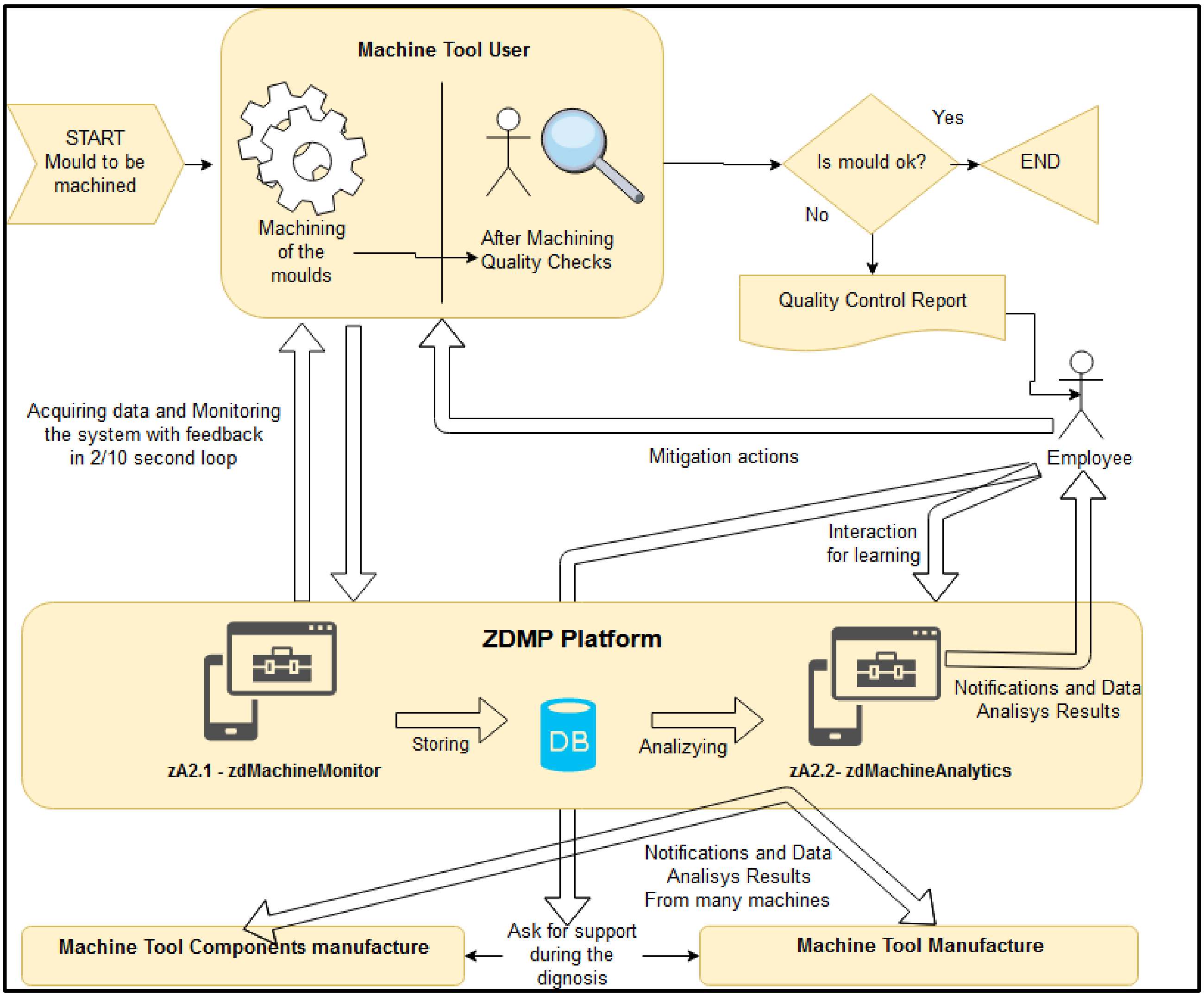


Figure 30: Business process model diagram "To-Be"

2.4.2.2 Candidate Solutions - zApps

The companies participating in this use case wish to reduce costs and reduce the number of waste parts generated. The goal is to advance from a scenario in which monitoring is a slow process and the collaboration is scarce; to a scenario where, using digital platforms and data processing, monitoring, and reacting are agile, quick, and collaborative processes.

Although a vertical and ad-hoc solution could also fulfil the purpose, the ZDMP Platform allows a quick development of relevant, and most of all, personalized applications. In addition, the different applications are integrated in the same platform and therefore the implementations are cheaper (since the basic blocks of the platform already exists) and faster to develop. The above goals will be reached by the development of the following major, equally important, Apps running in the ZDMP platform, see Figure 31.

zApp name	ID	Description	Timing
zMachineMonitor	zA2.1	The objective of zMachineMonitor is to automatically gather and store both equipment and machining process data. It is also able to monitor the task to detect sudden or abrupt changes that can lead to a premature failure and that needs to be taken care of by the operator quickly. When the system detects such an event, it will generate notifications to alert the operator or the shop floor manager. This data is temporal series of values read by the machine numerical control.	Reaction in 2 / 10 seconds
zMachineAnalytics	zA2.2	The objective of zMachineAnalytics is to automatically detect equipment or process deviation from standard working conditions that can lead to near failure events using data analysis algorithms. It will work on data already stored in a database by the zMachineMonitor zApp to identify degradation trends of the machine or components. It will run periodically and each time it will analyse the new and old data just recorded from the zMachineMonitor.	Reaction in hours / days

Figure 31: zApps selected for the Use Case

After a preliminary analysis, the WP7 and WP8 technologies tasks relevant to develop the zApps for this UC are:

- T7.3 Production Stage: Material and Energy Efficiency
- T7.2 Production Stage: Equipment Performance Optimization
- T8.4 Production: Supervision
- T6.2 Secure Business Cloud

2.4.2.3 Expected Impact on KPIs

The expected impacts are:

- Machining Cost reduction: Downtime reduction and service improvement
- Better service: Remote analysis and failure predictive detection
- Increased competitiveness: More secure delivery time, cost based on machining and not on down-time and rework expected on the historical database

With respect to the selected KPI the expected improvements are:

KPI	Description	Current Value	Target Value
Stop time due to collateral damage	Collateral damage is the part of the repair costs that would be avoided if the maintenance would be scheduled before the failure happens. Collateral damage also considers a percentage of additional downtime when a machine is not producing.	Specific to the fault type 2 h per tool holder damages 30 mins per tool damages	10% reduction
Rework time and related losses in €	Bad surface quality does not usually result in a scrap part but requires workpiece re-work. The need for this operation often arises after the workpiece is removed from the machine, so also the time for re-positioning and re-clamping the workpiece must be considered.	Specific to the fault type Year average 76.000€ losses	20% reduction Corresponding to a year average of 59.000€ losses
Servicing time	The time needed for a non-trivial maintenance intervention to start depends on the time needed by the provider of the machine to assess the situation.	Specific to the fault type Average remote assistance time (machine stop): 3 days Average intervention time (machine stop): 10 days.	30% reduction Average remote assistance time (machine stop): 2 days Average intervention time (machine stop): 7 days.
Ease of use	Test over at least 10 possible users working at all steps of the supply chain, with different programming and manufacturing skills, age, experience.	-	Target positive experience in 80% of cases. Target usage uncertainty below 15%. Target request to have the apps available in their day to day job from 50%.

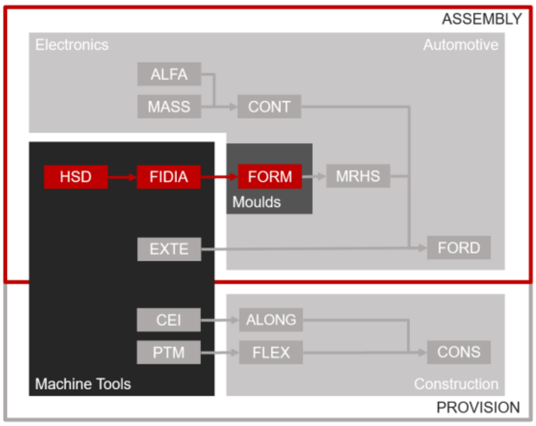
Figure 32: KPI: Expected improvements

2.5 UC2.2: Moulds manufacturing: Smart process parameter tuning

Figure 33: CNC control, visualization of the cutting tool parameters

2.5.1 As-Is: Analysis of the Current Situation

2.5.1.1 Partners Roles



This use case involves industrial partners: HSD, FIDIA and FORM

- **HSD**: Located in Italy, is one of the world's largest electro spindle manufacturers. HSD supplies the spindle data for the use case.
- **FIDIA**: LE located in Italy, FIDIA designs, manufactures, and sells Numerical Controls, High-Speed Milling Systems and Flexible Manufacturing System. FIDIA machines use HSD spindles.
- **FORM**: SME located in the Czech Republic, they are one of the leading maintenance and modification tool shops for large plastic injection moulds in Bohemia. FORM is the user of the machine tools FIDIA produces.

2.5.1.2 Business Process Model

The "As-Is" business process model is shown in Figure 28. FORM is producing moulds for plastic injections with a FIDIA milling machine that in turn is equipped with an HSD spindle. Especially in SMEs, this type of manufacturing relies on the competence of the programmer and on the knowledge of the operator in the selection of the correct parameters for setting the machine for that specific type of application. This kind of expertise mainly comes from experience and relies within the workers rather than the company. Whilst experienced workers are an asset in every company, especially in SMEs, the competence transfer to new workers is too often demanded from them instead of the company. Setting up this activity at company level is problematic and takes time, meaning the overall company knowledge and expertise not fully exploited during these transition moments.

Before a manufacturing operation starts, a designer prepares the CAD and the CAM, which is then converted to a "part programme", to be fed to the machine for producing the piece. Some fine adjustments are still needed from the operator part to reach the best surface quality. Now, this type of adjustment is left to the knowledge of the operator.

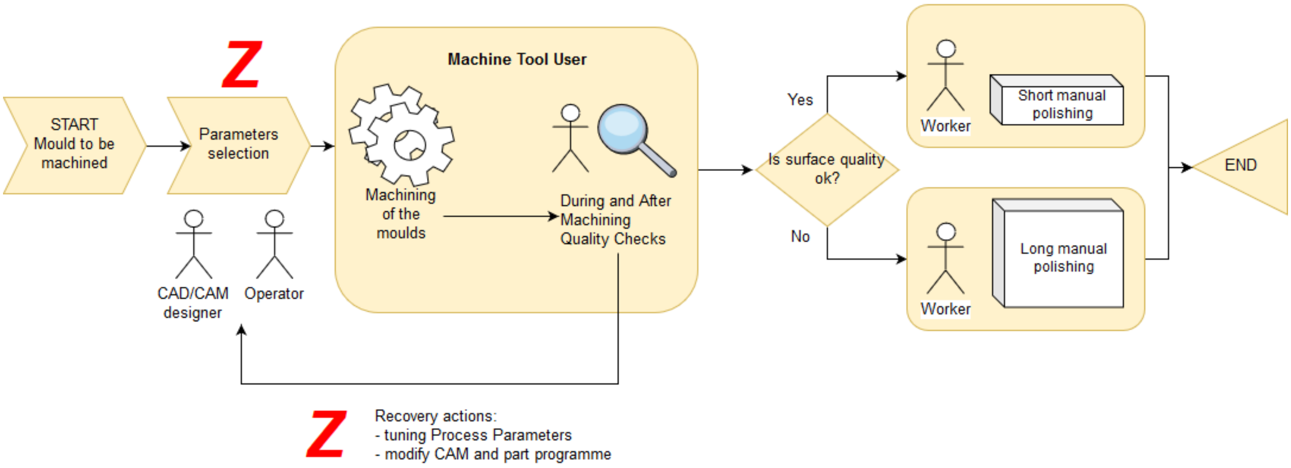


Figure 34: Business process model diagram "As-Is"

2.5.1.3 Zero Defect Key Issues

The finishing operation in milling is a very delicate step. The resulting surface of the mould is strongly dependent on a variety of parameters: the machine parameters, the environmental conditions and the parameters determined in the CAM at the design phase. Many of the surface defects are not easily measurable, but they usually can be seen by the naked eye (Figure 35). It is therefore up to the operator to detect and decide whether the surface quality of a product has reached the necessary quality.

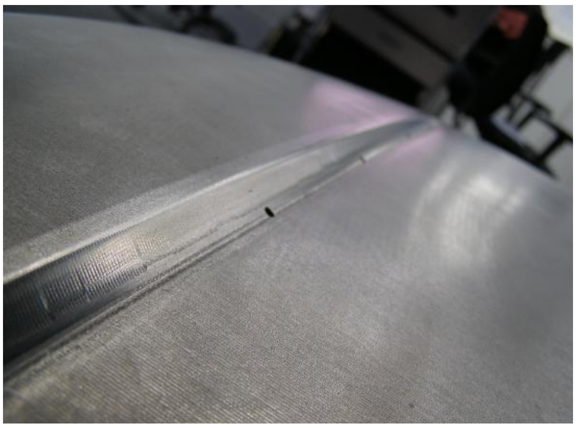


Figure 35: Example of surface with defects due to poor parameter selection

Experienced operators know how to modify manufacturing parameters based on the situation. When bad surface quality is detected by the operator during the manufacturing, visually or because the cutting noise is unusual, the first recovery action that can be emplaced is a manual variation of feed and speed parameters. If the quality does not improve, the manufacturing can be stopped, and the part programme sent back to the CAD/CAM designer for modifications.

Sometimes the poor surface quality goes undetected until at the end of the milling operation. In this case, the polishing operation requires a much longer time to reach the desired quality level. This latter case is very usual among junior operators, who do not yet have the experience to identify the situation at an early stage.

The polishing is manual and usually takes a similar time to a finishing milling operation. For example, for an 8 hour milling operation, polishing can take about 5 hours. This time can reduce to 4 hours for good surface quality parts and increased to 6 for bad quality parts.

2.5.2 To-Be: Analysis of the Expected Scenarios

2.5.2.1 Target Business Process Model and Partners Roles

The target business process (Figure 36) foresees the Machine Tool User (FORM) adopting the platform hosted outside the company. In the new model ZDMP platform acts as a knowledge storage for the company, who can update it and exploit it through the zApps. After each machining operation, after the in-line quality assessment, the operator submits a report containing (automatically completed) all relevant parameter settings or environmental variables, and a quick assessment of the surface quality results (manually added). This information populates a database on ZDMP.

At the start of a new manufacturing operation, the conditions and the selected parameters are sent to the ZDMP database analysis. An algorithm finds the most similar conditions and verifies that the parameters selected resulted in an acceptable surface quality. The system suggests to the operator potential changes to make. The operator can decide to apply or to ignore the suggestion based on his knowledge of the conditions and of the requirements. They can consult the CAM programmer if any changes need to be addressed at design level.

This new process allows inexperienced workers to profit from the collective knowledge of colleagues, especially skilled ones, to retrieve information on past manufacturing operations and how the results were.

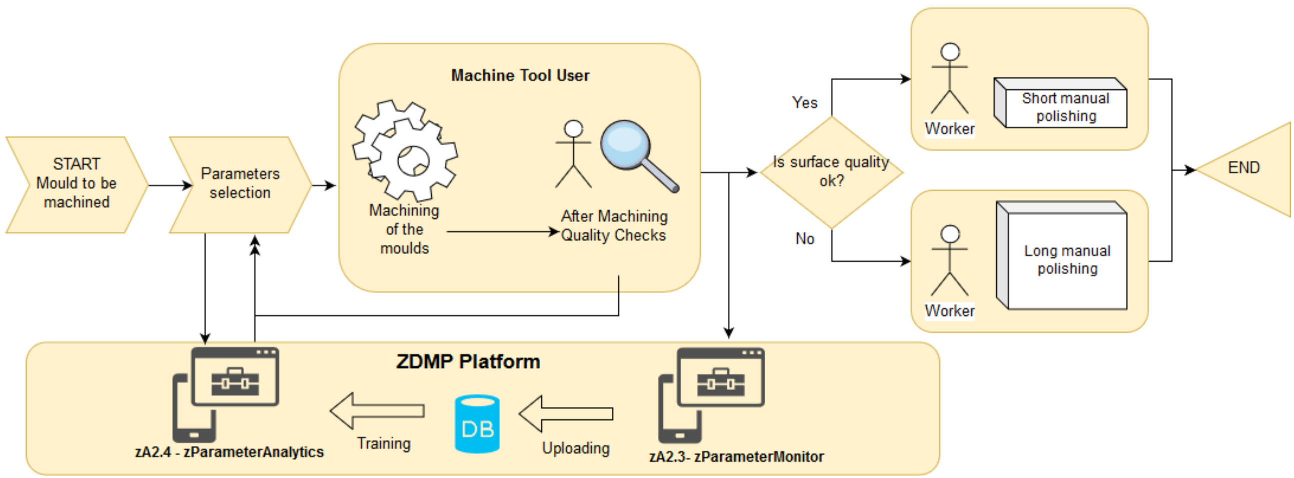


Figure 36: Business process model diagram "To-Be"

The ZDMP database can be private or shared with the suppliers. Since the manufacturing parameters are more related to the equipment, than the manufacturing itself, it could be useful to involve manufacturers in the knowledge chain. They could add relevant information to the database and enrich it with (anonymized) data from a larger pool of customers, making the suggestions more accurate.

From a suppliers point of view, gaining access to this type of data would provide them the means to develop higher quality products, based on the actual use and practise of the customers.

2.5.2.2 Candidate Solutions - zApps

zApp name	ID	Description	Timing
zParameterMonitor	zA2.3	The objective of zParameterMonitor is to automatically gather and store all parameters data and operators' feedback. Data structures should allow flexibility (eg Json files). The objective and the functioning of this zApp is similar to zA2.1, but in this case it might need a much simpler UI.	Reaction within the production cycle (hours)
zParameterAnalytics	zA2.4	The objective of zParameterAnalytics is, given a condition (e.g. type of machine, environmental variables, etc), to automatically detect which parameter combination provides the best results. It triggers the appropriate response to all new production requests and provides the machine operators a suggestion upon which parameters to use for their current situation. It has an UI local to the CNC control.	On demand – reaction seconds / minutes

Figure 37: zApps selected for the Use Case

After a preliminary analysis, the WP7 and WP8 tasks relevant to develop the zApps for this UC are:

- T7.2 Production Stage: Equipment Performance Optimization
- T8.4 Production: Supervision
- T6.2 Secure Business Cloud

2.5.2.3 Expected Impact on KPIs

A Zero Defect strategy aims to improve the overall quality and to exploit the operators experience and know-how at company level. The criteria to be followed to measure the impact are similar to those in UC2.1. In that case, the KPIs are evaluated as an effect of the damages due to machine errors. This case, on the contrary, focuses on the poor machine parameter selection, therefore all KPIs refer to defects caused by human error.

The expected impacts are:

- To reduce downtime costs by preventing surface quality issues

- To use safe and agile channels for the sharing of recorded data and know-how
- For the Machine Tool Manufacturer and Machine Tool Components Manufacturer, to increase indirectly their product values

With respect to the selected KPI the expected improvements are:

KPI	Description	Current Value	Target Value
Production time	Overall production time for one mould. FORM now plans parameters in an inefficient but reliable way, in order never to damage the part. With a higher credibility on the parameters, it would be possible to avoid unnecessary cycles and therefore reduce the overall production time.	Usually 4 or 5 cycles: • 1 roughing • 2 semi finishing • 1 or 2 finishing Corresponding for a typical mould to 32 h work	Reduced to 3 cycles: • 1 roughing • 1 semi finishing • 1 finishing Corresponding for a typical mould to 24 h work
Polishing time and related costs reduction	Bad surface quality does not usually result in a scrap parts but can require a polishing of the workpiece. The time for this operation is longer if the initial surface quality is lower.	5h on average	20% reduction 4h on average
Rework time and related losses in €	Bad surface quality does not usually result in a scrap part but can require a remanufacturing of the workpiece. The need for this operation often arises after the workpiece is removed from the machine, so also the time for re positioning and re clamping the workpiece must be considered.	3h on average, considering both the part program modification and the time the part programme already run which has to be repeated	Reduced by 20%
Ease of use	Test over at least 10 possible users working at all steps of the supply chain, with different programming and manufacturing skills, age, experience.	-	Target positive experience in 80% of cases. Target usage uncertainty below 15%. Target request to have the apps available in their day to day job from 50%.

Figure 38: KPI: Expected improvements

2.6 UC2.3: Moulds manufacturing: in-line 3D modelling

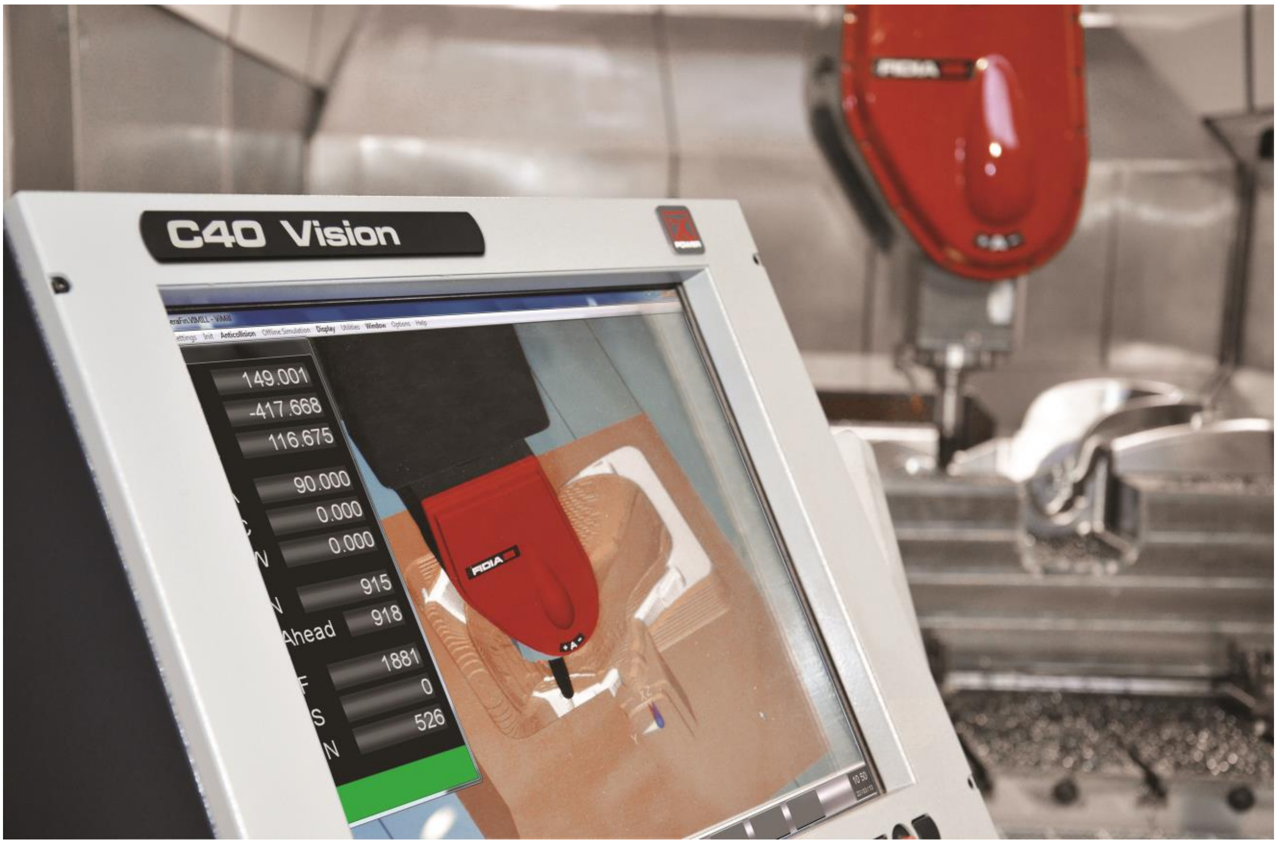


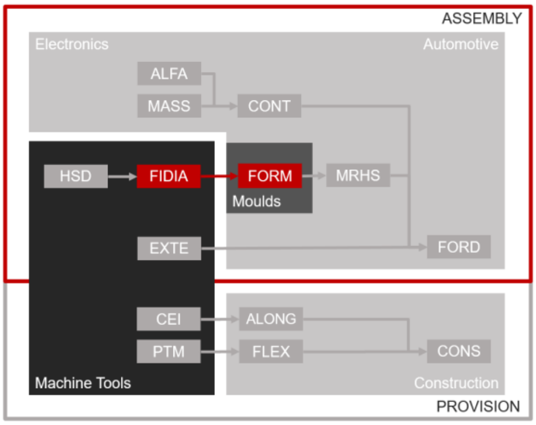
Figure 39: Anti-collision software running

2.6.1 As-Is: Analysis of the Current Situation

2.6.1.1 Partners Roles

This use case involves industrial partners: FIDIA and FORM

- **FIDIA**: LE located in Italy, FIDIA designs, manufactures, and sells Numerical Controls, High-Speed Milling Systems and Flexible Manufacturing System. FIDIA machines use HSD spindles.
- **FORM**: SME located in the Czech Republic, they are one of the leading maintenance and modification tool shops for large plastic injection moulds in Bohemia. FORM is the user of the machine tools FIDIA produces.



2.6.1.2 Business Process Model

The "As-Is" business process model is shown in Figure 41. FORM produces moulds for plastic injections with a FIDIA milling machine. To protect the machines, several simulators and anti-collision software packages are available on the market. ViMill is a software developed by FIDIA for avoiding collisions between the machine and the workpiece. It avoids collisions both during the automatic manufacturing operations and during the manual use of the machine (eg Maintenance, set-up operations, workpiece alignment). Contrary to other simulators, it can work in both the offline and online modes, the latter working on the real position of the machine some seconds ahead of the actual execution of the movements and is thus able to stop machining at any time.

These systems (ViMill included) use 3D models in .stl format of the entire system. This comprises modelling of: Machines, Tools, Target Workpieces (final expected shape after the milling operation), Stock Workpieces (initial shape before the milling operation) and all the other fixtures or objects within the working area. The machine model is prepared by the manufacturer once and is used during the entire machine life. Tools (and their holders) are usually modelled with the CAD/CAM system by the users. The workpiece target is the input for the CAD/CAM, and it is always available. The workpiece stock and all other objects are usually not modelled.

Differently to the solution proposed in UC2.1, this solution is ineffective against faults and crashes caused by the deterioration of the equipment and its components. Instead it targets the human error. In this range, the following errors are the most common:

- Manual mode crash: Caused by the operator where in manual mode moves the milling head crashing into the workpiece or the machine itself (tool changer, walls, table, ceiling, …)
- Automatic mode crash: Caused by the CAD/CAM designer, it defines paths involving movements that cause a crash. Figure 40 shows some example of the possible collisions due to part program.

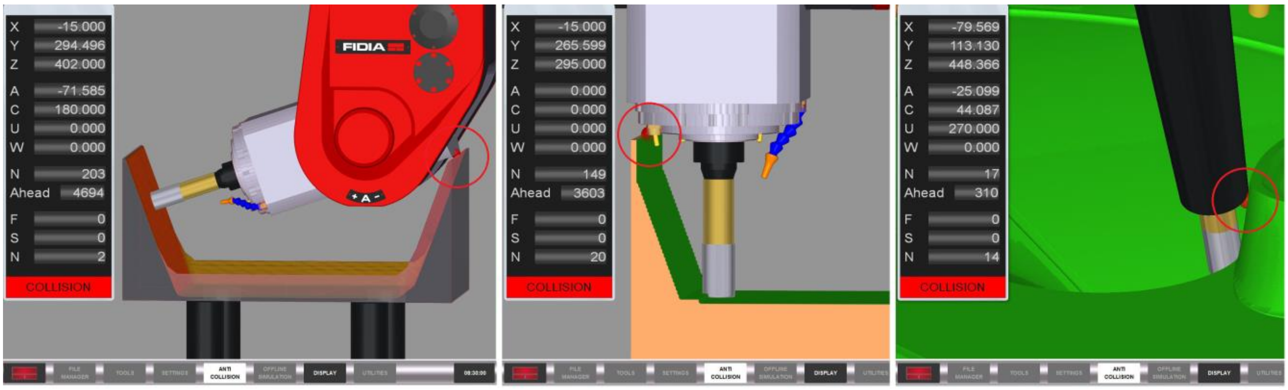


Figure 40 – Examples of possible collision

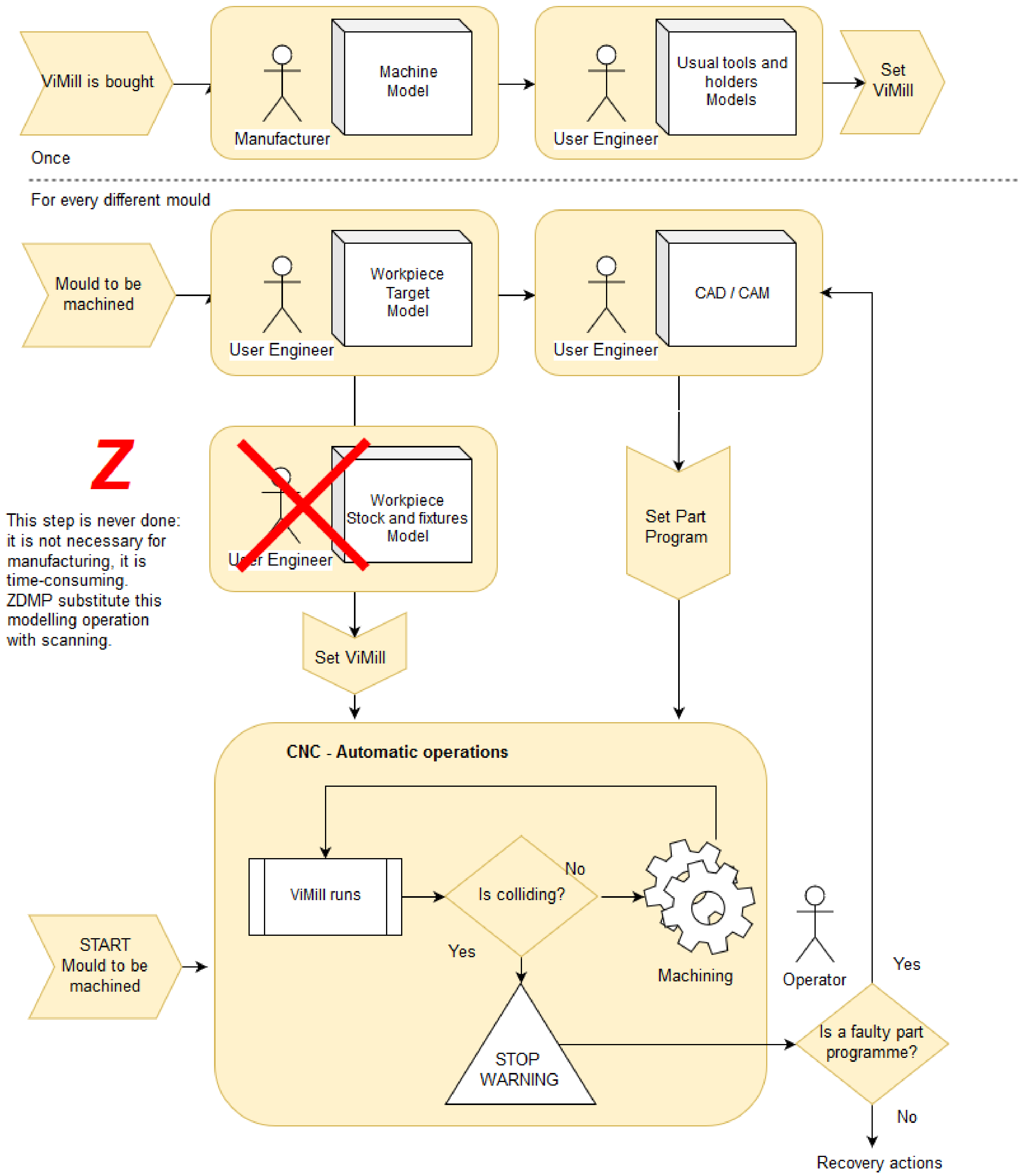


Figure 41: Business process model diagram “As-Is”. The step marked with the red X is

2.6.1.3 Zero Defect Key Issues

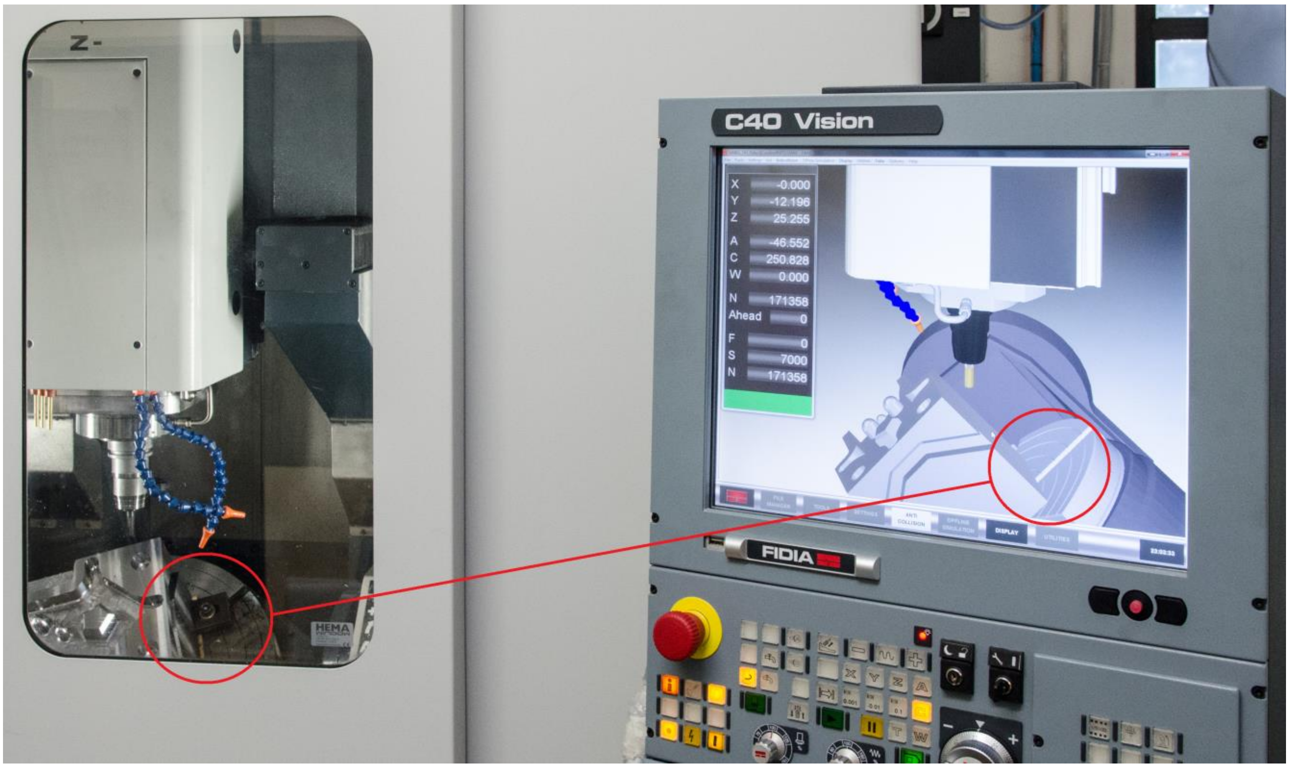


Figure 42: Example of clamping system not modelled

The workpiece stock and all other objects in the working area (such as fixtures, clamping system, etc.) are usually not modelled. Despite being necessary for the correct working of the anti-collision systems, these models are not necessary to create the part program for manufacturing the part. These models need to be prepared for every different workpiece adding CAD time license cost, and worker's time. Large companies often have dedicated personnel for this task, but SMEs, like FORM, cannot usually afford it, and end up not fully using the functionality.

Missing parts in the model are not blocking the functioning of anti-collision software but can undermine its complete function. This can result in false positive alarms (eg the machine stops for no reason) or unpredicted crashes against the non-modelled features. Other than scrap parts, crashes can lead to breakages of the tool or of the spindle, with all subsequent safety risks if the machine is not immediately stopped as well as being very expensive to repair. In some cases, crashes do not cause apparent damages, but determine a loss of precision that, if undetected, can compromise the machine performances.

CAD is not the only way to model a component. New scanning technologies can be used to scan the working area and gather a cloud of points that models the objects. Expert developers can manually convert these clouds of points in 3D models. This process involves cleaning the data and triangulating it and transforming it in a 3D viable model (such as .stl). There are libraries and third party software tools but similarly to CAD, skills, time and software licenses (as well as quite high performance hardware) are needed. ZDMP can help in automatizing this conversion, making the scanning solution applicable in real manufacturing operations.

2.6.2 To-Be: Analysis of the Expected Scenarios

2.6.2.1 Target Business Process Model and Partners Roles

The target business process (Figure 43) foresees the Machine Tool User (FORM) adopting the platform hosted outside the company. For an SME, the complete use of an anti-collision system in and quick and effortless way is fundamental. The targeted usage model would remain mostly unchanged until the workpiece is in place and fixed in the working area set up for machining. At this point, the operator scans the working area and the cloud of points is registered and sent to the dedicated zApp in the ZDMP where it is converted in the stl format. The resulting model is loaded in the anti-collision system.

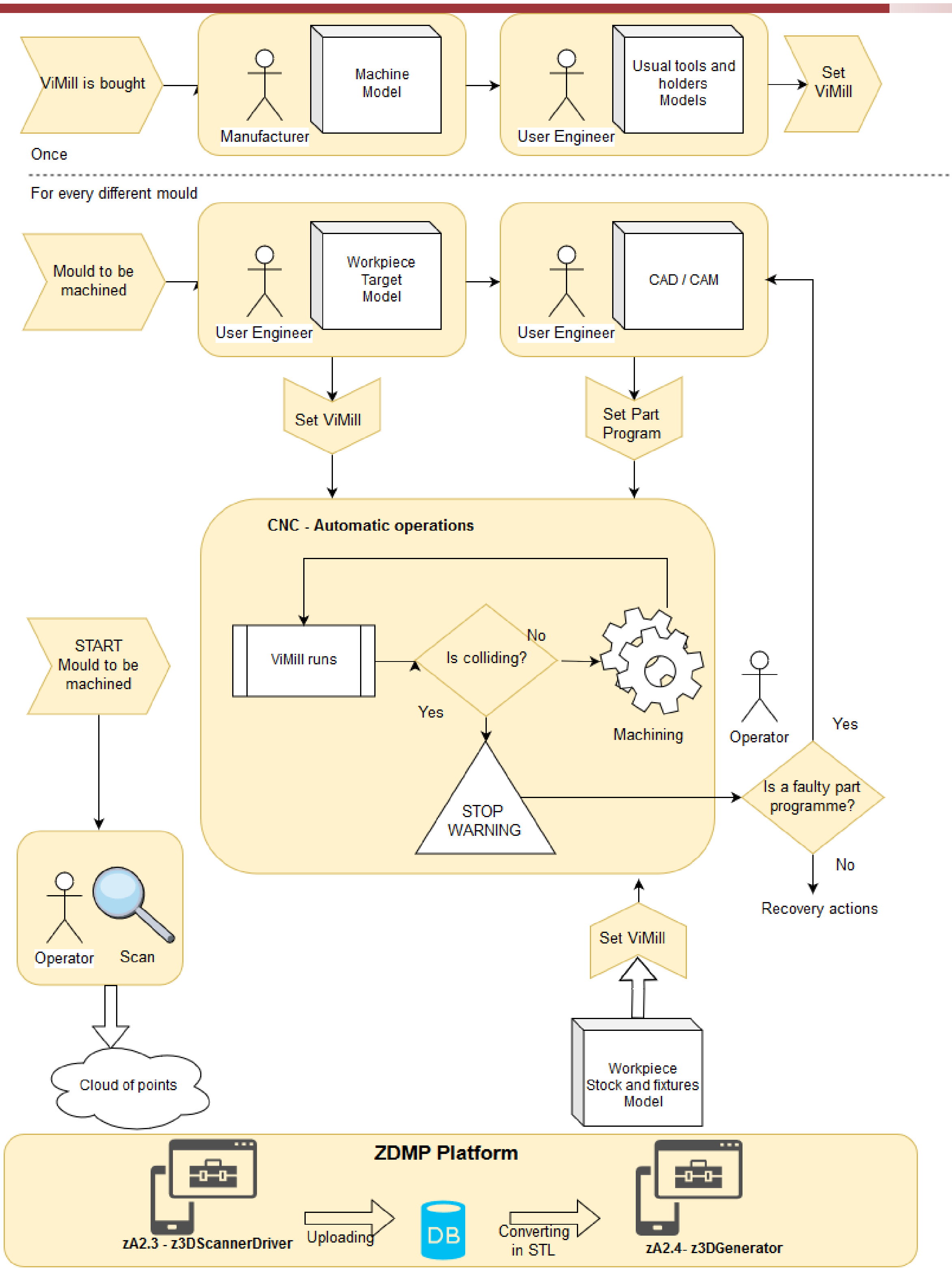


Figure 43: Business process model diagram "To-Be"

In this configuration, a first zApp (zA2.3 – z3DScannerDriver) could be an auxiliary component used to upload a cloud of points scanned on the platform and automatically start the generation of the model. A second zApp (zA2.4 – z3DGenerator) runs on the ZDMP platform and by means of libraries and tools for conversion, generates stl files from the cloud of points.

2.6.2.2 Candidate Solutions - zApps

The companies participating in this use case wish to reduce costs and reduce the number of waste parts generated, as well as having an alternative to CAD modelling simple and rapid. The goal is to advance from a scenario in which the preparatory phase is long and articulated, to a scenario in which, using digital platforms and data processing, the setup of auxiliary software is complete.

Although an ad-hoc solution could also fulfil the purpose, the ZDMP Platform complies perfectly with the requirements and it allows the developing of relevant and personalized applications, which can profit of additional computation power. In addition, the different applications are integrated in the same platform and therefore the implementations are cheaper (since the basic blocks of the platform already exists) and faster to develop.

The above goals will be reached by the development of two Apps running in the ZDMP platform, see Figure 44.

zApp name	ID	Description	Timing
z3DScannerDriver	zA2.5	The objective of z3DScannerDriver is just to make the upload of the cloud of points t the ZDMP platform more easy/automatic and then to trigger the conversion. This is an auxiliary application requiring the authorization of the operator, which should substitute the manual upload. If the format of the cloud of points generated by the Scanner is proprietary or not suitable as input for the z3DGenerator, a format conversion or adaption should be considered within the z3DScannerDriver.	Reaction in seconds / minutes
z3DGenerator	zA2.6	The objective of z3DGenerator is to clean the cloud of points, convert it in 3D format and if needed simplify it also in term of memory occupation. The output should be a 3D .stl file.	Reaction in minutes

Figure 44: zApps selected for the Use Case

After a preliminary analysis the WP7 and WP8 tasks relevant to the zApps for this UC are:

- T8.1 Characterization and Modelling
- T8.3 Production: Non-Destructive Product Inspection

Scanning system equipment should be available to retrieve the cloud of points.

2.6.2.3 Expected Impact on KPIs

The expected impacts are:

- To increase the chances of preventing a collision due to human error
- To reduce related downtime costs and collateral damages
- To reduce setup time for the anti-collision system
- From the software provider point of view, increase the adoption of the anti-collision system

With respect to the selected KPI the expected improvements are:

KPI	Description	Current Value	Target Value
Probability of collision detection	Using an anti-collision system that considers the models of the whole working areas allows to prevent more collision with respect to consider only the model of some objects in the working area.	95%	99%
€ and hours due to collateral damage	Collateral damage is the part of the repair costs due to damage to the machine or the cutting tool. Collateral damage also considers a percentage of additional downtime when a machine is not producing.	Specific to the fault type 2h per tool holder damages 30 mins per tool damages	10% reduction
Modelling time	The time needed for modelling with a CAM compared to the time needed to scan the workpiece and use the zApp solution.	Specific to the mould shape Average 2h	Reduced by 50% Average 1h
Conversion time	The time needed to make the conversion from the cloud of points to the stl format manually vs automatically through zApp.	Specific to the mould shape Average 10h	Reduced by 95% 30 minutes

Figure 45: KPI: Expected improvements

2.7 UC3.1: Electronic products manufacturing: Component inspection

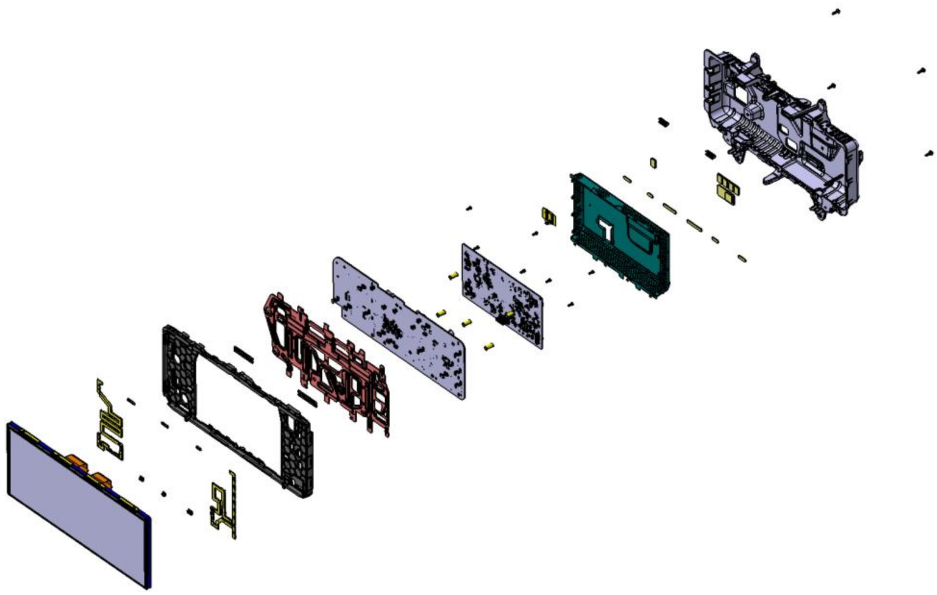
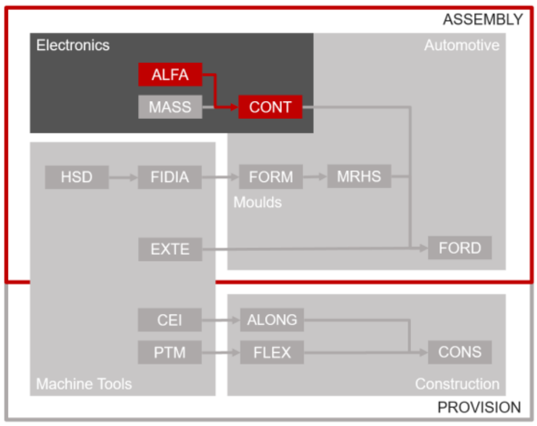


Figure 46: Exploded view of an instrument cluster

2.7.1 As-Is: Analysis of the Current Situation

2.7.1.1 Partners Roles



This use case involves industrial partners: ALFA and CONT

- **ALFA**: Located in Romania, is one of the leading companies for complete solution for AOI, X-Ray inspection using state of the art software design tools. It is in charge of x-ray inspection and test data analysis
- **CONT**: International leading automotive component supplier. CONT Timisoara Romania factory produces instrument clusters and displays for a wide range of car producers using a wide range of electronic and mechanic components. One of its production line provides the use-case.

2.7.1.2 Business Process Model

CONT produces electronic automotive products that contain usually one or more PCBs and other mechanical components (housing, screws, connectors, covers). Due to processes and technological limits, hard specifications for automotive products and strong price pressure, components provided by suppliers are not always to specification. Moreover, for the automotive products, safety is critical and the environment working conditions are difficult. Therefore, the quality of the components and materials are crucial in assuring the final product standard quality.

The “As-Is” business process model for checking the incoming material / components is shown in Figure 47. Materials / Components received from suppliers are inspected before production. Depending on the specific parameter to be inspected, a laboratory analysis is requested (eg Dimensional measurements, void in material percentage calculation, etc). Only few samples from each lot of materials / components are tested, due to time constraints. Each test report, and all the relevant information, is sent to the internal requestor for analysis (eg The responsible for supplier’s quality).

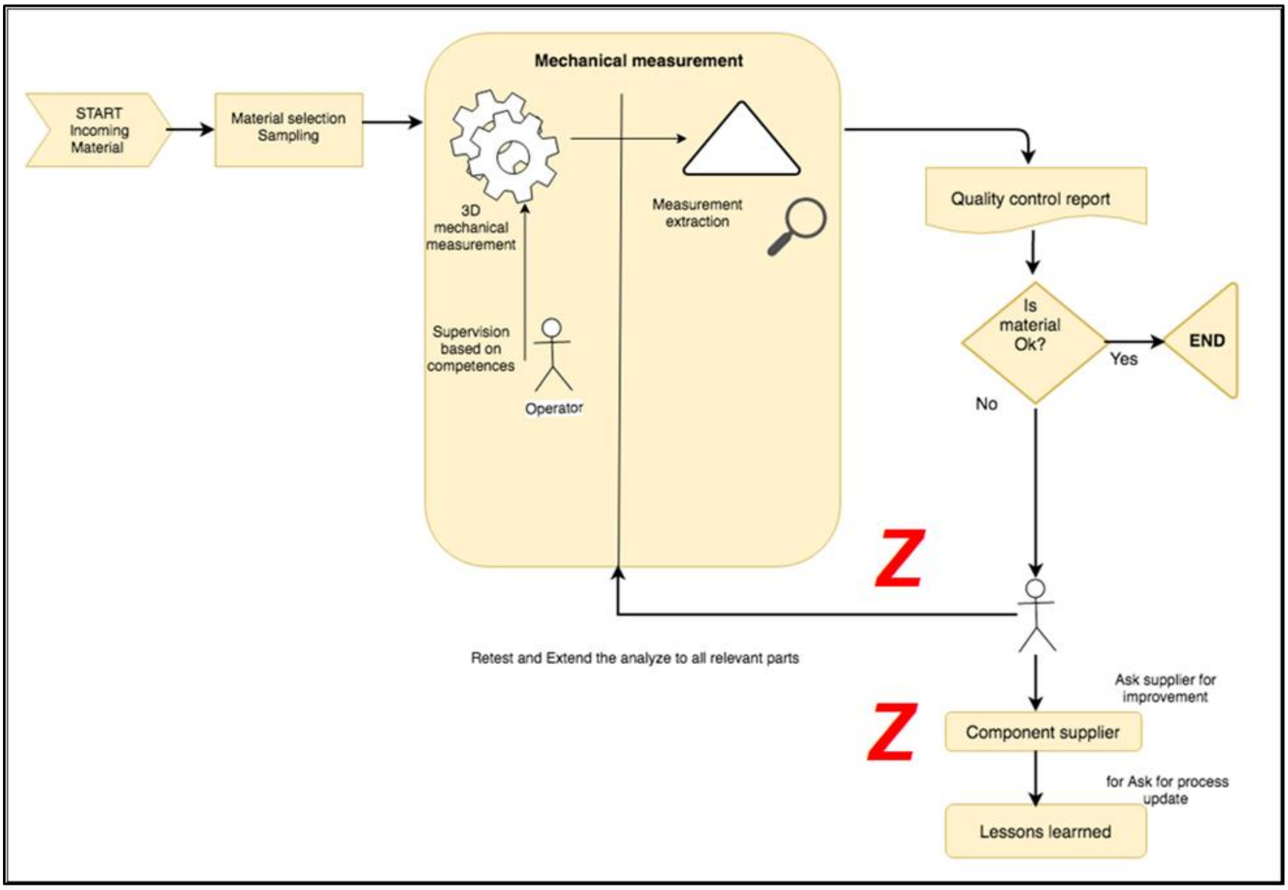


Figure 47: Business process model diagram “As-Is”

In case the analysed material has deviations from specification limits, the measurement report is generated and a more advanced analyse is started. If the mechanical deviation of the material has been proven, a more detailed analysis starts, and the measurement of the lot is extended in size. Based on measurement results, the supplier is informed about the component deviation and the 8D process is started. The correspondent 8D results corrective actions will be implemented and shared in the organisation based on lessons learned process.

2.7.1.3 Zero Defect Key Issues

Defective mechanical components may affect the final product functionality and furthermore, depending of the induced failure, the defect may occur in the assembly process, that can be either detected during the assembly process or during the use of the component, at customer’s premises. Considering the increasing product complexity (see an example in Figure 47), some of the material failures are not easy to detect, therefore, it is important to find the quality issues of primary materials / components at earliest possible phase of the processing flow.

An important factor to reduce the number of assemble defective component is the speed of reaction in case of product failure and further efficient containment actions.

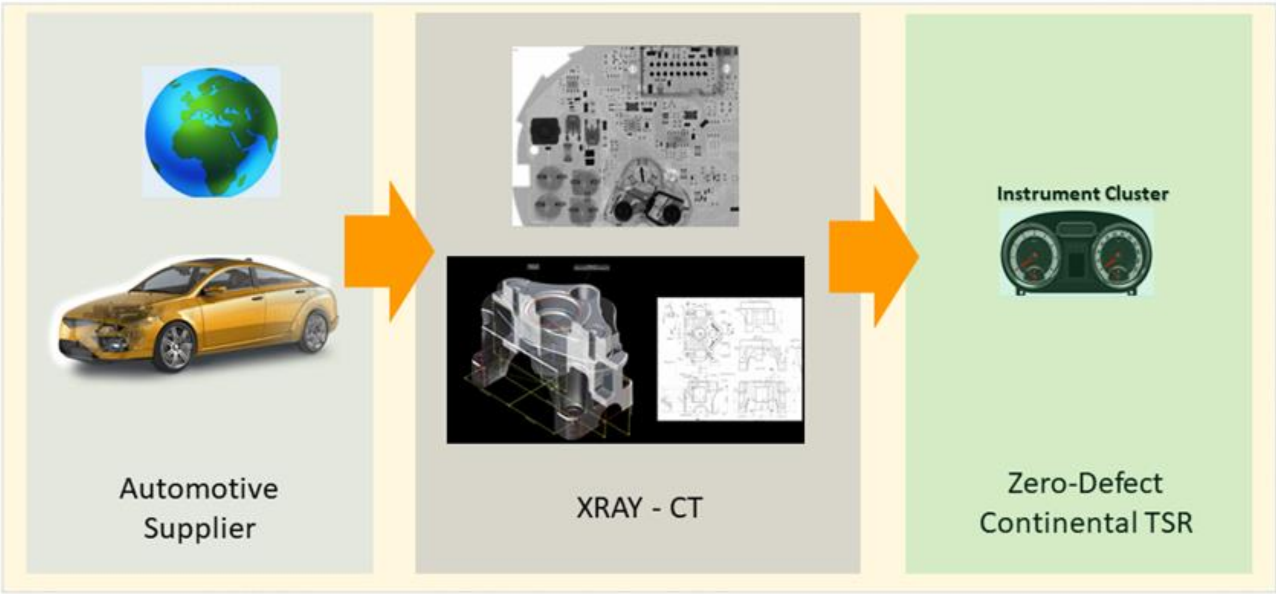


Figure 48: X-ray inspection flow

2.7.2 To-Be: Analysis of the Expected Scenarios

2.7.2.1 Target Business Process Model and Partners Roles

The target business process (Figure 49) foresees the introduction of XRAY/CT machine with product specific inspection routines, stored in a library, and software to collect the measurement deviation, store results and indicate deviations.

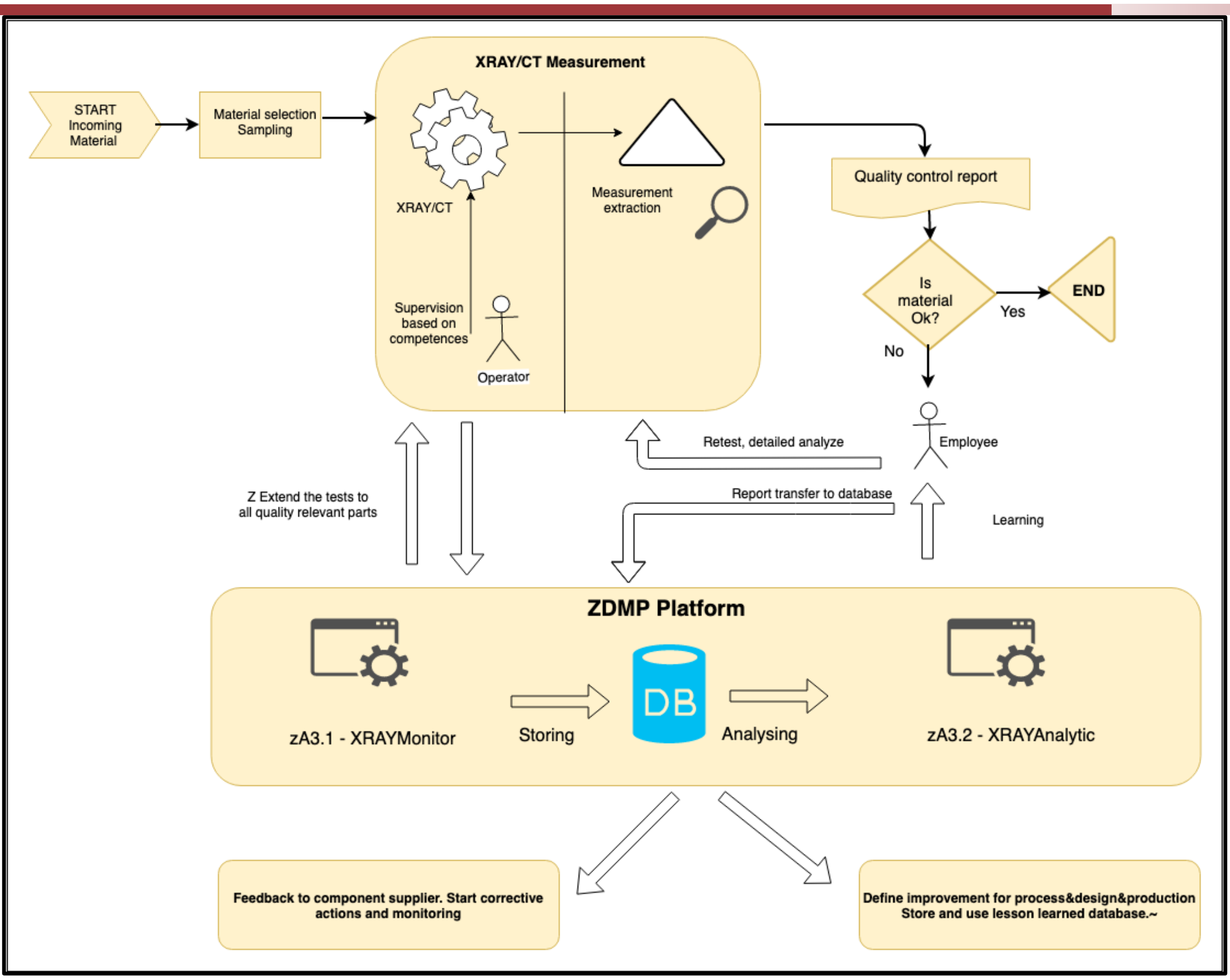


Figure 49: Business process model diagram "To-Be"

The XRAY/CT machine inspects the material / part using the built inspection routines, extracts critical measurement and compares it with the specification. If measurements are out of specification, a detailed analysis is performed to understand the issue and the report is stored in the database.

The application zA3.1 – zXRAYMonitor assures the communication between the XRAY/CT and ZDMP library database. Before the XRAY inspection starts for a material, the machine requests to the zA3.1 application to search in the library for the specific component inspection program. If the product inspection program is available, the XRAY/CT inspection starts automatically and at the output will generate the measurement report, which includes the result for the set of parameters defined in the inspection program. On average, the volume of each measurement output data is around few Megabytes and the estimated number of analyses per day is 40.

Application zA3.2 – zXRAYAnalytics performs a detailed statistical analysis of the measurement results generated from zA3.1, compares the current measurement with results from the database for similar materials. The comparison is provided in an understandable data format with the possibility to extract graphical representation of the results. The deviation tendency is monitored and zA3.2 application allows a fast-proactive approach in case of component deviations, by sending alerts in a mail format to the involved parties.

2.7.2.2 Candidate Solutions - zApps

This use case intends to reduce costs and number of waste parts generated by tolerance components. The goal is to advance from a scenario in which monitoring is a slow process and the collaboration is scarce to a scenario where, by using digital platforms and data processing, monitoring, and reacting to the monitoring is agile and more collaborative processes are set up.

The above goals will be reached by the development of the following major zApps running in the ZDMP platform, see Figure 50.

zApp name	ID	Description	Timing
zXRAYMonitor	zA3.1	The objective of zA3.1 XRAYMonitor is to automatically start the correct inspection program from the library, depending on the sample under testing and to make the comparison of the XRAY/CT information and the sample drawing & specification. For each type of material / sample, a set of special characteristics in the XRAY/CT library will be generated, measured, and controlled with the dedicated software. The application will generate for each measurement an output, which will be the input to the database of zA3.2, which will store the measured values and defined parameters for each sample under testing.	Reaction time below 5 seconds
zXRAYAnalytics	zA3.2	The objective of zA3.2 XRAYAnalytics is to have a database of the inspected parts and the measurement results. This allows comparing new measurement results for the specific part to the measurement results from previous analyses and generates statistical analysis and the deviation overview, trend line of measurements, including graphical representation. The direct results will be to have a preventive approach for the analysed set of material and to discover the defect or predict possible issues at the component supplier before it had occurred. In case of deviations, the application will send alerts in a mail format to the involved parties.	Reaction in seconds / minutes

Figure 50: zApps selected for the Use Case

After a preliminary analysis, the WP7 and WP8 technologies tasks relevant to develop the zApps for this UC are:

- T7.3 Production Stage: Material and Energy Efficiency
- T7.2 Production Stage: Equipment Performance Optimization
- T8.4 Production: Supervision

2.7.2.3 Expected Impact on KPIs

With respect to the selected KPI the expected improvements are:

KPI	Description	Current Value	Target Value
Evidence of part deviation results	Provide a complete set of measurements and analysis to prove that the components are within the specification.	No evidence (0%)	All detected deviation to be recorded
Reaction time for analysis	XRAY/CT reaction time for detailed analysis.	24h	2h
Predictive system	Capability to monitor trends for all statistical data and automatic alarming system in case of deviation and risk of deviation (%).	No prediction	85% accuracy

Figure 51: KPI: Expected improvements

2.8 UC3.2: Assembly line: AI-supported optical defects detection

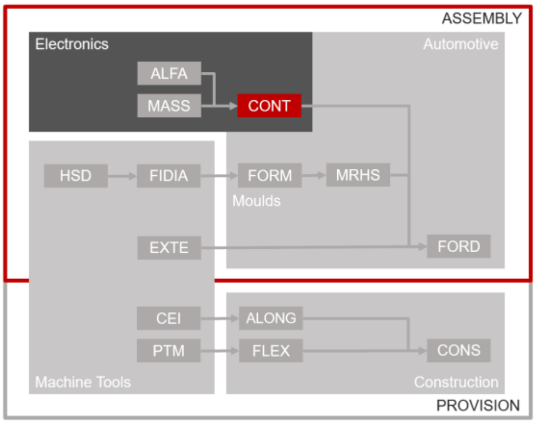
2.8.1 As-Is: Analysis of the Current Situation

Figure 52: Automatic Final test & Manual Final test

2.8.1.1 Partners Roles

This use case involves industrial partner: CONT

- **CONT**: International leading automotive component supplier. CONT Timisoara Romania factory produces instrument clusters and displays for a wide range of car producers using a wide range of electronic and mechanic components. One of its production line provides the use-case.



2.8.1.2 Business Process Model

CONT is producing electronic automotive instrument clusters and display products that usually contain one PCB, one display, and other mechanical components (housing, screws, connectors, masks, covers).

The main characteristics for the instrument cluster assembly line are:

- The assembly line has more optical check stations (3-5 stations depending on the product type) to detect the assemble failure or functional failures
- The assembly line is mostly automated, but some steps are still manually performed by the operators
- Several product variants are produced using the same assembly line (often up to 500 variants)
- There are differences in the list of products materials depending on the assembly variant (PCB, dials, pointers, calibration)
- Considering the number of variants, it is difficult to create and maintain and update all the optical inspection programs
- The optical inspection programs compare the reference image with captured images at pixel level. If the deviation is lower than the defined acceptable level, the test result is PASS
- The optical check area size could exceed the camera field of view
- The final functional tests are performed at the Automatic Final Test station while additional main functional test and esthetical aspects are check by operator at the Manual Final Test station

The actual process for Automatic Final Test and Manual Final Test is described in Figure 53.

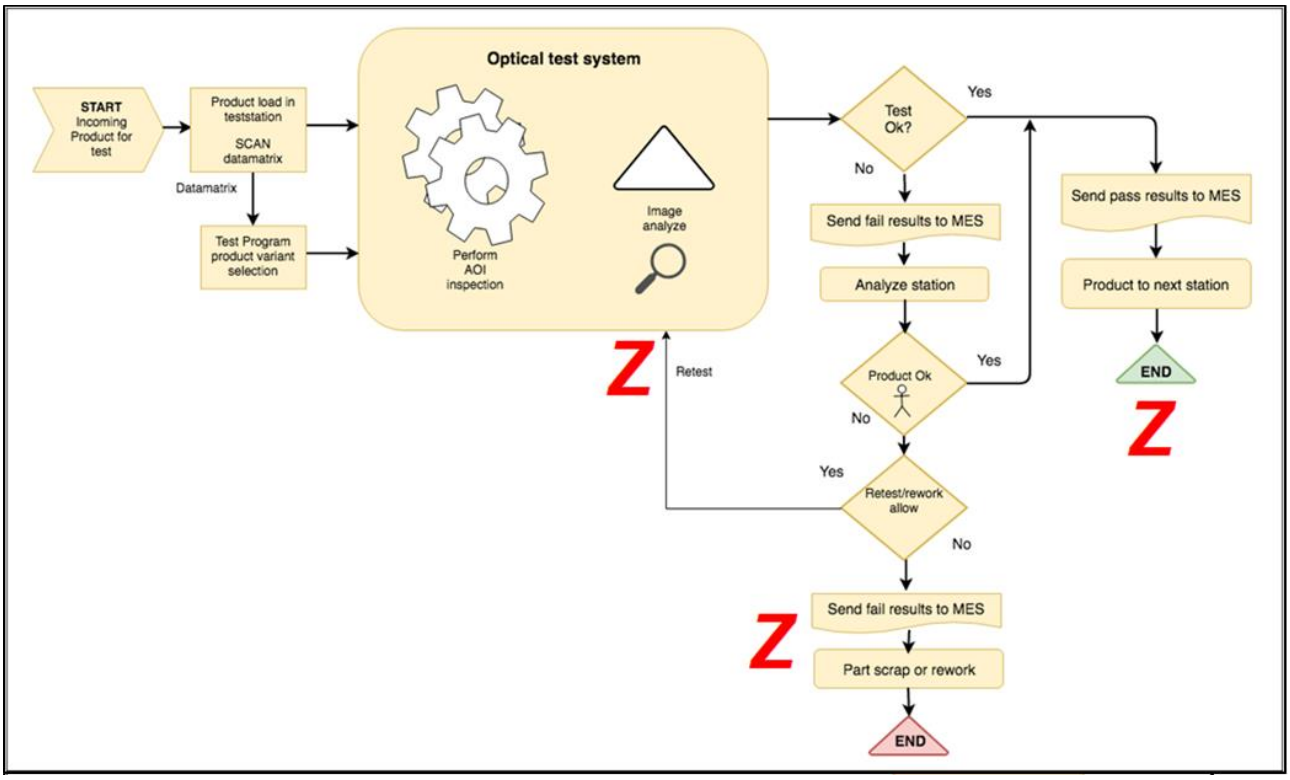


Figure 53: Business process model diagram “As-Is”

The product to be tested is loaded in the test station, product label datamatrix is read and the product is connected to power supply end. Based on the datamatrix product information the correct test program is used for testing.

In the Automatic Final Test (AFT), the display or cluster under testing is set to a defined status and the correspondent image is taken by one or more cameras. The real images are compared at bitmap level with expected images and, depending on differences assessed, is taken the decision Pass or Fail. Usually, more tests are performed for different illumination, symbol information or images on display (more than 50 tests for each test station). If all tests are PASS the product may continue to the next station in the flow.

In the Manual Final Test (MFT), the display or cluster under testing is set to a defined testing steps and the operator will compare the real product image with the reference image shown on the MFT monitor.

If one or more tests are FAIL, the product will be taken out from the assembly line and a detailed analyse will start at the analysing station. If it was a false error of the optical inspection, the product will be tested once again. If the maximum number of allowed tests was reached, the product is blocked in MES and declared scrap.

It can be seen in Figure 53 that there is no feedback or correction loop for the optical inspection and general image analyses. This is performed only by “classical” methods by comparing the bitmap differences.

2.8.1.3 Zero Defect Key Issues

The main disadvantages of the actual optical inspection solution:

- There is no feedback or correction loop for the optical inspection program, the inspection program does not lean from the failures
- There are cases when errors are undetected in the inspection program and there is no feedback loop or automatically correction process
- Considering the number of product variants and test cases, the resulting number of information in the reference database is very big and significant work and resources are needed to have a continuous improvement
- The level of reuse in terms of testing model library for new product introduction is low and in general, new product setup is time consuming and not failure proven
- For each optical inspection station (display check, pointer calibration, automatic final testing) there are quality risks

Considering that displays and clusters are decorative elements where the customers are very sensitive even to small quality defects, it is very important to find all the defects as fast as possible in the assembly line.

2.8.2 To-Be: Analysis of the Expected Scenarios

2.8.2.1 Target Business Process Model and Partners Roles

The target business process has to assure the reduction of quality incidents in parallel with a more secure and efficient optical inspection process (Figure 54). It foresees the need of artificial intelligence (deep learning) and automatic correction loops technology implementation. The target business process foresees the introduction of a feedback loop generated based on previous inspection and analyse results, as well as information about the leaked defect parts found in other processing phases or by customers.

For the MFT, it is required to introduce a camera that collects images during testing, information about operator’s decisions and reported leaked failed parts information. The application “zA3.3 zFeedbackMFT” will assure MFT to get the operator’s decision, with MES and Customer’s report database for fetching the leaked failure part information. Images will be acquired and stored by using the camera.

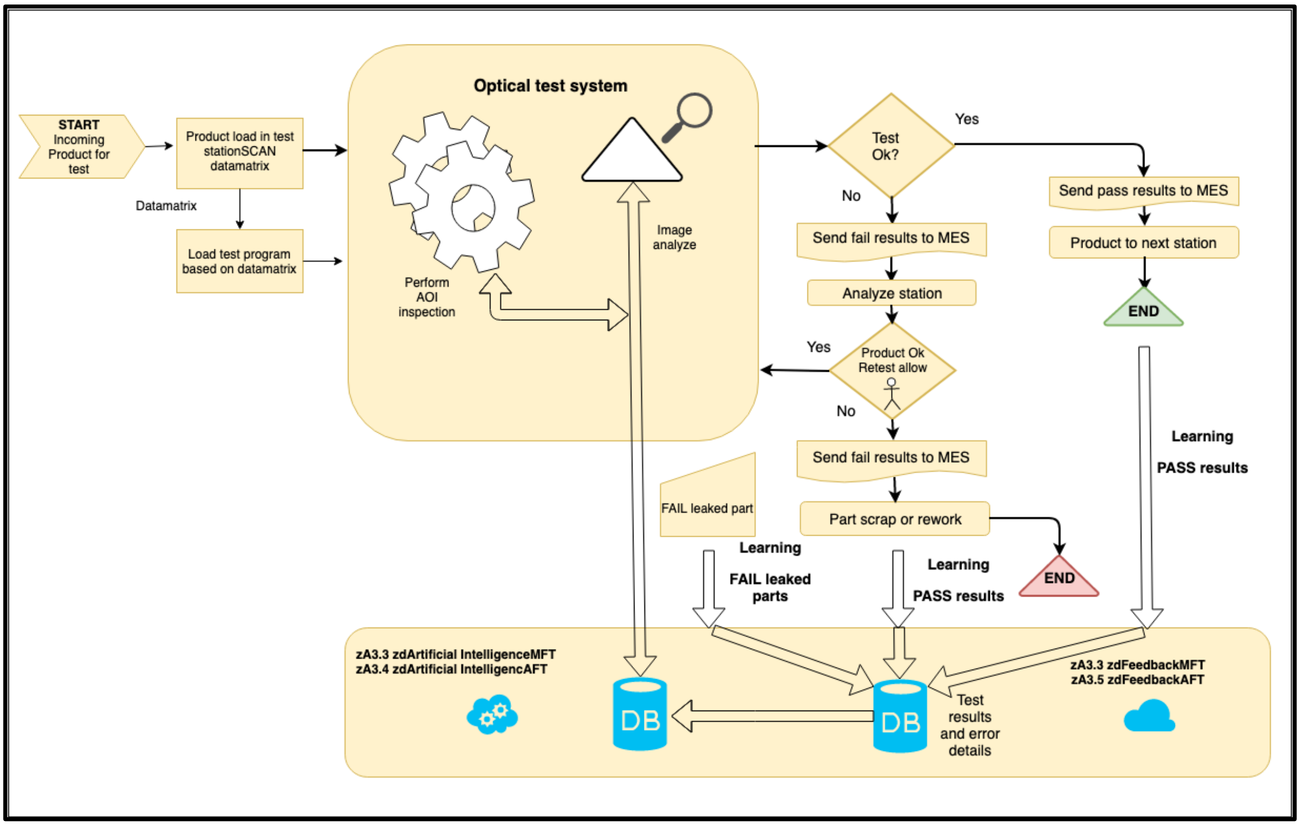


Figure 54: Business process model diagram “To-Be”

The application “zA3.4 zArtificialIntelligenceMFT” will get the test image from camera and based on the feedback from application “zA3.3 zdFeedbackMFT” will learn the defects type and acceptance limits. After defect learning is completed, the application “zA3.4 zArtificialIntelligenceMFT” will run alone the tests and will inform the operator on the test where quality risks have been identified.

For the AFT the application “zA3.5 zFeedbackAFT” will collect details regarding the false positive automatic inspection in terms of classification and leaked defects. This allows to improve the testing program in the AFT and to provide the required information for the “zA3.6 zArtificialIntelligenceAFT” application.

The main target of the “zA3.6 zArtificialIntelligenceAFT” application is to improve automatically the base models for optical check at AFT using the information collected on each testing and feedback loop “zA3.5 zFeedbackAFT”.

Consequently, the applications “zA3.6 zArtificialIntelligenceAFT” and “zA3.5 zFeedbackAFT” will run in data collection mode until the database receives the necessary reference data. After a training period, the “zA3.6 zArtificialIntelligenceAFT” starts to contribute to the improvement of the testing programs.

2.8.2.2 Candidate Solutions - zApps

This use case aims to improve the quality of the optical inspection, to increase the flexibility in the new product introduction process and to reduce the inspection time and the inspection effort. The goal is to advance from a scenario that involves difficult manual work of operators and engineers to a scenario where, by means of defect feedback information, Big Data and deep learning algorithms, the platform will improve automatically and help directly with the failure decision process.

The above goals will be reached by the development of the following zApps running in the ZDMP platform, see Figure 55.

zApp name	ID	Description	Timing
zFeedbackMFT	zA3.3	The objective of zA3.3 application is to assure the interface with MFT, collect images and operator optical inspection decision and leaked parts information. The collected information will be stored in a database and used by a Z3.4 application.	Reaction below 5 seconds
zArtificial IntelligenceMFT	zA3.4	The objective of zA3.4 is to apply the artificial intelligence algorithm for Manual Final Test, tests and to inform the operator for optical inspection test results.	Reaction below 1 seconds
zFeedbackAFT	zA3.5	The objective of zA3.5 application is to assure the interface with AFT, correlate the test image, test results, and quality of test result. The collected information will be stored in database and used by zA3.6 application to improve the testing program.	Reaction below 5 seconds
zArtificial IntelligenceAFT	zA3.6	The objective of zA3.6 is to apply the artificial intelligence algorithms for Automatic Final Test testing and to provide manual and automatic improvement of the testing program.	Reaction below 1 seconds

Figure 55: zApps selected for the Use Case

After a preliminary analysis the WP7 and WP8 tasks relevant to the zApps for this UC are:

- T8.1 Characterization and Modelling
- T8.3 Production: Non-Destructive Product Inspection

2.8.2.3 Expected Impact on KPIs

With respect to the selected KPI the expected improvements are:

KPI	Description	Current Value	Target Value
False positives	Number of false errors for 1000 parts tested with optical inspection.	7 every 1000 parts	5 every 1000 parts
Inspection time	Total inspection and analysis time for the optical inspection station.	Depending on the product. Average 40 s	Reduction 15% Corresponding to a new average of 34 s
Effort to introduce AOI for new	Work time for the engineer to setup the AOI program for a	Depending on the product.	Reduction 20%

product	new product/variant.	Average, one person/month	Corresponding to a new average of 16 days
Inspection leaked errors	Number of undetected errors for 1000 tested parts	3 every 1000 parts	2 every 1000 parts

Figure 56: KPI: Expected improvements

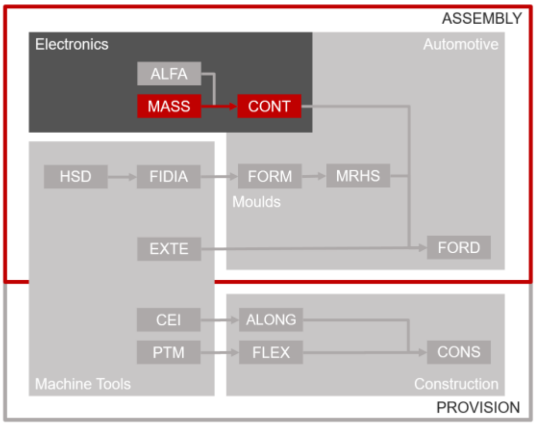
2.9 UC3.3: Assembly line: monitoring and control system

Figure 57: Assembly line

2.9.1 As-Is: Analysis of the Current Situation

2.9.1.1 Partners Roles

This use case involves MASS and CONT industrial partners:



- **MASS**: Manufactures equipment for process automation for electrical industries. It provides the equipment in the assembly lines.
- **CONT**: International leading automotive component supplier. CONT Timisoara Romania factory produces instrument clusters and displays for a wide range of car producers using a wide range of electronic and mechanic components. One of its production line provides the use-case.

2.9.1.2 Business Process Model

CONT is producing electronic automotive instrument clusters and display products that usually contain one PCB, one display and other mechanical components (housing, screws, connectors, masks, covers).

Below are the main characteristics for the assembly line:

- Usually assembling of electronic product is made with 6-11 workstations, the workstations and operations are product dependent (called WP)
- Considering the increasing quality requirements, the assembly line is mostly semi-automated / automated. There are assembly steps where operator is mandatory especially the handling processes that cannot be automatized easily or where the quality check needs the operator validation (aesthetic check)
- Often the production equipment is an independent machine (sometime from different suppliers in the same line) and mostly there is no direct communication between the workstations
- The product flow in the assembly line is assured by a conveyor or the operator / robot makes the necessary handling
- Typical steps on the assembly line equipment:
    - Introduction of product part / parts / check-in (often automatically based on sensor information)
    - Data matrix scanning / product identification
    - Check if product is valid (passed OK the previous station, variant OK)
    - Get / move additional material for assembling
    - Perform the assembly process (and / or the test)
    - Results are sent to PRIME
    - Store the results of the process or test Pass or Fail and send the complete process / test results to database (MES)
    - Checkout / part out

- Product quality is assured by monitoring the process specific parameters on each station. The main quality rule is to find the defect faster as possible in the process flow
- In the assembly line, more product variants are produced (often up to 500 variants) that have distinctive characteristics (example cluster variant with miles/h or Km/h indication, diesel or gasoline engine / indications). There is a significant risk to mix the product variant and change from one product version to another, this process needs to empty completely the line (product changeover process)
- There are differences in the products material list (example PCB, dials, pointers, calibration). Control of the product variant is performed using the MES based on product configuration information (routings) and material scanning operation
- Usually before production variant starts (specific product code) on each workstation it is necessary to download (manually) the correct work program

The current process and information flow in the assembly line is described in Figure 58.

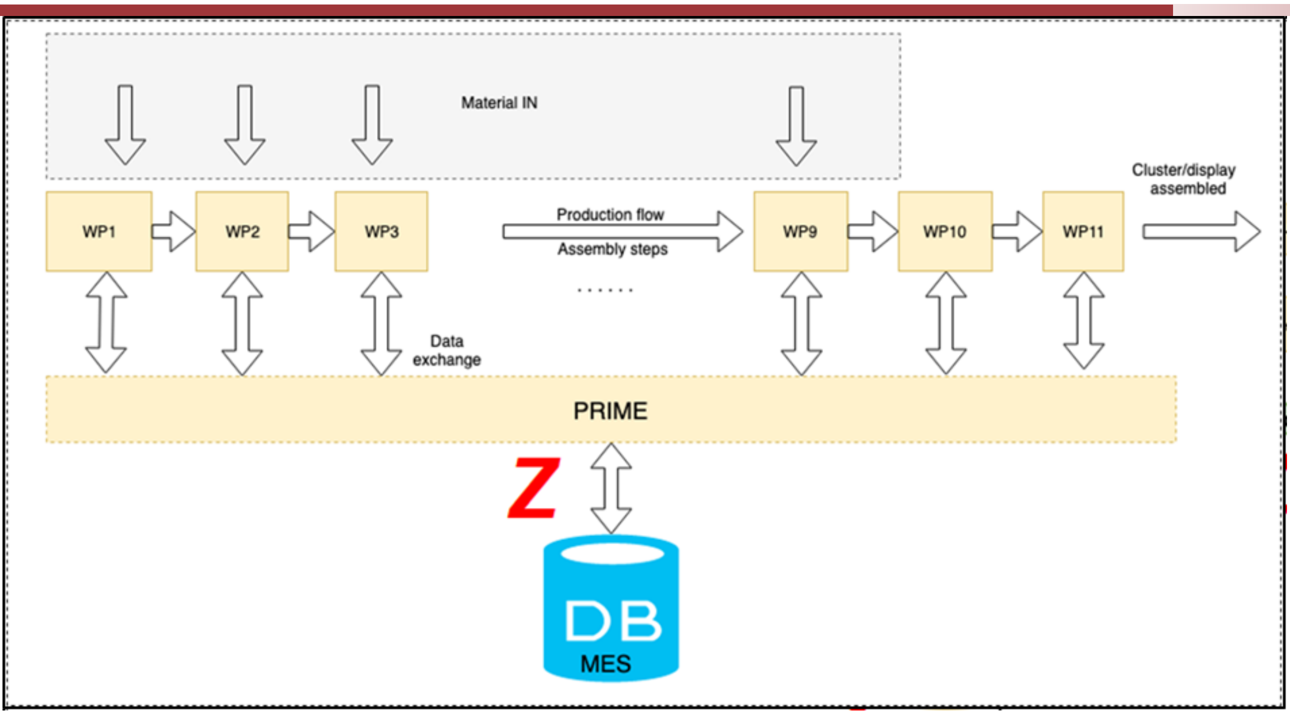


Figure 58: Business process model diagram "As-Is". "WP" is CONT internal term to refer to

Product assembly is performed systematically on each workstation (WP) by adding the necessary material, performing the specific process, checking the process, and sending the results to PRIME and generally to a MES. There is no direct data connection between the workstations and no control of the assembly line.

In order to receive an overview of the assembly line performance, for example product volume, scrap rate, or process machine time it is necessary to access the database and perform a specific search in the database. This is also true if it is necessary to get information on whether the current scan part was pass to the previous station. This indirect operation makes the reporting of assembly line results more complicated, delays the reaction time in case of failures, and limits the report usability.

2.9.1.3 Zero Defect Key Issues

The main disadvantages of the actual line monitoring and control:

- Line management & control is technically complex, but the result is improvable and line dependent. For example, to get an overview of the line performance (production volume, scrap rate, FPY) it is necessary to make queries in the MES database for the specific line, time interval, and to make additional specific information filtering and structuring
- Data systems and connections are too complex and it is hard to implement new features. There is a strong need to extend the assembly line monitoring and control with Industry 4.0 elements (machine automatic call for maintenance, zero product changeover, equipment automatic power saving mode, automatic material management & ordering, automatic material version control), but with the current SW architecture it is difficult to get the needed data and data links
- Risk of defects at change over (material, product version mix) and OEE reduction because of change over time

- Slow / delay in reporting system because of complex database and the high load on server limits the reporting usage
- Difficult to implement material version control: All the variant specific information and actions are part of the WP's program, difficult to implement a centralized product line configuration
- Specific CONT solution that need mandatory CONT MES system and the complex product specific configuration

Considering the automotive quality requirements, product complexity, and the number of product versions it is desirable to develop a standard data layer interface between the assembly line equipment and MES, data usable in developing new Industry 4.0 features.

2.9.2 To-Be: Analysis of the Expected Scenarios

2.9.2.1 Target Business Process Model and Partners Roles

The target business process must assure the reduction of quality incidents based on fast and preventive reaction on defect risks using assembly line monitoring and control system. It is clear that in the "To-Be" implementation (Figure 59) all WP information is sent to the MES system, but additionally all stations communicate with a line server monitor to control the assembly line.

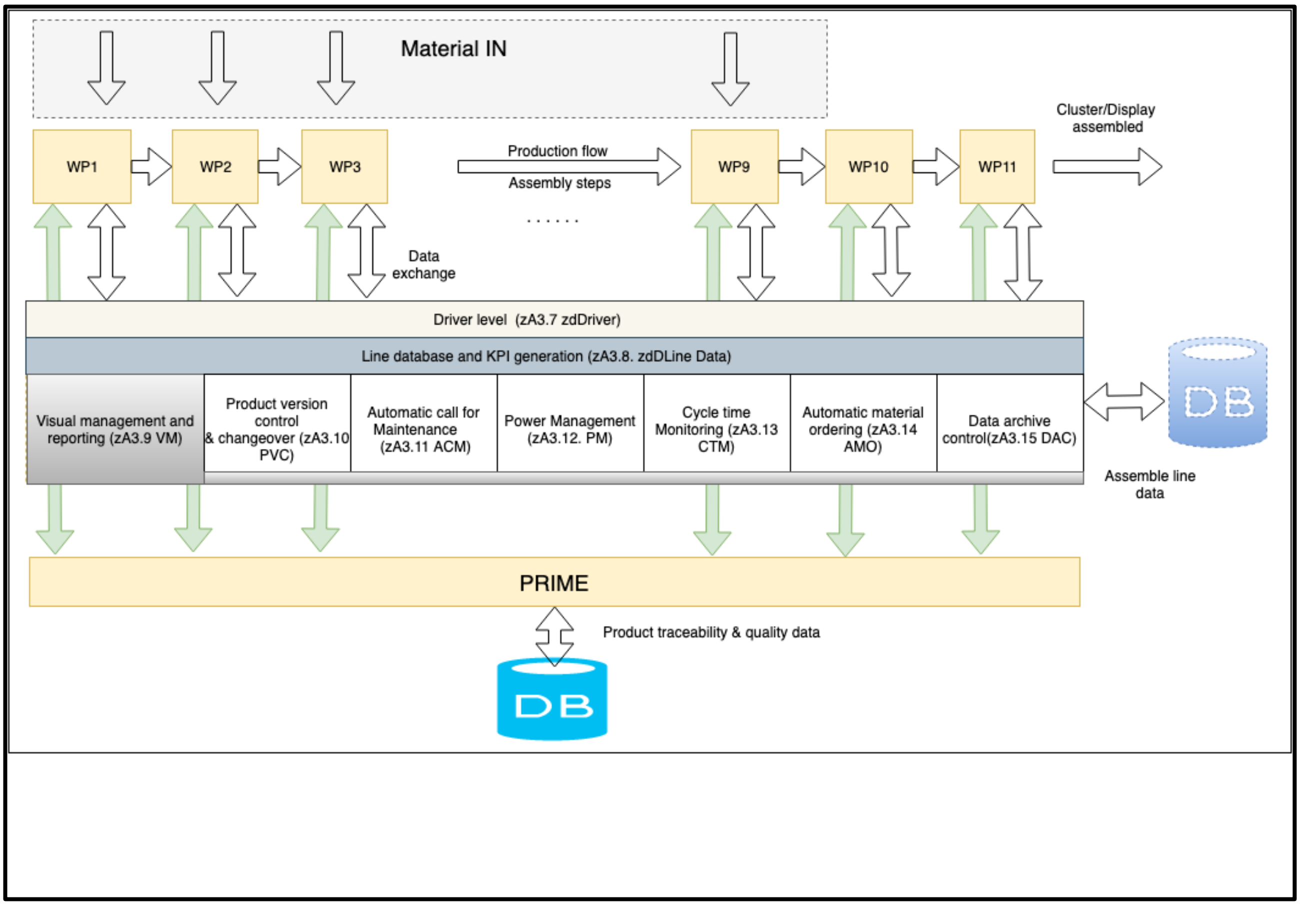


Figure 59: Business process model diagram "To-Be"

All the equipment will be connected to a driver layer (zA3.7) through TCP/IP Protocol that allows sharing the data between the equipment and additional defined server line level. The following generic information must be shared:

- Part serial number (datamatrix)
- Checking time
- Checkout time
- Operation results for each part (pass, fail)
- Error information (if the operation failed)
- Machine status (wait for operation, in work, off, error)
- Materials type in work, material that must be use based on product structure
- Material stock
- Generic data table for equipment specific extension

The visualisation application (zA3.9) assures the visualization of all relevant data in WEB pages in front of assemble line which is also accessible remotely.

The following WEB pages are considered for the visualisation:

- Line performance results for each shift (number of produce part/h, FPY, scrap, production time and percentage disturbance time)
- Standard work (machine, time, operator time, line performance)
- Maintenance information (machine breakdown overview, reaction time, interventions)
- Material management (stock status of material on the line, ordering process status)
- Power management information (equipment active time, idle time, configuration settings)
- Product change over details (number of variants and volume)
- Administration pages for different advance configuration (product setup information, call for maintenance number)

Applications zA3.10 to zA3.15 will handle the specific information extracted from the equipment, will store the data in the database, perform the specific actions defined in the table from Figure 59, and prepare the needed data format for the visual management application.

2.9.2.2 Candidate Solutions - zApps

This use case will provide quality and production performance details information to the assembly line personnel (just in time to the right person), will automatize and standardise the data information process contributing to defect reduction, increase productivity, and reduce “waste” of the managed assembly line.

The above goals will be reached by the development of a modular environment in the ZDMP platform (Figure 60) consisting in applications (zA3.7 to zA3.15) that operate together.

Considering the modularity of the application and the open interfaces the application could be adapted very easily for managing production process in all industrial areas independently or even in parallel with other systems.

zApp name	ID	Description	Timing
zDriver	zA3.7	The objective of the zA3.7 application is to assure the interface with the equipment and the line server database.	Less than 100 ms

		Communication is assured based on client server protocol on a predefined set of parameters with extensible data table	latency & less than 5% CPU Load
zLineData	zA3.8	The objective of zA3.8 is to store the received information from the driver in the database and to perform the strategic KPI calculations.	1 s
zVisualManager	zA3.9	The application zA3.9, is a WEB application that displays in web pages the specific information in collaboration with other applications (zA4.4-zA4.9).	3 s
zProductVersionControl	zA3.10	Application zA3.10 is responsible to assure that the produced part has used the right material version and the right equipment program for the mentioned product serial number. Additionally, the application automatizes the changeover process to avoid the change over time and quality risks.	1 s
zAutomaticCall	zA3.11	The application zA3.11 monitors the status of the equipment and if the equipment breakdown is larger than the specified time, it will automatically call the right phone number for the intervention. Additionally, it provides the details regarding the equipment maintenance plan details, corrective intervention history, and based on historical data provide a predictive view.	5 s
zPowerManager	zA3.12	Application zA3.12 handles the power management actions to reduce the total energy consumption of the assembly line. For example, if the production lot is finished, the data from the production plan may allow putting the equipment into a power save mode until needed again.	5 s
zCycleTimeManager	zA3.13	The application zA3.13 reads the production check-in and checkout timing and evaluates the KPI production (OEE cycle tine, breakdown)	1 s
zAutomaticMaterialOrdering	zA3.14	The application zA3.14 manages the current material stock in the line information and requests automatically materials to logistic.	5 s
zDataArchiveControl	zA3.15	Data Control and Archive application manages all the archiving data operations (archive, restore, clean database)	Minutes

Figure 60: zApps selected for the Use Case

After a preliminary analysis, the WP7 and WP8 tasks relevant to develop the zApps for this UC are:

- T8.2 Pre-Production: Product Quality Prediction
- T8.4 Production: Supervision

2.9.2.3 Expected Impact on KPIs

With respect to the selected KPI the expected improvements are:

KPI	Description	Current Value	Target Value
Time for automatic change	Time for the automatic change of process in the assembly	1h	50% reduction

	line compared with the current manual change time.		
Reduce equipment breakdown time	Time of equipment downtime with and without the equipment breakdown monitoring system and the automatic call for maintenance	2h for minor failures 1 day for average breakdowns	30% reduction
Line productivity increase, optimise bottleneck	Number of parts produced per time span	60 parts per hour	15% increase Corresponding to 70 parts per hour

Figure 61: KPI: Expected improvements

2.10 UC4.1: Steel tubes: production monitor

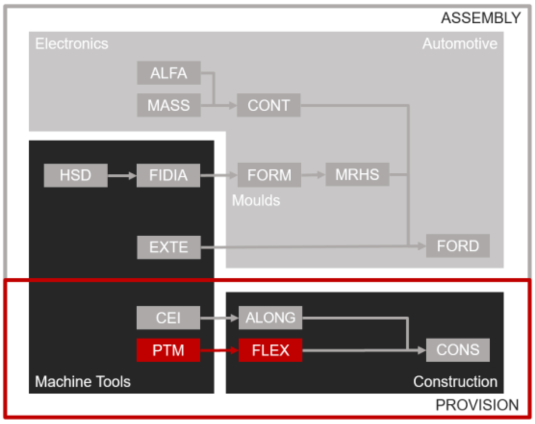
2.10.1 As-Is: Analysis of the Current Situation

Figure 62 Steel Tube Production Machine

2.10.1.1 Partners Roles

This use case involves PTM and FLEX industrial partners:

- **PTM**: SME steel and tube machine tool manufacturer
- **FLEX**: SME steel tubes producer, that currently uses PTM machines and tools in its operations



2.10.1.2 Business Process Model

Currently, the production of tubes within FLEX is performed through the continuous feeding of steel strip sheets, welded together by weld operators, with specialized machinery. This machinery is responsible for forming and welding the tube to x the final tube shape. Furthermore, the machinery is configurable and can produce steel tubes in different shapes and sizes through the adjustment of several individual components.

During production, the components responsible for shaping the tube can become misaligned, generating tubes that do not fit the specification. When this happens, the production needs to stop, and the individual components must be adjusted to correct the misalignment. Additionally, the applied solder must be tested for conformity to avoid failure in structural integrity (mainly) and other final tube quality and visual defects.

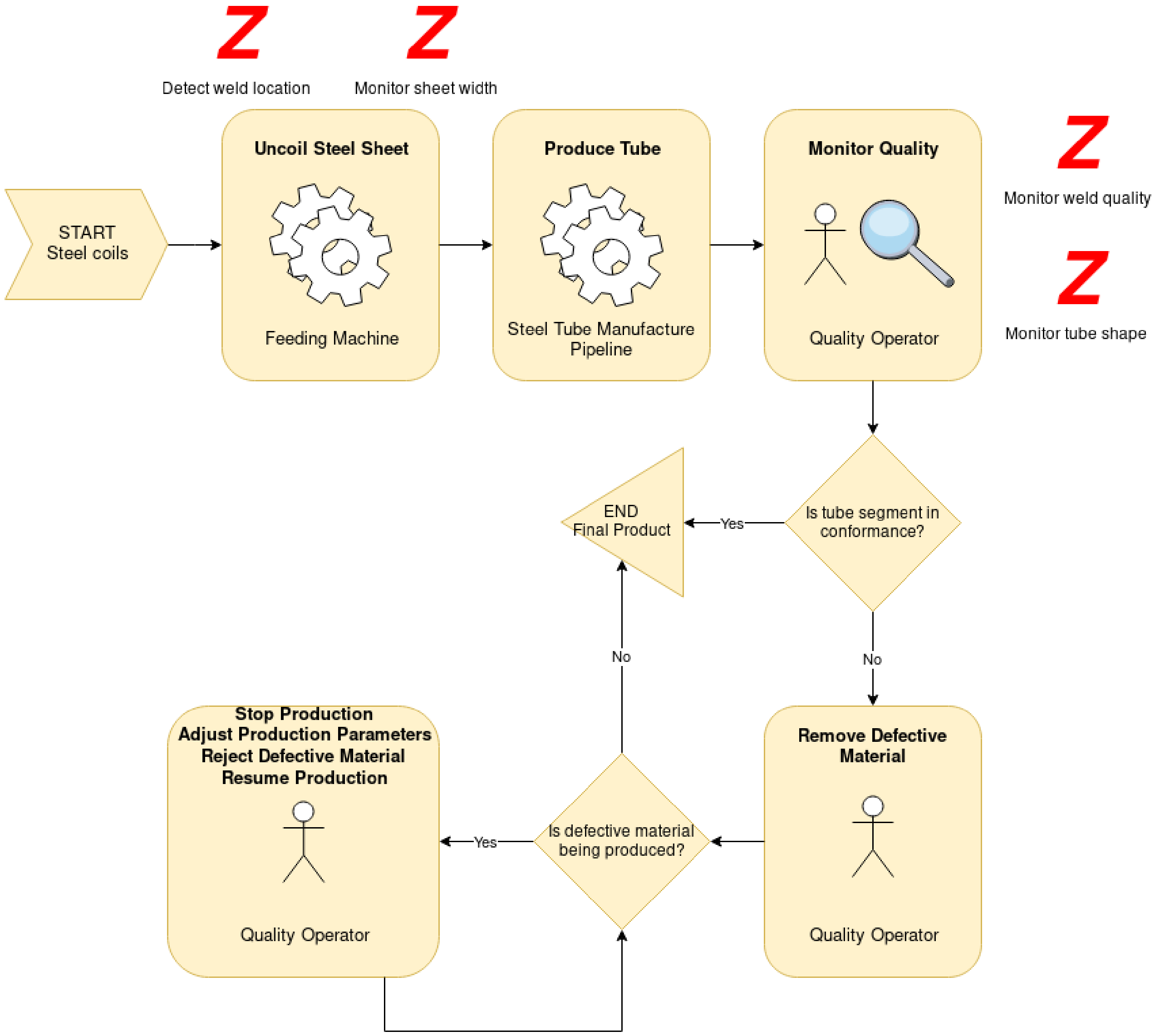


Figure 63 Diagram of the current production process.

The current method of quality control (Figure 63) relies on a quality control operator that evaluates the finalized tubes for defects. This method works through sampling of the output and relies on the operator experience to minimize the number of defective tubes. The operator works through the produced tubes checking for defects in shape and welding issues, as well as detecting mid steel sheet welded tubes (generated when connecting two steel sheets). If a defect is detected, the operator needs to halt production and initiate the process of adjusting the production parameters. Since these defects tend to propagate from one tube to the next, the sooner the defects are discovered, the least amount of defective and unusable tubes are generated and thus less scrap.

2.10.1.3 Zero Defect Key Issues

The current process of manufacturing steel tubes operates on a continuous manufacturing cycle thus contributing to maximization of the process efficiency. Once the machine is configured and an operator initiates the process, it does not stop without an instruction to do so.

Figure 64 (left) Steel Coils, (right) Steel Tubes.

As the individual components that mould the shape of the resulting tube wear out, defects are introduced into the product. Since the current process relies on direct observation by a quality operator, defects are usually detected late in the manufacture process. These defects tend to propagate, and the non-conformity generated from an anomaly will span several manufactured tubes. Thus, to minimize the amount of scrap generated in the process it is important to capture these faults as early as possible.

However, since the operator oversees several tasks at the same time it is possible for defects to be detected only after a few tubes are manufactured and placed into the staging area. Upon detection, the production needs to stop for maintenance and adjustments, and staged material must be scrutinized for defects.

On top of this, some defects may be imperceptible to the operator and can evade detection up until installation on the end client, which can lead to major delays and the affected perception over the quality of the product.

The parties expect to reduce the number of defects generated through the introduction of early detection systems, enabling the operator to act as swiftly as possible.

2.10.2 To-Be: Analysis of the Expected Scenarios

2.10.2.1 Target Business Process Model and Partners Roles

Upon deployment of ZDMP in the steel pipe production, the system becomes much more self-reliant. By deploying zApps that aid in controlling the width and horizontal weld location on the steel sheet entering the production process, the critical workload placed upon the operator is x reduced. Thus, instead of having to monitor the operations actively, they are warned immediately of abnormal situations and x can handle them efficiently. Moreover, the detection process evolves to a more reliable and stable process, since adequate sensors and ZDMP tools will computationally monitor and assist steel tube manufacture.

Further on in the production process, the vertical weld and tube shape are also automatically evaluated. This releases the quality operator from their cursory monitoring task, and it is moved into a reactive role. By the timely warning of the operator of even minor deviations, the amount of waste produced is reduced, and the number of quality products per meter of steel sheet is increased.

In both cases, human error is reduced, as subjective observation tasks are reduced proportionally. Machinery will be updated to use ZDMP tools to assist the manufacture process, thus enabling the aimed production digitalization and traceability.

Figure 65 is a model for the future scenario.

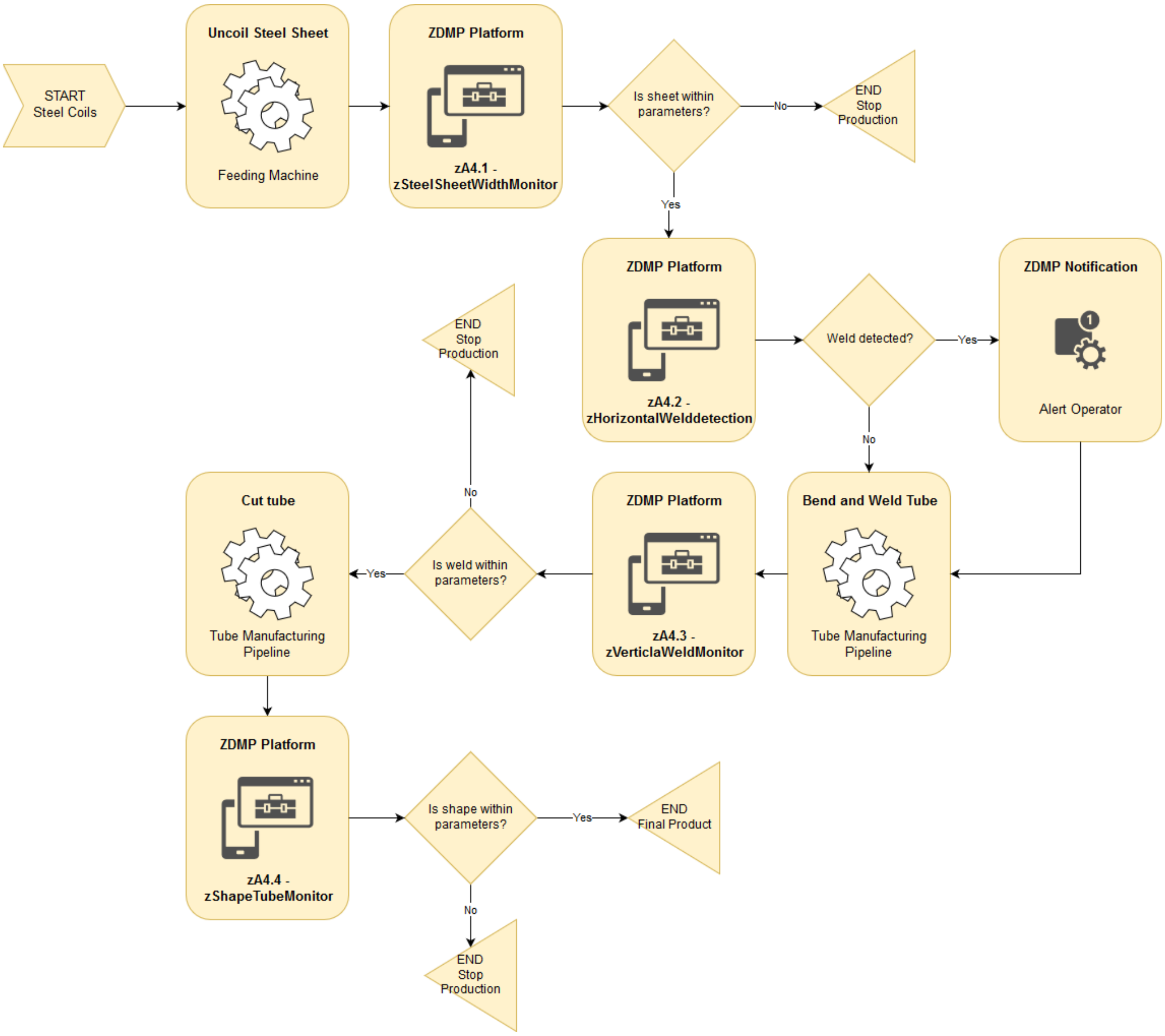


Figure 65: Diagram for the tube manufacture process “To-Be”

2.10.2.2 Candidate Solutions - zApps

For this use case, the main problem is in identifying possible defects in real-time during production minimizing waste through production and defective final product trace, detection and segregation. As such, it is suggested to introduce several applications (Figure 66) as follows:

zApp name	ID	Description	Timing
zSteelSheetWidthMonitor	zA4.1	The goal of zSteelSheetWidthMonitor is to automatically detect the width of the steel sheet to detect if the width of the sheet varies over time. In a situation that the width changes, the tube will be defective. When this problem is detected in time, tube waste is avoided.	1-2s

zHorizontalWeldDetection	zA4.2	The goal of zHorizontalWeldDetection is to automatically detect the horizontal weld of the steel sheet; this welding is made to connect the different steel coils to each other for production to continue uninterrupted. By detecting this defective welding the operator can be warned to remove the tube needing to be scrapped.	1-2s
zVerticalWeldMonitor	zA4.3	The goal of zVerticalWeldMonitor is to automatically detect the quality of the vertical weld of the steel sheet. In a situation where the vertical welding has a defect, it will cause the final product to be defective. Thus, it is necessary to readjust the machine every time that this happens, and it is also necessary to warn the operator.	1-2s
zShapeTubeMonitor	zA4.4	The goal of zShapeTubeMonitor is to automatically detect the conformity of the tube shape. It is necessary to detect if the shape of the tube is within the conformity, in case it is not necessary to warn the operator, to proceed with the reconfiguration of the machine.	1-2s

Figure 66: zApps selected for the Use Case

The zApps should be an on-premises solution for immediate response. The following WP7 and WP8 tasks may be involved possible solutions for integration:

- T7.2 Production State: Equipment Performance Optimisation
- T7.4 Process Quality Assurance
- T8.3 Production: Non-Destructive Product Inspection
- T8.4 Production: Supervision

2.10.2.3 Expected Impact on KPIs

It is expected to reduce the amount of waste generated during the production of steel pipes. The expected improvement should be reflected as described in the following table:

KPI	Description	Current Value	Target Value
Quality rejection based on welding	Number of flawed welding detected by the platform divided by the number of total defects detected. The total number of defects is the number of defects detected by the platform and the operator.	100% manual Corresponding to 1,5T of defective metal coil manually detected for every lot (each lot is 25T)	80% of automatic defect detection Corresponding to 1,2T of defective coil detected automatically and 0,3 T detected manually per lot
Quality rejection based on shape	Number of flawed shapes detected by the platform divided by the number of total defects detected. The total number of defects is the number of defects detected by the platform and the operator.	100% manual Corresponding to 20 kg of defective metal tubes manually rejected due to shape conformity for every 1000 kg lot.	70% of defective shape automatic detection Corresponding to 14 kg of defective tubes detected automatically and 6 kg detected manually per lot
Amount of scrap tubes	Quantity of scrap tubes in the production lot	20 kg every 1000 kg	50% reduction, corresponding to 10 kg every 1000 kg

Figure 67: KPI: Expected improvements

2.11 UC4.2: Stone tiles: equipment wear detection

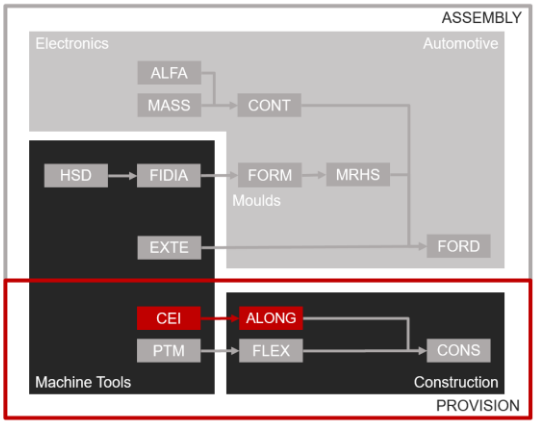
Figure 68: Stone Cutting Machine.

2.11.1 As-Is: Analysis of the Current Situation

2.11.1.1 Partners Roles

This use case involves two industrial partners: CEI and ALONG

- **CEI**: SME manufacturing stone cutting machines
- **ALONG**: SME, a producer of stone slabs and tiles, who uses the cutting machine CEI produces



2.11.1.2 Business Process Model

Stone cutting is a complex process involving several tools (cutting, polishing…) and typically is a time-consuming process, which depends of the stone properties, type, and topography. Stone is a natural material, with intrinsic complexity, which is difficult for a human to control the quality along the processing phases. Today, all control analysis procedures are performed by operators. The “As-Is” business process model (Figure 69) shows the entire stone cutting process performed by ALONG using CEI machines. The red “Z” in Figure 69 represents production stages where possible zero-defect applications can be implemented.

The stone cutting process starts with the raw stone cutting ie the raw stone is cut and divided in multiple stone slabs, which are subsequently submitted to a first quality control test carried out by operators. The quality control test is a manual procedure that evaluates the thickness compliance of stone slabs. In this process, stone slabs are subjected to a brief assessment to verify the regularity of the thickness, which is essential to next step, polishing. Stone slabs fulfilling the requirements are sent to the polishing machine. Those not compliant with the requirements are excluded from the following procedures and are identified as defective products. Polishing makes a smooth and shiny stone slab surface. Up to this stage, no data/information is stored.

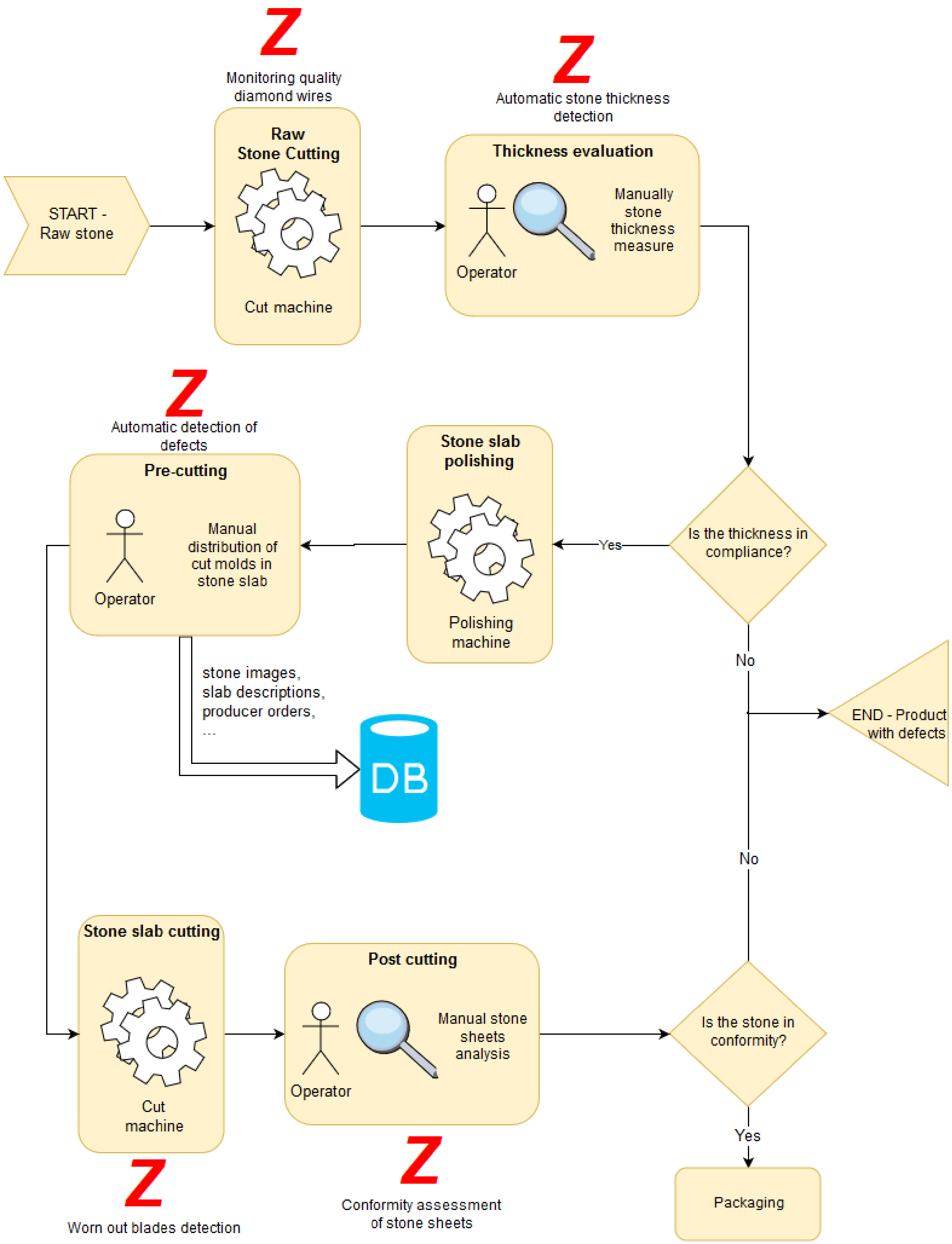


Figure 69: Business process model diagram "As-Is".

After the polishing process, the stone slabs are transferred to another section / stage, called "pre-cutting", where tiles moulds are projected onto them before the stone slabs are cut. The projection of tiles moulds is an automatic procedure, provided by CEI machines, which automatically adjusts the position of different tiles moulds on stone slab. CEI machines use cameras and projectors, pre-installed on the machines to perform the actions described. CEI machines have pre-installed a MySQL database capable of storing stone images, slab descriptions, model of slabs, and producer orders. On average four gigabytes of data is stored per year.

Although moulds distribution is an automatic process, there is a need of a manual procedure to identify defects on stone slabs. Sometimes, the stone slabs show defects, such as natural cracks, voids, etc, which are necessary to detect before performing a new procedure. When pre-cutting stage is completed, the stone is again cut, creating stone tiles. However, during stone cutting, sometimes a blade becomes worn out, causing flaws in the cutting process, increasing the time to produce stone tiles, as well as creating defects in stone slabs.

Finally, the last step in stone cutting procedures is a quality control test. In this step, an operator evaluates the different tiles and tests the conformity of stone measures. When the product is compliant, it can be sent to clients.

2.11.1.3 Zero Defect Key Issues

Cutting stones is a sequential process that suffers when any one of the steps fails. The problems identified in stone cutting process are expressed as:

Figure 70: Stone slab in the storage

- **Monitoring quality diamond wires** - This is the initial stage of the process, where the raw stone is cut. It is necessary that the cutting cables are in good condition and aligned, this work being done by the operator
- **Stone thickness detection** - After the cutting of the raw stone, the stone slab goes to polishing, where its thickness must be within conformity. Conformity detection is made by the operator
- **Worn out blade detection** – During the stone slab cutting, the operator needs to verify continuously the condition of the blade. Every time that the blade is worn out, and the operator does not identify it, the blade will be stuck, and the machine can be damaged
- **Distribution of cut moulds in stone** - After polishing, the stones are ready for the final cut, and this cut is performed according to customer orders. The operator decides how to cut the stone slab to make the final stones tiles. This decision depends on the experience of the operator
- **Conformity assessment of stone tiles** - After the stone tiles are cut, it is necessary to verify that the stones slabs were measured with the necessary conformity, which is performed by the operator

2.11.2 To-Be: Analysis of the Expected Scenarios

2.11.2.1 Target Business Process Model and Partners Roles

Considering the business model and aiming at automation and improvements in the stone cutting business model use case with associated zApps, an adapted process to achieve these objectives is shown in the figure below.

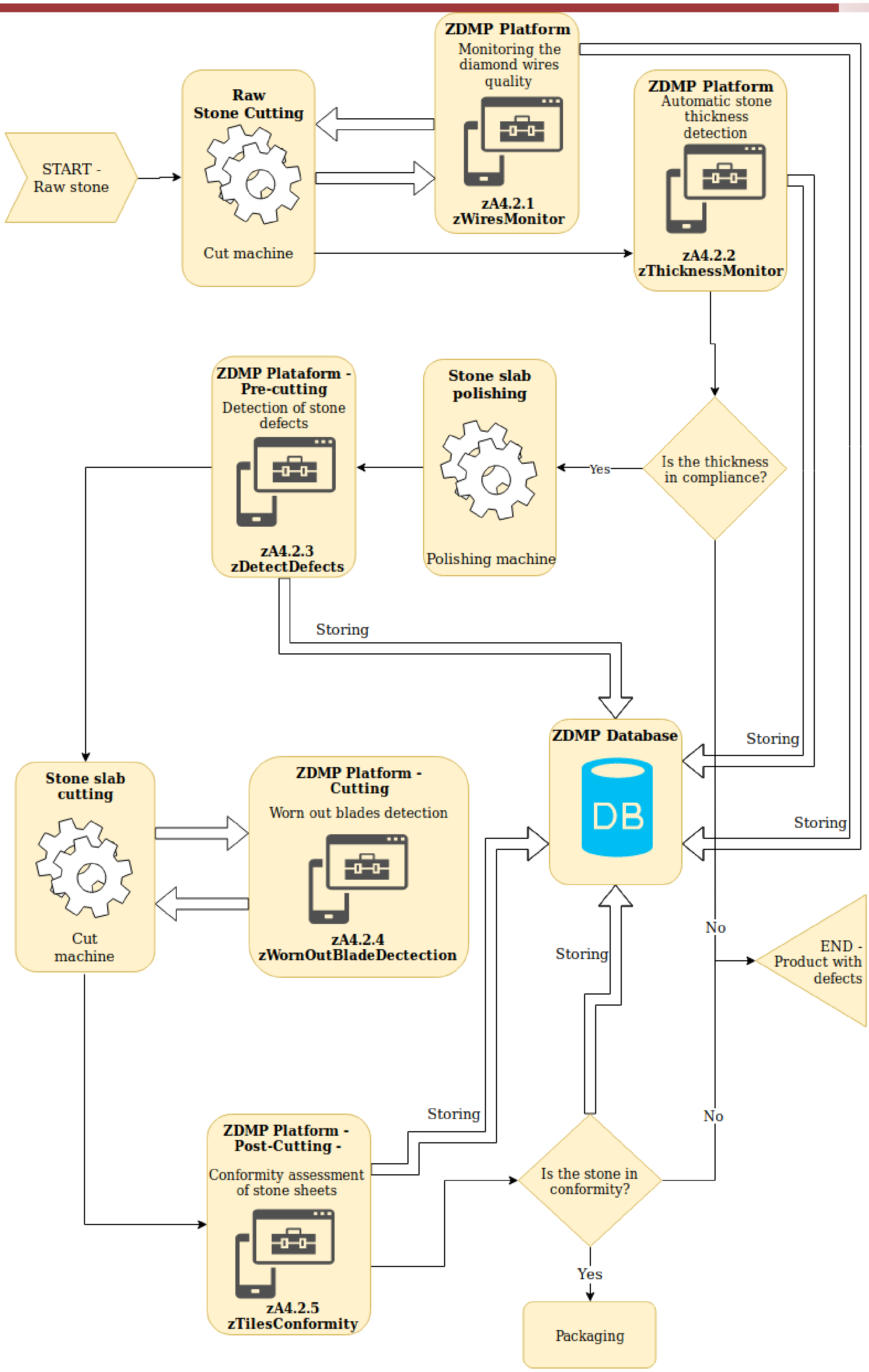


Figure 71: Business process model diagram “To-Be”.

All the zApps and the new business model ("To-Be" model) can be seen in Figure 71. To easily deploy and validation of zApps only should be considered three types of stone: marble, granite, and limestone.

The first zApp (zA4.5 - zWiresMonitor) will be a monitoring application that will allow verifying the positions of the raw stone cutting machine wires. It runs in parallel with the cutting process.

The second zApp (zA4.6 - zThicknessMonitor) is an application that will allow automatic verifying, after raw stone cutting, if the stones slabs have the correct thickness to continue in stone cutting process. The idea of this app is to eliminate the current manual assessment, performed by operator, and make this process into an automated process. When this operation is completed, all the stone thickness assessment data is stored in the database.

The third zApp (zA4.7 – zDetectDefects) is an application that will allow the automatic detection of defects in stone slabs. Similarly to the last zApp, this application is an optimization in the process of stone cutting because until now detection of defects in stone slabs is a manual process that takes a lot of time. All data generated in this process is stored in a database.

The fourth zApp (zA4.8 – zWornOutBladeDectection) intends to automatically detect worn out blades during the stone slabs cutting. This app will monitor the condition of blades during the stone slab process

Finally, the latest zApp (zA4.9 - zTilesConformity) is an application that will validate the compliance of the final product before it is packaged. Before any product is packaged, it needs quality check. As in the previous cases, this task is currently performed manually by the operators. The introduction of this zApp makes this an automatic procedure. All data generated in this process is stored in a database.

2.11.2.2 Candidate Solutions - zApps

The companies participating in this use case wish to reduce operation costs through the previously identification of defects products, such as natural cracks, voids, defects, and patterns, or through the optimization of their services.

zApp name	ID	Description	Timing
zWiresMonitoring	zA4.5	The goal of zWiresMonitor is to detect automatically broken cables or irregular movements of cables and the alignment of the cable, in first step of stone cutting. When a stone is being cut, the cables, responsible for this work, can break or move irregularly, creating defects in the stone. To solve these problems, the zCableMonitor intends to implement sensors capable to detect when a cable is broken or moving irregularly.	2-10 seconds
zThicknessMonitor	zA4.6	The main goal of zThicknessMonitor is to automatically detect defects in the thickness of stone slabs. For a correct polishing, the stone slabs need to be in a certain size range. To verify compliance, this zApp allows real-time analysis of the thickness of stone slabs.	30 seconds
zDetectDefects	zA4.7	The objective of zDetectDefects is to automatically assign stone moulds to stone slabs.	5 minutes

zWornOutBladeDectection	zA4.8	The goal of zWornOutBladeDetection is to automatically detect worn blades during the stone slabs cutting.	2-10 seconds
zTilesCorformity	zA4.9	The goal of zTilesConformity is to validate the conformity of the final product before it goes to packaging. This zApp will be the last step in the stone cutting process and will act as a validator of stone cutting procedures.	5 minutes

Figure 72: zApps selected for the Use Case

After a preliminary analysis, the WP7 and WP8 technologies needed to develop the zApps for this UC are:

- T7.2 Production State: Equipment Performance Optimization
- T7.4 Process Quality Assurance
- T8.3 Production: Non-Destructive Product Inspection
- T8.4 Production: Supervision

2.11.2.3 Expected Impact on KPIs

The expected impact of zApps implementations are described in next table.

KPI	Description	Current Value	Target Value
Natural defects process detection automatization	Number of defects detected automatically divided by the number of total defects detected.	0% (All manual)	35%
Production defects detection automatization	Measurement of the increment of work pieces with defects detected automatically, improving the production of stone sheets of final zero-defects quality, from the beginning of the process until final packaging.	80% manual 20% assisted	100% assisted
Waste	Number of parts from equipment failures during cutting stage and mould spatial optimization.	8 every 100 parts	25% reduction 6 every 100 parts
Worn out blade detection	Automatic detection of blade wear to avoid stone slab damage, excessive production time and machine damage.	Full manual	Full automatic, with 85% reliability

Figure 73: KPI: Expected improvements

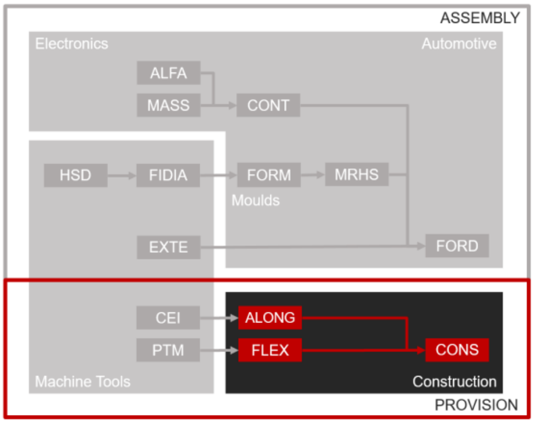
2.12 UC4.3: Construction supply chain: quality control at construction site

Figure 74: Material reception at construction site

2.12.1 As-Is: Analysis of the Current Situation

2.12.1.1 Partners Roles

This use case involves the industrial partners CONS, FLEX and ALONG



- **FLEX**: SME steel tubes producer who uses the cutting machine. In this use case, FLEX will produce steel tubes to be used at the construction site
- **ALONG**: SME stone slabs producer. In this use case, ALONG will produce stone masonry to be used at the construction site (for example, for surfaces stone lining)
- **CONS**: CONS field of activity includes all stages of infrastructure construction, from feasibility assessment and design through to construction supervision / monitoring / management and infrastructure operation. Among the other responsibilities, it manages raw material at production sites.

2.12.1.2 Business Process Model

The “As-Is” business process model corresponding to Use Case 4.3 is shown in Figure 75.

FLEX and ALONG are suppliers hired by the Works Contractor and approved by the Works Supervisor (CONS) to provide, respectively, steel tubes for the formwork and stone slabs for the infrastructure being built.

Each supply must be accompanied by a set of documents (paper format, eventually sent also by email as XLS or PDF) that provide evidence about the quality controls performed on the final product to be shipped, plus other mandatory documents required by the applicable legislation (for example, compliance with CE marking, if applicable). The volume of data depends on the number of supplies.

The documents are checked by the supervisor (CONS) upon arrival of the supplies at the work site. Together with a sample visual inspection, in the case of tubes and stone slabs (other materials may require other sorts of tests), they are the basis for accepting or rejecting the supply. This visual inspection is registered manually on a paper template and is later transferred onto an XLS file. This documentation is collected, scanned, and stored, both as a paper archive and as a digital one (composed of the scanned files). The supplies must be delivered according to the construction work schedule, prepared by the Works Contractor, verified, and approved by CONS.

CONS' team prepares its own activity schedule for acceptance inspection, based on the main work schedule, to ensure that the relevant team member is present when the material arrives. The main work schedule can be performed through XLS files. CONS team's activity schedule is usually performed in Excel (XLS).

Delays in supplies are not systematic, but they can occur and, when they do, they have impact on the works schedule and on CONS team's activity schedule. This impact may be minor and easily accommodated or may be significant and require considerable rescheduling. The impact is generally higher the shorter the delay notice is. The Works Contractor is expected to maintain contact with its suppliers and to inform CONS team of delays. This is an extra step in the process and may add to the impact the delay may have. Additionally, the rejection of a supply at the work site, due to lacking or inadequate documentation, or due to a defect detected upon inspection, will also have a serious impact on work schedule and, consequently, on the Supervisor's activity schedule.

Corrections are implemented after the delay is known or when the rejection occurs, which is not always straightforward. Additionally, if the defects detected on arrival at the work site can be related to the production process, as they normally are, this means the supplier keeps on producing defective parts since the materials were shipped until the defect was detected.

Clear information on the types of controls applied by the supplier during the production of the materials delivered is unknown. Usually, an audit may be carried out to assess the systems the supplier has in place to ensure production quality; however, no further information concerning production control is provided when the materials are supplied.

Ideally, CONS' team should get up-to-date, real time information on shipment delays, which allows it to quickly or automatically adjust its work plan. Also, to have digital real-time access to the whole characteristics of the material being shipped, would save time in setting up the archive and would allow documentation problems detection much before the materials arrive at the work site. Additionally, CONS' team could have access to production process data, if it chooses to, thus it would be able to understand the reason behind the defects detected at the site or even to detect them during shipment. Finally, the supplier would be able to access information quickly concerning its supplies reception at the work site and could act on its production process, if it chooses to do so, in a quicker way.

The following figure represents the situations described above and shows were the ZDMP Applications (shown with a red Z) could intervene.

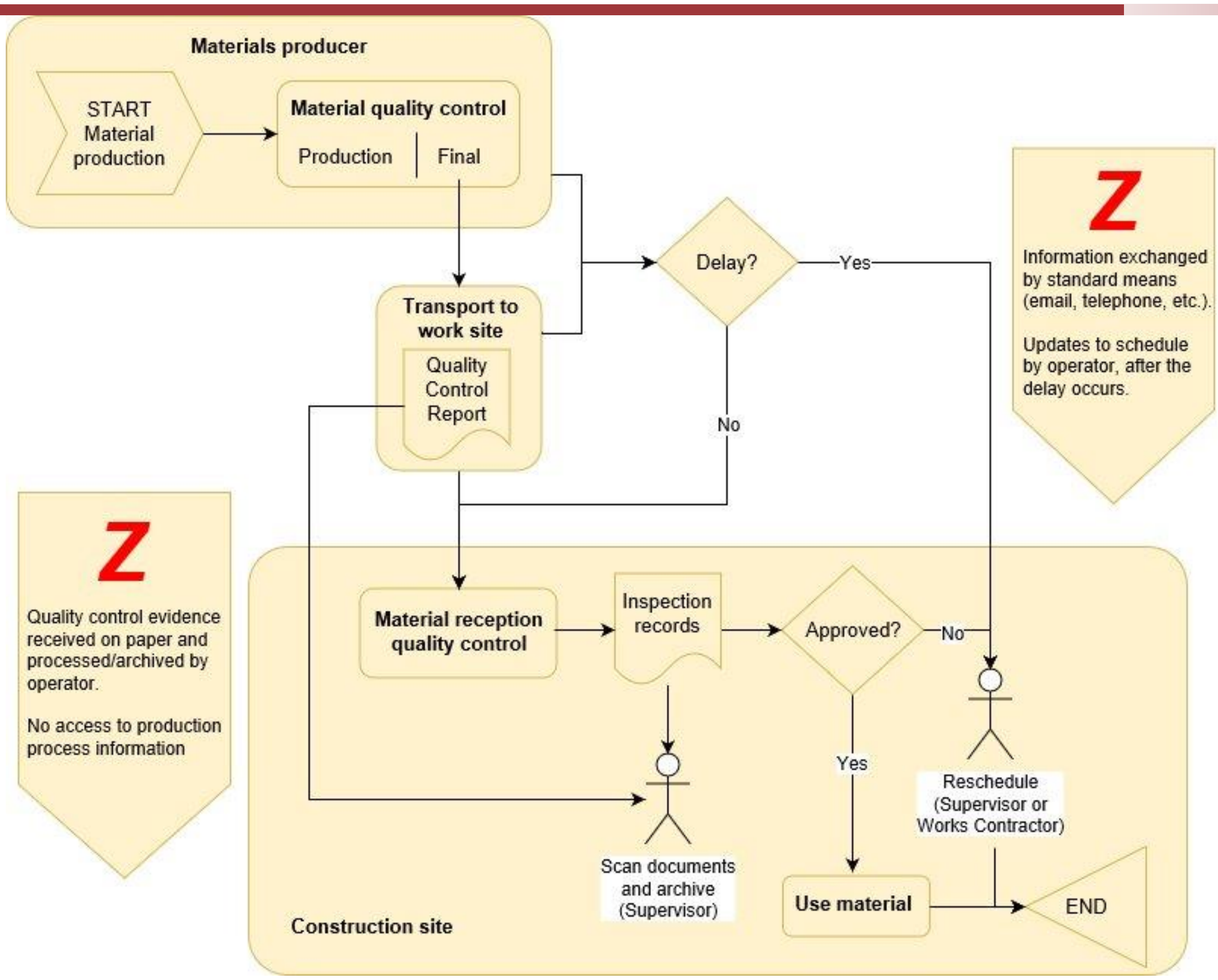


Figure 75: Business process model diagram “As-Is” for Zero-Defect of Supply Material (Reception)

2.12.1.3 Zero Defect Key Issues

Supply delays in construction works are not the rule, but they are frequent, and can be caused by anything from failure at reception quality control at the work site or by shipment delays. Usually, they can be accommodated without much impact on the overall schedule, but situations do occur in which the impact on work schedule is more significant. Frequently, delays are known or reported at short notice.

Apart from that, the impact on the parties’ daily activities schedule, whether it is the Works Contractor itself or the Supervisor, is probably less relevant, but by no means a lesser cause for productivity losses. In effect, a delayed supply always involves some time wasted in rescheduling activities, usually using Excel or MS Project - time that could be used for other activities.

It is the client’s requirement that the construction project it sponsors is implemented on time and on schedule. Similarly, the parties involved require that their teams’ work is performed efficiently and, again, implemented in the given time and maximising productivity. Deviations from this objective can be understood as a defect.

Thus, to reduce the chance of a defect, it is essential that the parties involved (the Supervisor, in this case) have early access to information concerning a potential delay and are able to act quickly, preferably automatically, so as to minimise its consequences. This also involves having early access to documentary evidence supporting the quality of the supplies, to avoid the shipping of material that may be rejected upon arrival at the site, but also to be able to effectively reschedule activities if necessary.

2.12.2 To-Be: Analysis of the Expected Scenarios

2.12.2.1 Target Business Process Model and Partners Roles

The target business process considers the use of zApps, accessible by the Supplier (FLEX and ALONG, in this case), by the Works Contractor and by the Supervisor (CONS, in this case).

The first zApp (zA4.10 – zRemoteQC) will allow the parties at the works site to have an early access to documentary evidence of compliance with specifications of the materials to be shipped and, should they choose to, to have also access to production quality control information relating to the lots of material being supplied.

The material manufacturer stores in the platform / cloud the information concerning the production of a specific lot. This information is automatically generated by its own system and apps developed under this project or inserted manually into the app. The volume of data is considerable and, for construction materials, needs to be stored for 10 years, which is the legal guarantee period.

The materials manufacturer informs the works contractor of the materials being shipped and their expected time of arrival at the work site. This information can be made available through an email that can be generated by the app itself, with a button to access a site / platform / cloud, and/or through a mobile version of the app, with an alert system, which will then give access to information on:

- The order identification (essential)
- The lot(s) being shipped, including corresponding certifications (essential)
- Estimated time of arrival at the site (essential)
- Details on the lot(s)' production process controls (access optional).

The zApp must be setup with specific login data for each party (Supplier, Works Contractor, Supervisor), and through email and password, and each party will have access to different areas of the zApp. This must be customised for each construction project.

The second zApp (zA4.11 – zRescheduler) will allow the potential supply delays impact assessment on the works schedule and activities schedule. This can happen in case the production of the material is delayed, due to unforeseen circumstances, or in case a problem occurs during transportation. Both situations are reported through the zApp, either by the supplier (mobile app or site) or by the truck driver himself (via mobile app, in situations such as accident or intense traffic).

The zApp forwards the notification to the interested users (supplier, works contractor, works supervisor). The zApp should be able to propose modifications to the construction schedule, to be accepted by the works contractor and approved by the supervisor. After the user receives the notification and acknowledges reception, the zApp automatically forecasts the impact of such delay and suggests a rearrangement of tasks and has to minimise the effects of such delay and reduce down time. The supervisor analyses this information and edits it, if they choose to do so. Any changes made by the supervisor are stored and the new activities schedule version is taken as reference.

Each user will have different levels of interaction with the zApp. Both contractor and supervisor should have access to the construction schedule, but their own task schedules should only be accessible to each of them. Similarly, the Supplier will not have access to the Supervisor or Works Contractor's areas and vice-versa.

Figure 76 shows the target business process.

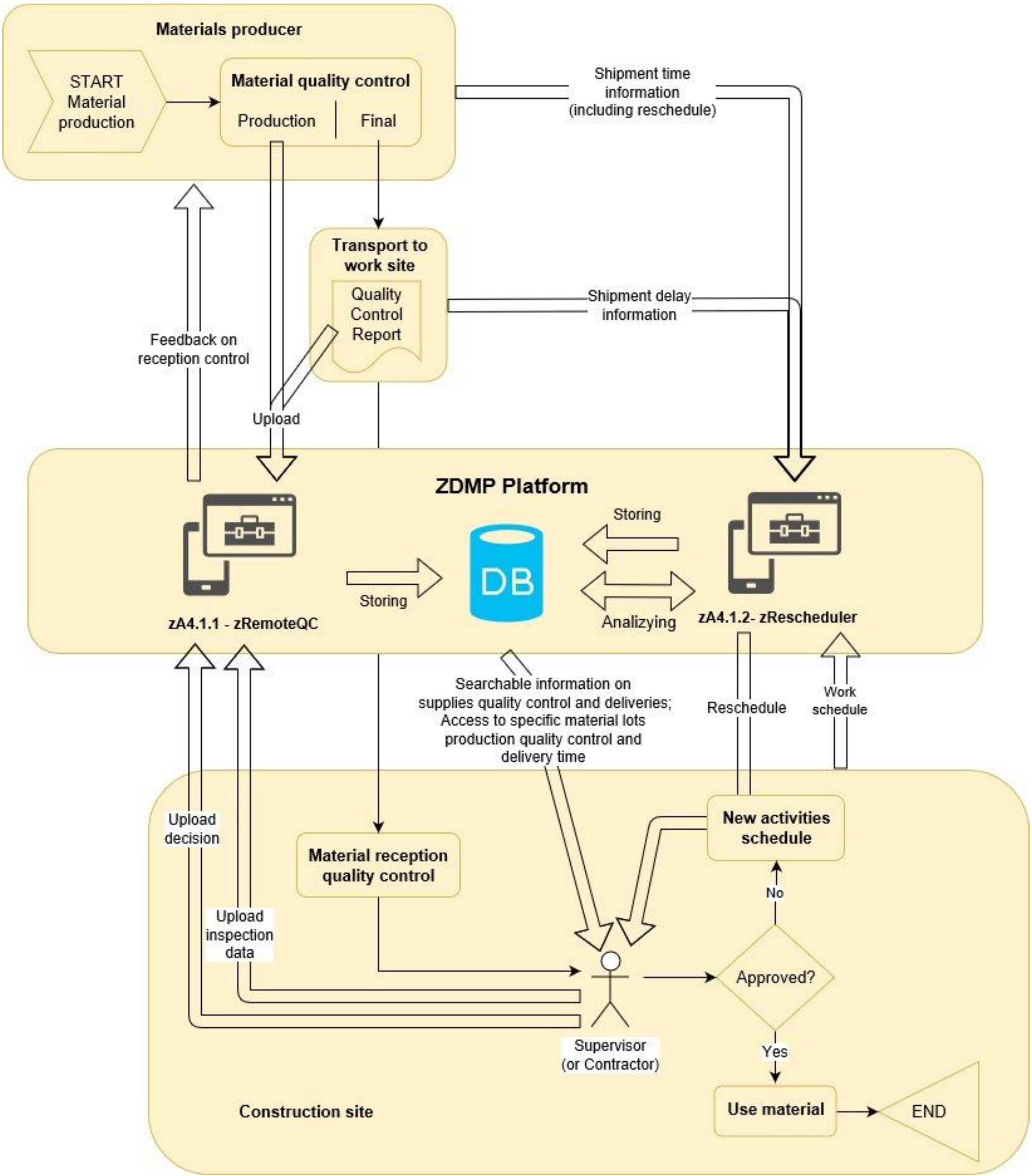


Figure 76: Business process model diagram "To-Be"

2.12.2.2 Candidate Solutions - zApps

The companies involved in this use case wish to improve information sharing and increase productivity, by improving materials defects detection and reporting, and by reducing time wasted due to production problems or quality issues. Taking advantage of the ZDMP Platform, it allows quick development, the use of different applications on the same platform and, thus, more efficient information access and sharing, the following two zApps running on the ZDMP Platform will be developed, see Figure 77.

zApp name	ID	Description	Timing
zRemoteQC	zA4.10	The objective of zRemoteQC is to allow access to and easy archiving of documentary evidence of compliance regarding material including their specifications. This facilitates the documentation assessment and the detection of potential errors, even before the supplies leave the manufacturing facility. It will also allow the access to production quality control records of the corresponding material lots, if the user chooses to do so.	Reaction in 2/10 seconds
zRescheduler	zA4.11	The objective of zRescheduler is to allow a quick adjustment of works schedule in case of delays in supplies, thus reducing productivity losses that normally would occur due to the Supervisor taking time from other activities to redo the schedule.	Reaction in 2/10 seconds

Figure 77: zApps selected for Use Case 4.3

After a preliminary analysis, the WP7 and WP8 tasks expected to be required to contribute to the zApps for this Use Case are:

- T7.3 - Gathering, Monitoring and Real Time Process of Industrial DATA
- T7.4 - Real Time Dashboards and Reporting
- T8.3 - Real time processing for future and past analysis
- T8.4 - Design and implementation Dashboard

Graphic User Interface (from T6.3) will also be required.

2.12.2.3 Expected Impact on KPIs

The expected impact is:

- To be able to have a timely access to the material supply documentation and detect issues that could lead to rejection early enough, thus minimising impact on construction works implementation
- To eliminate the need to scan materials quality control documentary evidence and, thus, to quickly check it and archive it
- To receive an timely warning of supply delays and to accommodate them through a quick reschedule of activities
- To be able to access production quality control information and improve the cooperation with the manufacturer in identifying production process issues that may be the cause for defects detected

With respect to the selected KPI the expected improvements are:

KPI	Description	Current Value	Target Value
Adjustment time	Time required to the supervisor to adjust the schedule following the occurrence of a delivery delay	Depends on the delay impact Up to maximum 4 hours, for significant impact delays	75% reduction Maximum 1 hour
Archive set up time	Time required to the supervisor to set up the archive corresponding to a specific lot of material received	Maximum 1 hour	50% reduction Maximum 30min
Quality assessment time	Time required to assess production process quality controls	Maximum 20 hours	80% reduction Maximum 4 hours

Figure 78: Target values for KPIs

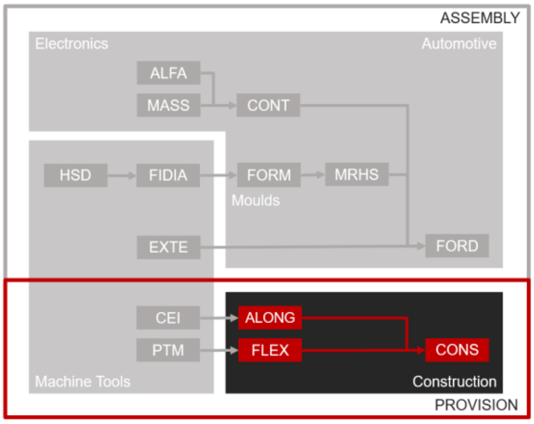
2.13 UC4.4: Construction supply chain: Quality traceability

Figure 79: building site during construction. The material already in place has lost

2.13.1 As-Is: Analysis of the Current Situation

2.13.1.1 Partners roles

This use case involves the industrial partners CONS, FLEX and ALONG



- **FLEX**: SME steel tubes producer who uses the cutting machine. In this use case, FLEX will produce steel tubes to be used at the construction site
- **ALONG**: SME stone slabs producer. In this use case, ALONG will produce stone masonry to be used at the construction site (for example, for surfaces stone lining)
- **CONS**: CONS field of activity includes all stages of infrastructure construction, from feasibility assessment and design through to construction supervision / monitoring / management and infrastructure operation. Among the other responsibilities, it manages raw material at production sites.

2.13.1.2 Business Process Model

Following the situation described in 2.12.1.2, and once the supply is accepted at the construction site, the material is applied at the location and using the construction process defined in the design.

Usually, the exact location where a specific lot of material is applied is unknown (except for critical structures). In general, the design specifies that a certain type of material (regardless of lot or shipment) is to be used in a certain type of area or, at best, in a specific area (regardless of the specific location). This leads to the following difficulties:

- In case of problems that can be related to material failures occurring during construction, testing, or infrastructure operation, the information concerning the specific material used in a specific location is unavailable.
- The access to documentation related to a specific material that failed during infrastructure use (post-construction) is difficult, mostly due to the difficulty of relating a failure to a specific lot of material or shipment. Furthermore, the size of the archives makes it difficult to quickly track the material quality control documentary evidence. This quality control documentary evidence is generated by the supplier or during reception inspection or during material utilization. It is is usually stored as scanned documents (pdf or jpg), as most of them are completed manually or generated and printed by legacy systems. A paper archive is also kept.
- Except in particular circumstances (critical materials or materials used in critical sections), the supplier does not get precise information that can help it to understand what happened in its production process that may have caused the failure during use. The most frequent situation is that the supplier gets information concerning a specific shipment, which can include several lots, or concerning a specific lot, which can span several shipments.

It would be of relevance to be able to know what specific material lot was used on a specific location on the infrastructure, as this would allow a better tracking of the correspondent documentation and a clearer feedback to the supplier, who could use it to reassess its production process and introduce corrections to avoid future similar defects. This will require that the suppliers introduce material (lot or even part) specific identification methods in their processes.

The following figure represents the situation described above and shows where a ZDMP Application (shown with a red Z) could intervene.

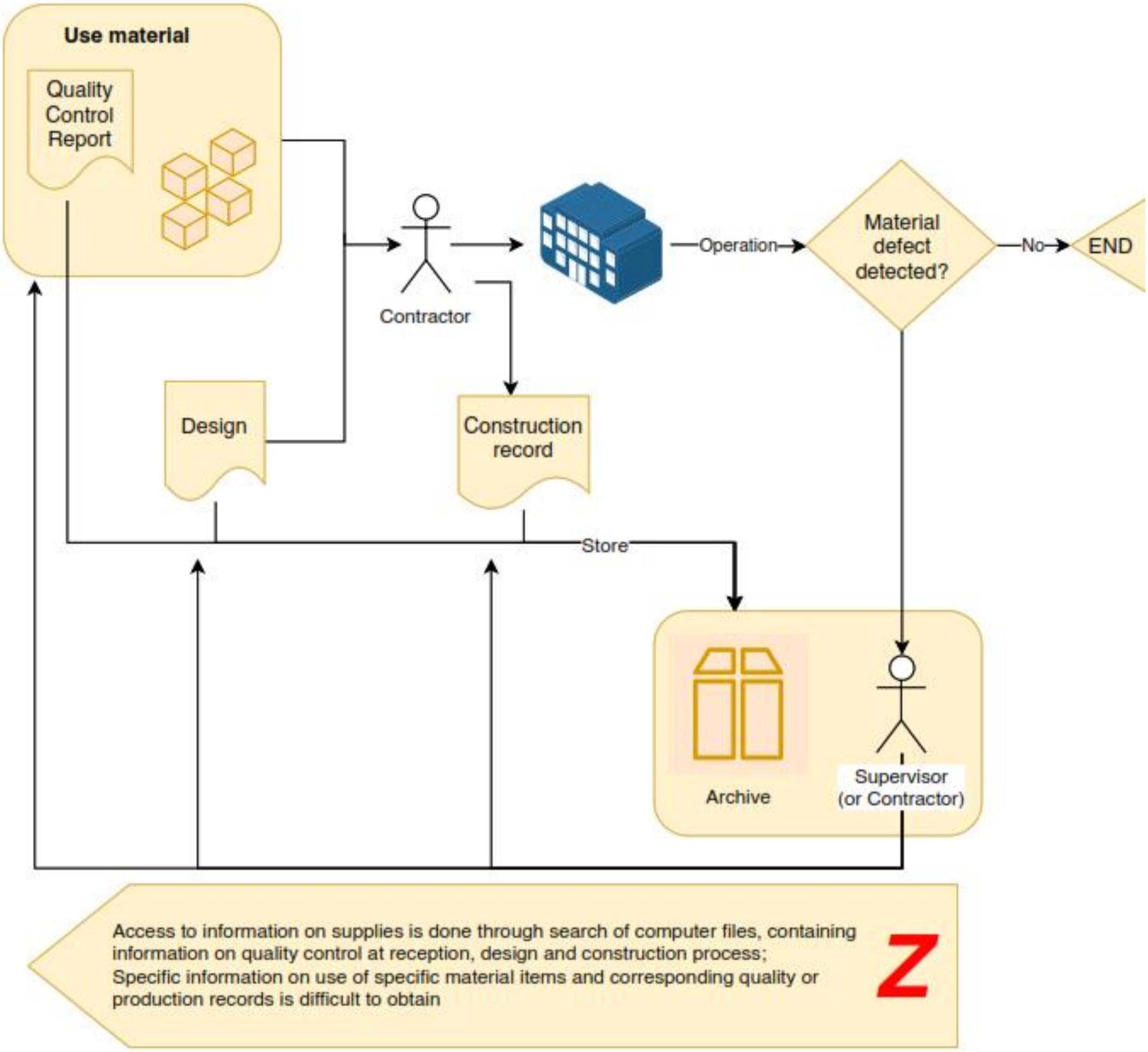


Figure 80: Business process model diagram "As-Is"

2.13.1.3 Zero Defect Key Issues

Verification of compliance and acceptance of a material upon delivery at a work site does not guarantee that defects will not occur from then on, including construction itself, testing, and infrastructure operation. This is the reason all built structures have a guarantee period, during which the Works Contractor has the legal obligation to correct defects that may occur. The idea here is to be able to trace the information concerning to a specific defective material, detected during construction, testing or operation, back to its production process.

Thus, it should be possible to know what specific lot was been used in the location where the defect was detected, its characteristics and the details of its manufacturing process. In this way, the manufacturer can access information concerning the defect and can analyse the production process to find the causes and to take corrective measures.

2.13.2 To-Be: Analysis of the Expected Scenarios

2.13.2.1 Target Business Process Model and Partners Roles

The target business process predicts the use of several zApps, one accessible by the Supplier (FLEX and ALONG, in this case) and the other accessible by the Works Contractor and by the Supervisor (CONS, in this case) and with access only to certain features by the supplier (FLEX and ALONG).

The first zApp (zApp4.12 – zMaterialID) allows the establishment of an identification system capable of creating a unique identifier for varied materials (lot or parts) and associates it to the corresponding quality control information; both production process control and final product quality control. The materials will be traceable throughout the production process and, later, at the construction site, through this identifier. This could be a bar code or any other system that allows it to be related to the information provided by zApp4.10, ie, the material identification should be able to relate the material to its location at the work site but also to its production process.

The data generated can be significant, depending on production rate and identification strategy (parts, for ALONG, lot for FLEX) and must be stored for at least 10 years, which is the usual guarantee period of a built structure. Production information will be generated by legacy systems, exported to the zApp, and related to the corresponding labels issued. The zApp has differentiated accesses for the production operator, production supervisor, and production quality control. It needs to be customised regarding the type of product being produced, which is particularly relevant in the case of ALONG. It will be accessed only by the supplier and will need to be customised for each construction project. It must also allow setting up login information, eventually through email and password or through any other system in use at the supplier. This typically necessary to be performed by a mobile phone.

zApp4.13 (zMaterialTracker) allows the actors to associate a specific material to a specific location, which implies that all the supporting quality control documentary evidence associated to that specific material to be related to a location. This zApp allows:

- Reading the information on the identification label, issued according to the identification system from zApp4.12, as the material is picked up for use in construction, through a bar code reader or equivalent
- To insert identification of the drawing and / or the part where the material is going to be used. This will be made manually by the operator directly onto the zApp
- To search for quality control information concerning a specific part in a specific location

The information is uploaded onto the platform / cloud and stored with the history of that material lot production. zApp4.13 will also allow information searches such as:

- To know what material lots were used, for a specific drawing / construction area
- To know the location(s) of a specific lot
- To have access to all information concerning a lot used on a specific section, ie, access to information from zApp4.12

The zApp will be customised for each construction process and it will require setting up login information. The Works Contractor will have full access to all zApp areas. The Supervisor will have also access to all areas but will not be able to edit inspection records issued by the Supervisor. Similarly, the Supervisor will have access to all areas, but will not be able to edit inspection records issued by the Works Contractor. The "To-Be" business model is shown schematically in Figure 81.

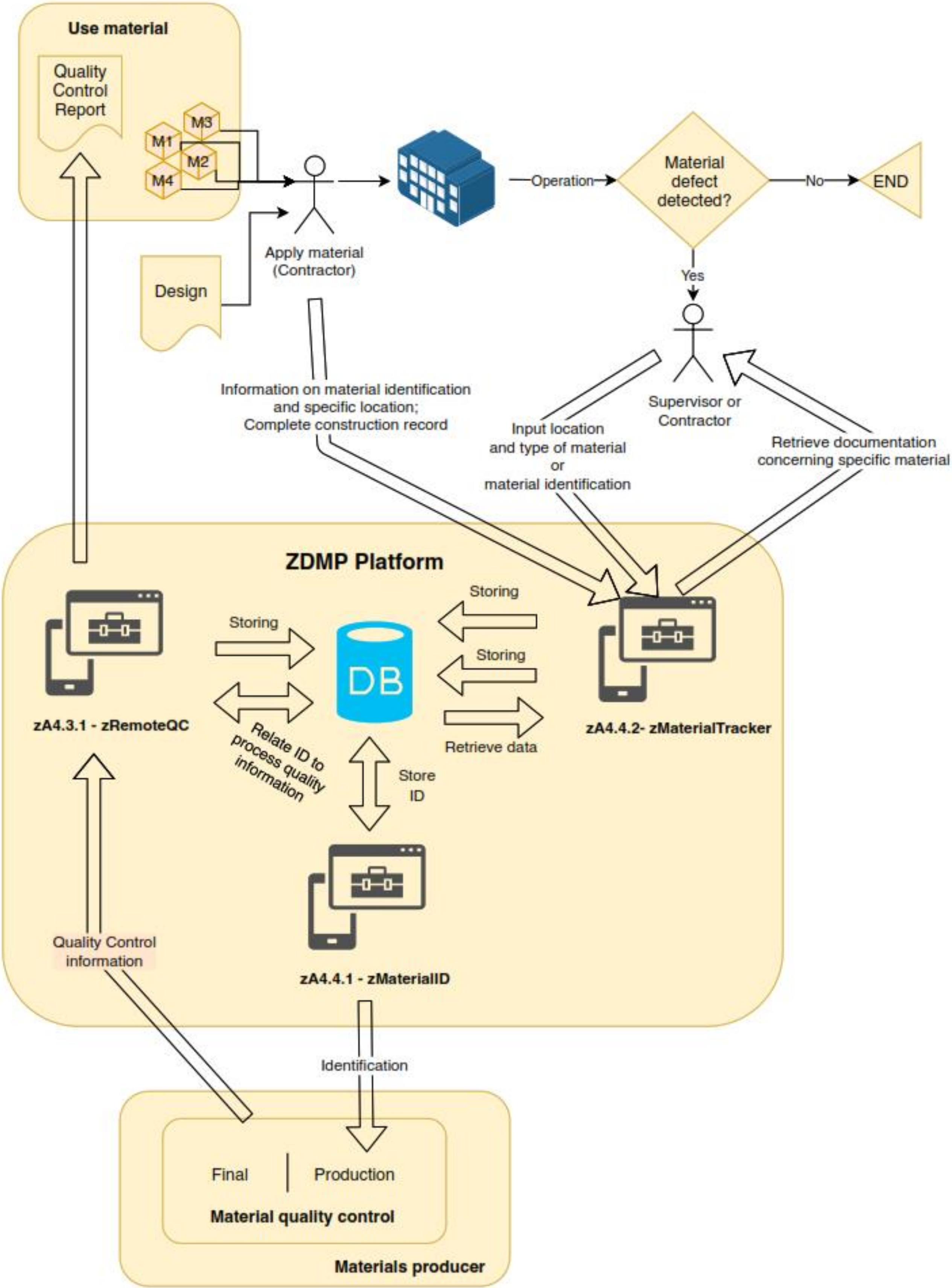


Figure 81: Business process model diagram "To-Be"

2.13.2.2 Candidate solutions – zApp

The companies involved in this use case wish to ensure information traceability concerning the materials used in a construction site, allowing access to all stages of the materials life span, from production to use. The following zApp running on the ZDMP Platform will be developed, see Figure 82.

zApp name	ID	Description	Timing
zMaterialTracker	zA4.12	The objective of zMaterialTracker is to allow the recording of the use of a specific material at a specific location, and based on that, to allow access to all the documentation related to that specific material, be it construction records, quality control records, shipment records or production control records. The zApp will interact and access information stored by zApp4.1.1	Reaction in 2/10 seconds
zMaterialID	zA4.13	The purpose of zMaterialID is to create an identification system capable of creating a unique identifier for different materials and corresponding quality control information. Through this identifier the materials will be traceable throughout the production process	Reaction in 30 seconds

Figure 82: zApp selected

After a preliminary analysis, the WP7 and WP8 tasks expected to contribute to the zApp for this Use Case are:

- T7.3 - Anomalies detection in the consumption
- T7.4 - Real time processing for future and past analysis
- T8.1 - Design and implementation Dashboards
- T8.3 - Usage of advanced User interfaces

Graphic User Interface (from T6.3) will also be required.

2.13.2.3 Expected Impact on KPIs

The expected impact is:

- To easily identify which specific lot of material, or even which specific item, can be associated to a defect occurred during construction, testing, or operation at a specific location;
- To quickly access all the documentary evidence related to that specific lot of material, or even specific item, supporting the correspondent quality control during construction, reception at the work site and even during production

With respect to the selected KPI the expected improvement is:

KPI	Description	Current Value	Target Value
Defect tracing time	Time required to relate a specific defect to a specific lot of material. It depends upon the type of material, its use, and the stage (construction, final testing or use/operation) in which the defect is detected. Example values are	Time required to relate a defect of a steel tube used for piping to a specific steel tubes lot: • 5 to 30 minutes, during construction	50% reduction Corresponding to: • 3 to 15 minutes, during construction

	provided.	• 10 to 60 minutes, during final testing • 2 to 4 hours, during infrastructure use	• 5 to 30 minutes, during final testing • 1 to 2 hours, during infrastructure use
Time required to access defect information	Time required to access information and documentation related to a specific defect. It depends upon the type of material, its use, and the stage (construction, final testing or use/operation) in which the defect is detected. Example values are provided.	Time required to access information on a specific steel tube used for piping: • 10 to 30 minutes, during construction • 10 to 60 minutes, during final testing • 3 to 8 hours, during infrastructure use	50% reduction Corresponding to: • 5 to 15 minutes, during construction • 5 to 30 minutes, during final testing • 1 to 4 hours, during infrastructure use
Time required to access historical information	Time required to access historical production process information concerning a specific product	1 day	80% reduction 2 hours

Figure 83: Target KPIs

2.14 Cross-Domain Validation

2.14.1 Cross-Domain Demonstrator

The four application scenarios share many features and needs. To demonstrate the validity of the proposed solutions in contexts independent from the companies who participate in the 13 use-cases described in the previous sections, ZDMP proposes a cross-domain demonstrator. This demonstrator is built on the typical supply chain of an assembly line composed of: Machine Tools – Electronics – Automotive. This type of supply chain, independently from which companies are involved in it, has quality requirements at supply chain level, as for example real-time analysis of the manufacturing data, the traceability of the quality and the management of the line not only for the operative, but also from the quality point of view.

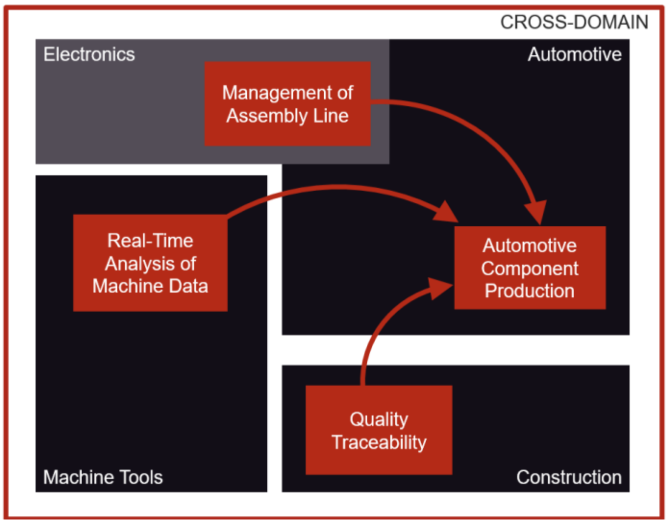


Figure 84: Quality needs expressed by ZDMP industrial partners to be demonstrated in the cross-domain validation

The typical supply chain business process is represented in Figure 85. An assembly line, such as an automotive production line, has several suppliers of components and processes. Among the component suppliers, they can be raw materials suppliers or manufacturers of pre-processed components, having their own supply chain. The assembly line then has a variety of equipment suppliers and services.

Whenever a defect is detected, the assembly company must identify the cause (human error, software bug, equipment malfunction, component defect, improper pre-processing, material contamination, etc). Once the cause is identified, the interested supplier must be contacted by phone or email. Before intervening physically, such as by sending technicians on premises or by re-manufacturing the unfit component, the supplier needs to receive all the defect information. The information gathering phase is usually inefficient, lasting a long time without targeting the significant data. The supplier then analyses the data in its technical offices and eventually reaches one of its suppliers.

In this scenario, the introduction of ZDMP solutions brings some significant changes (Figure 86). The quality data is shared, with the desired restrictions, in the platform. A variety of analysis and prediction tools can make predictions based on that information. The results can be shared quickly and safely with the entire supply chain. A set of zApps, running on ZDMP or locally, allows new services as quality tracking along the supply chain or in the assembly line.

To be valuable on the market and fully exploitable, these zApps need to be independent from the specific companies. For this reason, the cross-domain demonstrator, hosted by Tampere University and contributed to by all industrial partners, will validate the selected zApps on an assembly line with a pre-defined set of processes.

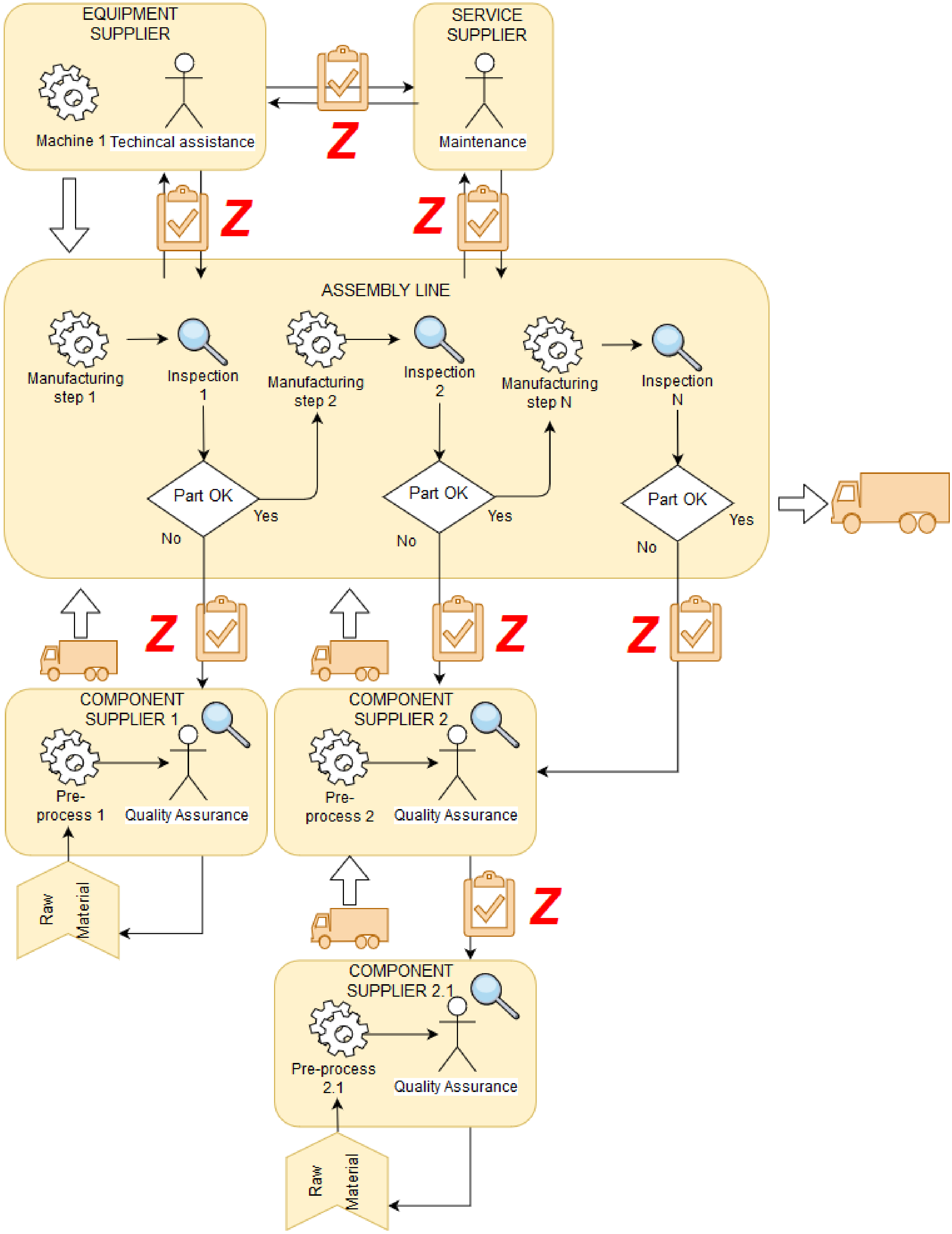


Figure 85: Business process model diagram of a generic supply chain “As-Is”

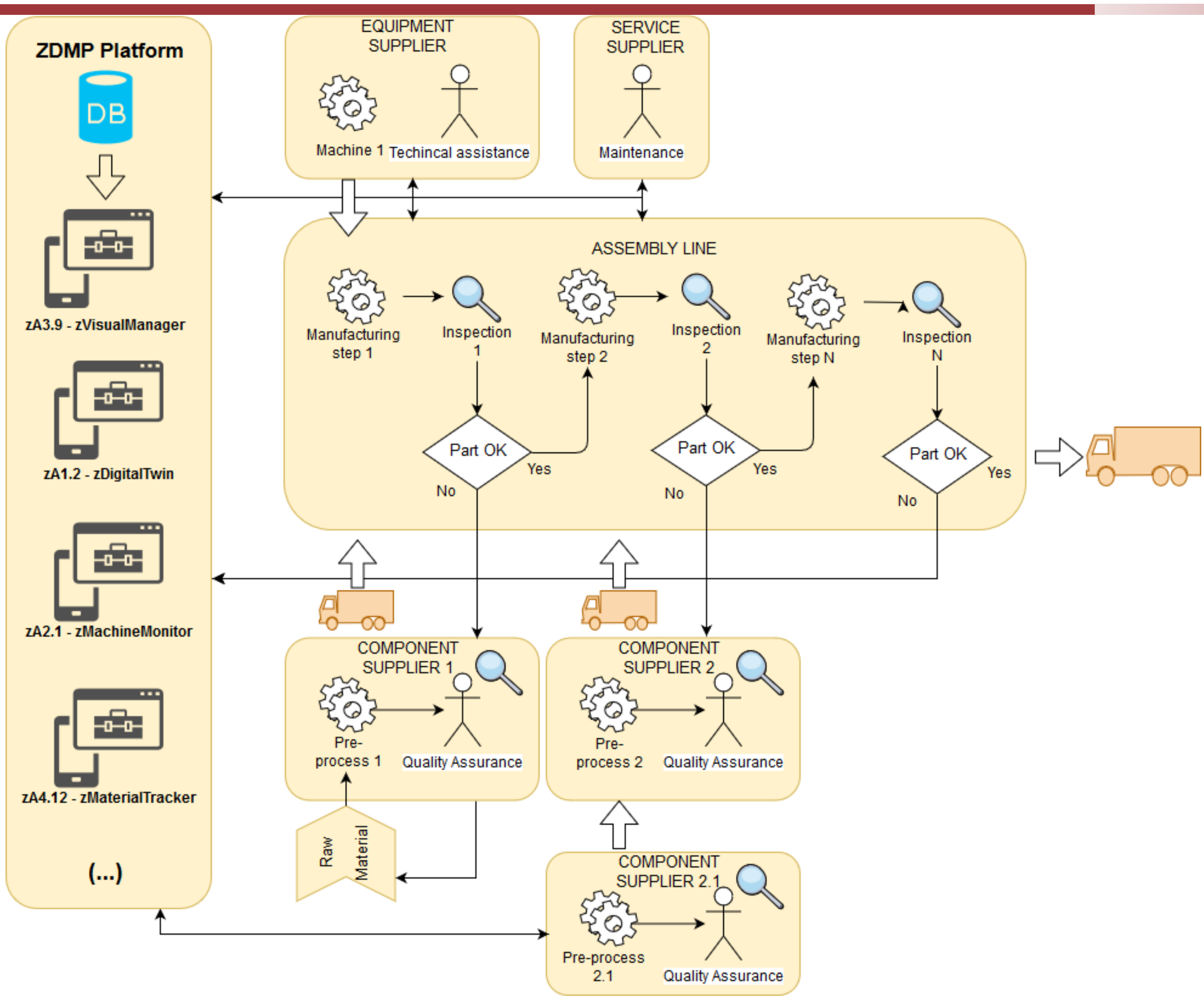


Figure 86: Business process model diagram of a generic supply chain “To-Be”

2.14.2 Methodology and Facility

Validating the platform and all its functionalities beyond the restrictions and limits of the use-case specific scenarios requires a flexible and reconfigurable environment. Such validation activity should ideally be independent from the industry type and be applicable to different domains, with a focus on their interaction. It is envisioned that the platforms of the pilot sectors described in the previous chapters are used along with the results of T11.1 (Experimentation Facility Establishment and Operation) and T11.2 (Reference Implementation Establishment and Support), which will orchestrate them.

For experimentation and demonstration purposes, a scale production environment will enable ZDMP to instantiate and validate business models, technical aspects, and policies. This enable to verify and quantify gains from ZDMP and document a reference implementation of the following generic scenarios:

- Prepare ZDMP-ready systems
- Find and run an existing zApp
- Development of a zApp/Driver
- Run locally

- Publish API/zApps
- Run zApps in the cloud

Tampere University provides two environments to accomplish this at its FAST-Lab facility. The assembly lines of FESTO MPS and FASTory are demonstrative modular production and assembly lines including (but not limited to) the following functions:

- Buffering (conveyed)
- Conveyor line
- Milling (CNC – EMCO – Concept mill 105)
- Robotized distribution
- Mechanical testing
- Mechanical processing (rotary file and testing)
- Robotized assembly
- Classification and storing
- Automated storage and retrieval system

There are two processes implemented, FESTO MPS line produces and assemblies cylinders by a predefined process Figure 87), whilst FASTory mimics phone production. FESTO MPS line follows a predefined set of processes, while FASTory's process is completely adaptable and reprogrammable by an orchestrator.

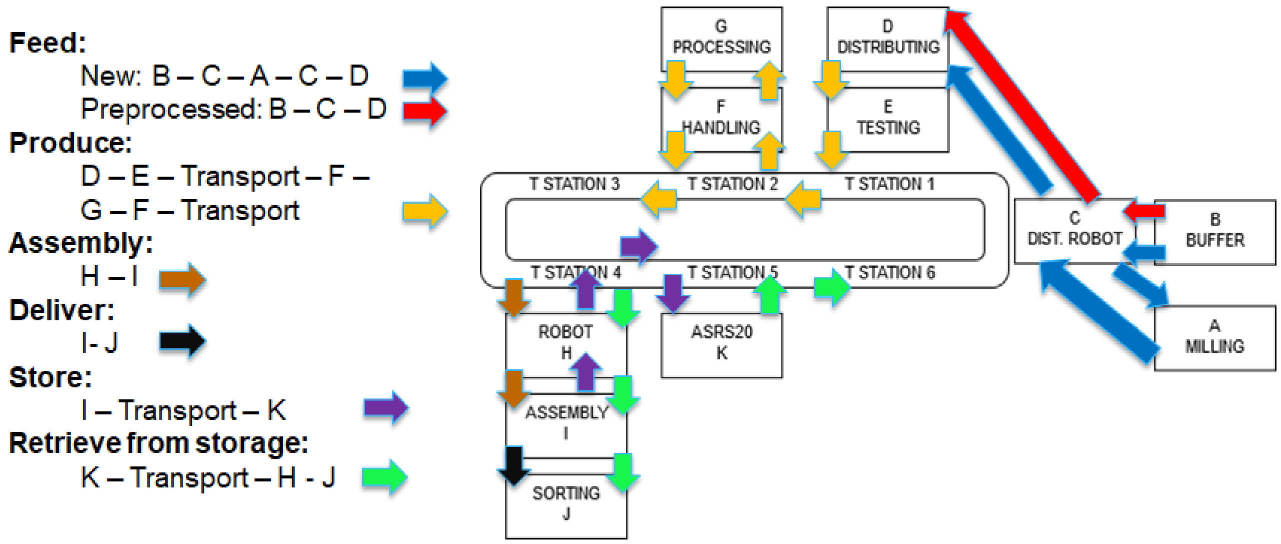


Figure 87 Process map - FESTO MPS line. On the left a list of the high-level processes and

Technologies on both lines include:

- Industrial controllers
- Ethernet gateways
- Energy monitoring
- Process orchestration
- OPC UA – Profinet – Profisafe

Due the nature of the experimental environment, safe, quick, and efficient control of error conditions is possible during the demonstrative process execution. This enables the ZDMP development team to validate features and quantify gains from implementing the platform.

Figure 84 provides a mapping of ZDMP features on the cross-domain demonstrator functions.

Cross domain demonstrator functions	ZDMP features (cross domain use cases)
Conveyor line	Production line (Electronics)
Milling (CNC – EMCO – Concept mill 105)	Machine setup modification
	Machine analytics – Process deviation
Robotized distribution	Scheduling
Mechanical testing	Data acquisition and monitoring during process
	Automatic and human quality inspection
	Product measurement and conformity assessment
Mechanical processing (rotary file and testing)	Monitor process variables
Robotized assembly	Predict faults from process data
Classification and storing	Data collection and material identification
Automated storage and retrieval system	Storage and supply data management
Adjustable modular process	Bidirectional process communication
	Supply, validate, assembly and store pieces with +500 variants
Computing – Network infrastructure	Leak test
	Reporting to remote entity
	HMI
	Notifications
	X-ray Images gathering
	Comparison between X-ray images and 2D drawings
	Interface for customer feedback
	AI
	Optimize updates on MES
	Data ontology and linking
Vision applications	Visual porosity
	X-Ray data
3D Scan	Fast 3D modelling by scanning
Data generators and interfaces	Wearables
Controlled error generators	Repeat analysis and detect false positives

Figure 88: Concept linking between cross-domain demonstrator and ZDMP features

Validating the platform and all its functionalities beyond the restrictions and limits of the use-case specific scenarios requires a flexible and reconfigurable environment. Such validation activity should ideally be independent from the industry type and be applicable to different domains, with a focus on their interaction. It is envisioned that the platforms of the pilot sectors described in the previous chapters are used along with the results of T11.1 (Experimentation Facility Establishment and Operation) and T11.2 (Reference Implementation Establishment and Support), which will orchestrate them.

3 User Scenarios Classification and Analysis

The use-case scenarios depicted for ZDMP, despite describing very different realities of very different manufacturing sectors, show several common features. Figure 89 summarizes the ZDMP technologies common to the different zApps proposed for the use-cases. The necessary features and functionalities identified for these zApps by the end-users are:

- **Digital Twin**: Replica of the current machine, line or process
- **Analytics**: Analysis of data gathered
- **Training of the algorithms**: Training time needed, due to learning based analysis
- **Cloud / Platform**: Cloud instance of the platform for running the zApps (for computational power, shared access, or any other reason)
- **Database**: A local or cloud based version of a database is needed to store data
- **Supply Chain Shared Access**: Different actors of the supply chain need access to all or a part of the data, results, functionalities
- **Different access levels**: Different access rights (eg operator, maintenance personnel, plant manager, admin, etc)
- **Response Times**: Response time for the results below 10 seconds
- **Distributed Data Source:** Data is gathered from many machines, in different lines or plants
- **Scheduling**: Scheduling functionalities needed
- **Tracking**: Tracking materials or products
- **Alert**: Messages and alerts needed
- **Artificial Vision or Scanning**: Use of cameras or scanners, resulting in data like pictures or cloud of points
- **Communication / Data flow**: Communication outside the support hosting the zApp
- **Environmental Data**: Gathering or using environmental data (eg temperature, humidity, pressure, etc)
- **Energy Consumption**: Energy analysis

zApp	ID	Digital Twin	Analytics	Training of the Algorithms	Cloud / Platform	Database	Supply Chain Shared Access	Different access levels	Very Low Response Times	Distributed Data Source	Scheduling	Tracking	Alert	Artificial Vision or Scanning	Communication / Data flow	Environmental Data	Energy Consumption
zAnomalyDetector	zA1.1		✓	✓		✓	✓	✓	✓	✓		✓	✓	✓		✓	✓
zDigitalTwin	zA1.2	✓	✓	✓		✓	✓			✓							
zAlarm	zA1.3					✓	✓	✓	✓			✓	✓				

zMachineMonitor	zA2.1		✓			✓			✓				✓		✓	✓	✓
zMachineAnalytics	zA2.2		✓	✓	✓	✓	✓	✓		✓					✓		
zParameterMonitor	zA2.3												✓		✓	✓	
zParameter Analytics	zA2.4		✓	✓	✓	✓	✓	✓		✓			✓		✓		
z3DScannerDriver	zA2.5													✓	✓		
z3DGenerator	zA2.6		✓		✓									✓			
zXRAY Monitor	zA3.1		✓	✓		✓		✓		✓			✓	✓	✓		
zXRAY Analytics	zA3.2		✓	✓		✓		✓									
zFeedbackMFT	zA3.3					✓			✓				✓		✓		
zArtificial IntelligenceMFT	zA3.4		✓	✓		✓			✓					✓			
zFeedbackAFT	zA3.5					✓			✓				✓		✓		
zArtificial IntelligenceAFT	zA3.6		✓	✓		✓			✓					✓			
zDriver	zA3.7								✓				✓		✓		
zLineData	zA3.8					✓			✓						✓		
zVisualManager	zA3.9		✓	✓	✓	✓									✓		
zProductVersionControl	zA3.10					✓		✓							✓		
zAutomaticCall	zA3.11					✓									✓		
zPowerManager	zA3.12														✓		✓
zCycleTimeManager	zA3.13					✓			✓			✓					
zAutomaticMaterial Ordering	zA3.14					✓			✓				✓				
zDataArchiveControl	zA3.15					✓				✓							
zSteelSheetWidthMonitor	zA4.1	✓	✓	✓			✓	✓	✓				✓	✓			
zHorizontalWeldDetection	zA4.2	✓	✓	✓			✓	✓	✓				✓	✓			
zVerticalWeldMonitor	zA4.3	✓	✓	✓			✓	✓	✓				✓	✓			

zShapeTubeMonitor	zA4.4	✓	✓	✓			✓	✓	✓				✓	✓			
zWiresMonitoring	zA4.5		✓	✓			✓	✓	✓				✓				
zThicknessMonitor	zA4.6		✓				✓	✓	✓				✓				
zDetectDefects	zA4.7	✓	✓	✓			✓	✓					✓	✓			
zWornOutBladeDectection	zA4.8		✓	✓			✓	✓	✓				✓				✓
zTilesCorformity	zA4.9	✓	✓				✓	✓					✓	✓			
zRemoteQC	zA4.10						✓	✓	✓	✓		✓	✓		✓		
zRescheduler	zA4.11						✓	✓	✓		✓				✓		
zMaterialTracker	zA4.12	✓					✓	✓	✓	✓		✓	✓		✓		
zMaterialID	zA4.13						✓	✓	✓	✓					✓		

Figure 89: Technologies or functionalities representing a common need to the different

Some non-technological features of the zApps described in the previous chapters are summarized in Figure 90. This figure lists the preferences of the users on some key features:

- **Type**: This parameter identifies whether the zApp is thought to be a self-standing zero-defects application (APP) or a component to support or enable a zero-defect application (COMP)
- **Priority**: This entry describes the level of priority the users give to the zApp. The priority can be both the expression of an interest (eg the company is highly interested in commercializing or using this type of solution) or also a logical priority (eg the zApp is the support and the basis for other applications or components, that cannot work without it). It is expressed in high (H), medium (M) or low (L)
- **UI**: This parameter stands for User Interface and identifies the necessity for the zApp to include a graphical interface. It is expressed as yes (Y), no (N) or maybe (M), in case this necessity has not yet been identified
- **Where**: This entry identifies if the zApp should run locally (LOCAL) (on a computer, a smartphone, numerical control or any local device), on a dedicated space in ZDMP platform (ZDMP) or if this is still to be decided with the help of the technological partners (TBD)
- **Custom**: This parameter describes the degree of customization of the zApp. In other words, a zApp with low customization (L) could be used by other users and applied to other companies with zero or minor changes. A zApp with medium (M) customization requires a few modifications for being extended to other users, while a zApp with high (H) customization is built for the specific machine, line or company, and, a part from its concept being applicable in other cases, adapting the zApp itself would require some major effort.

zApp name	ID	Type (App, Comp)	Priority (H, M, L)	UI (Y, N, M)	Where (Local, ZDMP, TBD)	Custom (H, M, L)
zAnomalyDetector	zA1.1	APP	H	Y	TBD	L
zDigitalTwin	zA1.2	APP	M	Y	TBD	M
zAlarm	zA1.3	APP	H	N	LOCAL	L
zMachineMonitor	zA2.1	APP	H	Y	LOCAL	H
zMachineAnalytics	zA2.2	APP	H	N	ZDMP	L
zParameterMonitor	zA2.3	COMP	L	M	LOCAL	H
zParameterAnalytics	zA2.4	APP	L	Y	ZDMP + LOCAL	M
z3DScannerDriver	zA2.5	COMP	L	M	LOCAL	H
z3DGenerator	zA2.6	APP	H	M	ZDMP	L
zXRAY Monitor	zA3.1	APP	H	M	LOCAL	L
zXRAY Analytics	zA3.2	APP	H	Y	LOCAL	M
zFeedbackMFT	zA3.3	APP	H	Y	LOCAL	H
zArtificial IntelligenceMFT	zA3.4	COMP	H	M	LOCAL	M
zFeedbackAFT	zA3.5	APP	H	Y	LOCAL	H
zArtificial IntelligenceAFT	zA3.6	COMP	H	M	LOCAL	M
zDriver	zA3.7	COMP	H	N	LOCAL	H
zLineData	zA3.8	COMP	H	M	LOCAL	L
zVisualManager	zA3.9	COMP	H	Y	LOCAL	L
zProductVersionControl	zA3.10	APP	M	M	LOCAL + ZDMP	L
zAutomaticCall	zA3.11	APP	M	M	LOCAL	L
zPowerManager	zA3.12	APP	M	M	LOCAL	M

zCycleTimeManager	zA3.13	APP	M	M	LOCAL	M
zAutomaticMaterialOrdering	zA3.14	APP	M	M	LOCAL	L
zDataArchiveControl	zA3.15	APP	M	M	LOCAL	M
zSteelSheetWidthMonitor	zA4.1	COMP	M	N	LOCAL	L
zHorizontalWeldDetection	zA4.2	COMP	M	N	LOCAL	L
zVerticalWeldMonitor	zA4.3	COMP	M	N	LOCAL + ZDMP	H
zShapeTubeMonitor	zA4.4	COMP	H	Y	LOCAL + ZDMP	M
zWiresMonitoring	zA4.5	COMP	L	N	LOCAL	H
zThicknessMonitor	zA4.6	COMP	L	N	LOCAL	L
zDetectDefects	zA4.7	COMP	H	Y	LOCAL + ZDMP	H
zWornOutBladeDectection	zA4.8	COMP	M	N	LOCAL + ZDMP	L
zTilesCorformity	zA4.9	COMP	H	Y	LOCAL + ZDMP	H
zRemoteQC	zA4.10	APP	M	Y	LOCAL + ZDMP	L
zRescheduler	zA4.11	APP	M	Y	LOCAL	H
zMaterialTracker	zA4.12	APP	M	Y	LOCAL + ZDMP	M
zMaterialID	zA4.13	COMP	H	M	LOCAL	H

Across all the zApps, those with the lower degree of customization are expected to be the easiest to apply in other scenarios, outside ZDMP project. As stated before, all the zApps described are the answer to a zero-defect problem of the manufacturing sector they refer to, therefore all of them have a high potential impact on many types of applications. Some of them are however easier to export, because they are more general in their applicability to other companies or domains. The following table (Figure 90) lists the applications that at this stage are thought to be the most widely exploitable, with a small description of the conditions to be met in order to be applicable, and an estimation of the size of the interested market. The zApps not listed in the table are of two categories:

- **High Customization Level**: The zApps of this type have lower marketability since they are specific to the machine, equipment, line or plant they are built for. These applications are in most cases components, which have been split from the zApp they are linked to, to separate the high customization from the low customization features. This is the case, for example, of the 3DScannerDriver (zA2.5), which is a component supporting zA2.6. It is the driver for the automatic start of zA2.6 and depends highly on the system on which is installed, since it needs to collect the data and send them to ZD platform where the computation takes place. This app allows zA2.6 to be widely applicable but has low marketability.

- **Dependent**: Some of the zApps depend on others and are therefore not marketable stand-alone. It is the case of zA3.10-15. These applications provide the data and the analysis to be visualized in zA3.9, the zVisualManager, which is the main tool.

zApp name	ID	Conditions to meet to be applicable	Possible Market
zAnomalyDetector + zAlarm	zA1.1 zA1.3	• The process has different measurable parameters, and deviations of one or more of them could have a measurable impact on the quality of the product • Each product produced is traceable with a specific serial number • Process parameters for each individual part are available in a database, and data can be sent to the zApps • Quality results per individual part are measured, quantified, and classified, and then sent to the zApp	The Applications developed for UC1.1 could be directly used (not requiring any adaption or set-up) at any manufacturing company, for any production process of serial parts, with the previous characteristics. The possible market goes beyond the automotive sector, since the zApps applicability is not dependent on the product itself, but on the equipment and the line. Any production process characterized by medium to large batches has possible market opportunities for these zApps.
zMachineAnalytics	zA2.2	• The system that creates the dataset to be sent to this zApp can measure many physical variables • A “normal” working condition can be identified • A deviation from normal working conditions implies an accuracy loss (otherwise, it is not used as a zero-defects zApp, but can still be used for other monitoring purposes)	The zMachineAnalytics can apply to all sorts of machines, not necessarily to high-speed milling. The app is ideally installed by the machine tool builders and CNC builders, and used by the machine users, which are distributed in every manufacturing sector. It is best applied to new high quality equipment, despite being also applicable on already installed machines The EU production of machine tools is 25 billion Euros every year. A large share of this production is high quality equipment, since volume production equipment is usually coming from Asian market. This share is considered the possible market for this application.
z3DGenerator	zA2.6	• Have a 3D scanner • The cloud of points needs to meet the technology constraints (in terms of volume and format)	Any 3D scanner for every type of application should be able to send data to this zApp. The resulting model can be applied to any CAD program. Given this extremely wide applicability, the market for this application is not restricted to anti-collision systems. Potentially it could be used in every scanning

			application to extract a model from a cloud of coordinates.
zXRAY Monitor + zXRAY Analytics	zA3.1 zA3.2	• Assure the connection with XRAY/CT machine • Manage the automatization of different used software packages (XRAY/CT scanning, 3D rendering, component analyse & measurement)	A software automatisation layer could be part of additional software package provided with XRAY machines. The global industrial x-ray inspection system market has grown at a sustained CAGR of 5.7% in the period 2012-2017 and amounted to USD 526 million in the year 2017.
zVisualManager	zA3.9	• Receive PLC data from working stations either with the database of zLineData (zA3.8) and the zDriver (zA3.7) or with a similar solution • Include any monitoring app (zA3.10-15)	The Visual Management and Reporting application is the visualization tool for an entire assembly line. Since this component is suitable to include production control apps, maintenance alarms, power management systems, cycle time monitors, material stock trackers and databases, it is suitable for a wide range of assembly lines. The market of this type of application is compatible with the SCADA systems market. The global SCADA market size was valued at $ 27,900 million in 2016, and is projected to reach at $ 41,603 million by 2023, growing at a CAGR of 6.00% from 2017 to 2023. The EU share of this market is today about 21%.
zSteelSheetWidthMonitor	zA4.1	• Have a digital camera • Steel sheet production	This zApp can be integrated into the steel tube production machine to monitor whether the steel sheet has been well cut and the width is correct. In 2017 the sheet metal fabrication services market was worth 4.4 Bn $.
zVerticalWeldMonitor	zA4.3	• Have a digital camera • Automatic welding system	This App can be integrated into the steel tube production machine to monitor whether the steel tube has been produced with zero-defects. Its application goes beyond the steel tube production and could be applicable to any automatic welding system. The welding products market size in 2015 was 1.1 Bn $, of which 35% is considered to be automatic equipment.
zShapeTubeMonitor	zA4.4	• Have a digital camera • Steel tubes production equipment	This App can be integrated into the steel tube production machine to monitor whether the shape of the steel tube is in conformity with the parameters defined, that are a

			standard. This zApp could be applicable to any tube and pipe production machine.
zThicknessMonitor + zDetectDefects	zA4.6	• Have the required hardware installed (sensor) • Stone cutting machine	This App can be integrated into the stone cutting machine to monitor the thickness and the quality of the stone slab.
zRemoteQC	zA4.10	• The process requires measuring at least one parameter related to product quality, at the end of production at the supplier and upon reception at the Client • Quality results per lot or part supplied need to be stored and made available to various authorised stakeholders • Quality control results of a given material or supply need to be associated to its corresponding production process and process controls	The zApp addresses a typical process in any construction project. This sector represented, in 2017, ca.9% of EU-28 GDP, at € 1384 billion. The zRemoteQC has, however, the potential to be used in any manufacturing sector where materials quality control in the supply chain is relevant (from production process at the supplier, through to reception quality control at the client / user).

Figure 90: zApps exploitability beyond the companies working in the use-cases

4 Conclusions

This deliverable provides a generic understanding of the different scenarios of applicability and requirements of the selected use-cases in the respective fields. It provides several meaningful examples of specific needs in these scenarios that ZDMP can address.

For each use case, the document presents the current workflow and data management. The approach to quality control, production logistics, and maintenance policies is, in most cases, not integrated and relies more on the workers experience than on actual data. On-line inspection tools for understanding, monitoring and real-time fault diagnosis of machine operations and product quality are missing. Systems for collecting and storing heterogeneous data are not deployed. Whenever maintenance, production and quality systems are adopted, they are often products or services of different organisations that cannot communicate with each other.

The industrial partners participating to each use-case then describe the future business flow and data flow including ZDMP platform and applications. A change desired by all parties is a larger involvement of the supply chain actors and a better traceability of the product quality. In the described scenarios the access to quality data is often shared, partly or completely, among the suppliers and customers.

It is also expressed a general desire for the adoption and exploitation of condition-based and learning approaches for correlating the machine degradation state to the workpiece quality.

The deliverable provides a list of suggested applications (zApps) to be built with the blocks and services in ZDMP. The description of the applications includes the constraints due to compatibility and companies' regulations, the desired usability and a set of desired non-technological features.

All the proposed KPIs to evaluate the impact of the introduction of the zApps in the described application scenarios, along with the methods to assess them, will be further elaborated and specified in D9.1 and D10.1.

This deliverable will be exploited for the design of ZDMP requirements (D4.1) and mock-ups (D4.2).

Annex A: History

Document History	
Versions	V0.1.x: • Draft produced by editor V0.2.x: • Inclusion of all user partners • Upgrade of chapter 1 • First complete draft V0.3.x: • Upgrade of chapter 3 • Addition of cross-domain validator section • Requests from technical partners at M4 plenary meeting V0.4.x: • Feedback from first Reviewer V0.5.x: • Feedback from second Reviewer V0.6.x: • Feedback from third Reviewer V1.00: • EU Submitted Version V1.10: • Resubmission following review 1
Contributions	FIDIA: • Raffaele Ricatto • Alessia Focareta UNIN: • Jose Ferreira MRHS: • Mariano López-Catalá • Eduardo Vila HSD • Paolo Galli FORM: • Jindrich Svoboda FORD: • José Maria Monasor Hernndez CONS • Paulo Rodrigues CONT: • Petru Demian • Horia Petrila EXTE: • Juan José Gabilondo ITI • Santiago Cáceres Elvira IKER: • Eduardo Saiz • Oscar Salgado ICE • Stuart Campbell – Formal Reviewer 3 TUT • Ronal Rodriquez SIVECO • Mircea Vasile – Formal Reviewer 1

	• Monica Florea SAG • Verena Henrich, SAG

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