ZDMP: Zero Defects Manufacturing Platform

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

EU ID: D029: Cross Platform Analysis Document (M18) - Vs: 1.0A

ZDMP ID: D2.6a

POST SUBMISSION VERSION – SEE HISTORY & Section 0.10

Deliverable Lead and Editor: Martin Heß, SAG

Contributing Partners: ITI, SOFT

Date: 2020-06

Dissemination: Public

Status: EU Approved

Abstract

This document assesses which 3rd party platforms are relevant for interlinking with ZDMP and which platform features could be interlinked for mutual benefits. The foundation of this assessment forms an analysis of the business and technical aspects that comes into play when interlinking ZDMP with a 3rd party platform.

Grant Agreement: 825631

Document Status

Deliverable Lead	Martin Heß, SAG
Internal Reviewer 1	Petru Demian, CONT
Internal Reviewer 2	Paulo Malheiro, PTM
Internal Reviewer 3	Stuart Campbell, ICE
Type	Deliverable
Work Package	WP2: Business Challenge: Vision, Market, Use Cases, and Interlinking
ID	D029: Cross Platform Analysis Document (M18)
Due Date	2020-06
Delivery Date	2020-06
Status	EU Approved

Project Partners:

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

Executive Summary

Inter-platform linking and the interoperability with external platforms for mutual benefit is a central aspect of the ZDMP project. For example, this enables external platforms to extend their functionality through the cross-platform marketing of ZDMP Apps (zApps) and other ZDMP features. Similarly, the functionalities and data sources provided by external platforms could be useful for the users of ZDMP.

The purpose of this document is to assess, which 3rd party platforms are relevant for interlinking with ZDMP and which platform features could be interlinked for mutual benefit. The foundation of this assessment forms an analysis of the business and technical aspects that comes into play when interlinking ZDMP with a 3rd party platform. This includes, for example, which applications could be cross-marketed to extend the functionality of ZDMP, and the interlinked platforms and which technical requirements must be fulfilled to enable the cross-platform usage of these applications.

This document represents the first iteration of a living document for further release at M30 and M48. The initial version focuses on a selection of widely used commercial and open source 3rd party platforms and platforms developed in other research projects, which are thematically related to ZDMP. Later iterations may extend this initial study with additional platforms and revisit the findings of this iteration based on the current development state of the ZDMP platform.

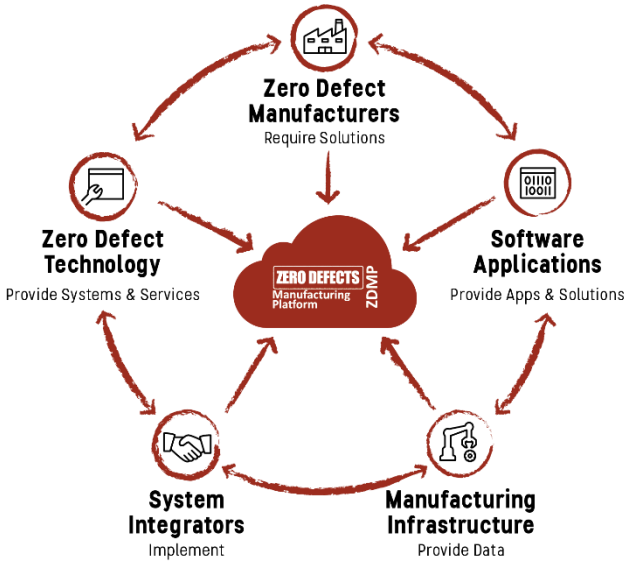
Table of Contents

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 (ie 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 "D29 (Cross Platform Analysis Document (M18))" is to analyse the feasibility and mutual benefits of inter-linking ZDMP with other 3rd party platforms. From a business perspective, this includes an overview of 3rd party platforms that could be interlinked with ZDMP and an analysis of which platform features should be interlinked for mutual benefits. At a technical level, this document investigates the technical requirements for interlinking the platforms. This includes, for example, relevant transport protocols, runtime environments and security aspects such as user authentication/authorisation and data encryption.

Specifically, the DOA states the following regarding this Deliverable:

O2.6 To assess and interlink with other platforms at a business/community level

T2.6	**Cross Platform Analysis and Inter-Linking**			**SAG**	**M16-18, 28-30, 46-48**
D029 D030 D041	Cross Platform Analysis Document	R	PU	D029 D030 D041	Cross Platform Analysis Document
N/A)	Cross Platform Inter-Linking	N/A - Activity	PU	N/A)	Cross Platform Inter-Linking

This task will analyse the feasibility of inter-linking ZDMP with other computing platforms both at the business and technical level. At a business level, this task also provisions for physical on-going cooperation activity and at a technical level it can provide an implementation framework for T6.5 (Inter-platform Interoperability). Business cooperation will investigate, for example, which common Apps could be made and marketed across platforms or how mutual advantage of platform assets and interconnections could be taken. At a technical level it will analyse the feasibility of using ZDMP software applications in other computing platforms. Specific software characteristics, for example if it will need to be built, or if it will run directly on a platform without special preparation, will be considered. Common or standard Interpreters or run-time packages belonging to different platforms will be reviewed as well as the application programming interfaces (API) associated to these platforms. This will also act as a relevant input for building the ZDMP SDK (WP6) and for the development of zero-defect applications to be performed in WP9/10.

0.3 Target Audience

The Project Handbook aims primarily at project participants although in addition it provides the European Commission (including appointed Independent experts) with an overview of ZDMP's plans for interlinking with other 3rd party platforms.

0.4 Deliverable Context

This document's relationship to other documents is as follows:

Primary Preceding documents:

- **D024: Industry Scenarios and Use Cases:** Specifies and describes the zApps that are being developed in ZDMP. The functionality of these zApps represent ZDMP features that could be interlinked with other platforms

- **D026: Regulation and Trustworthy System / D027: Regulation and Trustworthy System:** Cover legal issues related to data management in the project, which can affect the interlinking of ZDMP with other platforms
- **D033: Market and Business Opportunity Analysis:** Provides an overview of Digital Manufacturing Platform trends, which contains references to 3rd party platforms that could be relevant for interlinking with ZDMP
- **D050: User Mock-ups:** Provides further details about the planned zApps through mock-ups
- **D051: Global Architecture Specification:** Describes the high-level functionality of the ZDMP components, which form the ZDMP features that could be interlinked with other platforms
- **D053: Function Specification:** Contains further details about the functionalities of the ZDMP components and zApps, ie ZDMP features that could be interlinked with other platforms

Primary Dependant documents:

- **D135: Ecosystem Establishment and Market Building:** Deals with the furtherance of the ZDMP market. It analyses and demonstrates the market and its extinctions in terms of usability by the end users and their engagement.

0.5 Document Structure

This deliverable is broken down into the following sections:

- **Section 1: Overview:** This section provides an overview of the interlinking study presented in this document
- **Section 2: Interlinking Study:** This section presents the results of the interlinking study through detailed analysis reports for each assessed platform
- **Section 3: Summary:** This section summarises the findings of the interlinking study and rates the interlinking feasibility of the analysed platforms on a higher level
- **Section 4: Conclusion:** This section concludes the document and suggests 3rd party platforms for interlinking with ZDMP

- **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. It can be used by external parties to obtain insights into the project activities regarding the interlinking of 3rd party platforms and projects with ZDMP.

0.7 Document Dependencies

This document is part of an iteration of living deliverables. This first version is delivered in M18 and covers an initial interlinking study comprising 10 3rd platforms. The second version is scheduled for M30. It revisits the findings of the initial study based on the development state of the ZDMP platform in M30 and introduces additional platform

analyses if necessary. The third and final iteration scheduled for M48 completes the document.

0.8 Glossary and Abbreviations

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

0.9 External Annexes and Supporting Documents

- None

0.10 Reading Notes

- None

0.11 Document Updates

- None

1 Overview

Inter-platform linking and the interoperability with external platforms for mutual benefits is a central aspect of the ZDMP project. For example, this enables external platforms to extend their functionality through the cross-platform marketing of ZDMP Apps (zApps) and other ZDMP features. Likewise, the functionalities and data sources provided by external platforms could be useful for the users of ZDMP.

The purpose of this document is therefore to assess, which 3rd party platforms are relevant for interlinking with ZDMP and which platform features should be interlinked for mutual benefits. The basis of this assessment forms an analysis of the interlinking aspects in the context of specific 3rd party platforms, both on a business level and from a technical point of view.

This section provides a general overview of the features provided by ZDMP and 3rd party platforms that may be interesting for interlinking ZDMP and the external platform. It discusses potential problems and issues that may affect the interlinking study and the interlinking of ZDMP with other platforms in general. The rest of this section presents the list of 3rd party platforms assessed in the interlinking study and the structure of the analysis reports.

1.1 ZDMP Features

The features provided by ZDMP can be separated into the following categories:

- **zComponents**: The first category comprises of the ZDMP components. These components are an integral part of the ZDMP platform and provide core functionalities that can be used by other sources. The T5.6 AI-Analytics Run-time, for example, implements the functionality to deploy and run machine learning models using real-time production data to predict potential errors. In the context of interlinking ZDMP with another platform, these ZDMP components could be used by an external platform to extend its core functionality, eg with new AI capabilities, which can be used by multiple applications running on the platform.
- **zApps**: These represent the second category of ZDMP features. They typically provide a specific functionality, tailored for a specific purpose, or use case. Thereby they make use of ZDMP platform components such as the T5.6 AI-Analytics Run-time and other zApps. For instance, the zAnomalyDetector ingests real-time data from multiple sources and performs a multivariate analysis to detect system anomalies. Since zApps usually provide a specific functionality, they could be useful for external platforms to satisfy more specific needs. For example, a 3rd party platform could extend its application domain to the Stone Processing domain by interlinking with ZDMP and buying the Stone Processing zApps from the ZDMP Marketplace.

1.1.1 Planned ZDMP Features

With the currently planned zApps and platform components, ZDMP provides a large set of features that could be used by another platform. However, not all features are suited for interlinking or may necessarily provide a real benefit for external platforms.

For instance, some features may be already available at the 3rd party platform or cover use cases that are not relevant for the external platform’s application domain. Also, some of the planned zApps are part of bigger applications and cannot be used standalone making

them irrelevant for interlinking. Similarly, some zComponents are not relevant for interlinking because it either does not make sense to use these components from another platform or it is just not feasible to implement an interlink without rebuilding or adapting the target platform to a large extent. The orchestration component is such an example.

A comprehensive list of ZDMP features (zApps and ZDMP components), which could be relevant for interlinking with other platforms is shown in Figure 1.The last column provides a general rating of a feature in terms of its potential usefulness for other platforms using the following schema:

Rating	Explanation
🟢	Very useful for interlinking. Supports multiple use cases
🟢	Useful for interlinking. Can be adapted to other use cases with some effort
🟡	Less useful for interlinking. Not adaptable to other use cases or provides no real benefit

Feature	Description	
Automotive domain zApps		
zAnomalyDetector	Enables machine Learning -based quality control. Useful for platforms that do not provide model-based anomaly detection on their own	🟢
zDigitalTwin	Enables monitoring and simulation of IoT devices. Useful for platforms that do not provide a Digital Twin functionality out-of-the-box	🟢
zAlarm	Enables event-based alerts. Not especially useful to others because most platforms have their own alerting system	🟡
Machine Tools domain zApps		
zMachineMonitor / zMachineAnalytics	Monitoring tool for machines and equipment that detects deviations from standard work conditions. General purpose zApp that may improve a platforms' equipment monitoring	🟢
zParameterMonitor / zParameterAnalytics	ML-based optimisation of machine parameters. General purpose zApp, useful for all IIoT platforms	🟢
z3DGenerator	Generates a 3D model from a point cloud. Use case specific zApp that could be interesting for platforms that work with 3D scanners	🟢
Electronics domain zApps		
zXRAYMonitor / zXRAYAnalytics	Detection of deviations using X-Ray images and historical data. Could be useful to extend the functionality of platforms that already support X-Ray scanner devices	🟢
zFeedbackMFT / zArtificialIntelligenceMFT	AI-supported Manual Final Testing for electronics. Only applicable to the electronics use case	🟡
zFeedbackAFT / zArtificialIntelligenceAFT	AI-supported Automatic Final Testing for electronics. Only applicable to the electronics use case	🟡
zProductVersionControl	Material selection dialog for products to ensure correct material usage and easy switch over of materials. Useful for other platforms depending on the use case	🟢
zAutomaticCall	Inventory & maintenance manager which automatically calls support. Useful addition for platform w/o dedicated inventory and maintenance management	🟢
zPowerManager	Automatically switches a line into power save mode when work is completed. Usefulness for other platforms depends on their existing features and the use case	🟢

Feature	Description	
zCycleTimeManager	Cycle time controller. Usefulness for other platforms depends on their existing features and the use case	
zAutomaticMaterialOrdering	Automatic material ordering. Useful addition to other platforms for automating logistics processes	
zDataArchiveControl	Archive & retention rule controller. Same functionality should already be available on other platforms	
Steel Processing domain zApps		
zSteelSheetWidthMonitor	Detects deviating material widths. Useful for other platforms depending on the use case	
zHorizontalWeldDetection	Detects horizontal welds. Useful for other platforms depending on the use case	
zVerticalWeldMonitor	Detects vertical welds. Useful for other platforms depending on the use case	
zShapeTubeMonitor	Detects shape deviations of tubes. Useful for other platforms depending on the use case	
Stone Processing domain zApps		
zWiresMonitor	Detects defect stone cutting wires. Only applicable to this particular use case	
zThicknessMonitor	Monitors the thickness of a material. Useful for other platforms depending on the use case	
zWornOutBladeDectection	Detects defect blades. Useful for other platforms depending on the use case	
zTilesConformity	Final testing for stone slabs. Only applicable to this particular use case	
Construction domain zApps		
zRemoteQC	Allows to access, archive, and assess quality control documents and detection of potential errors. Useful for other platforms depending on the use case	
zRescheduler	Work rescheduling to compensate for supply delivery delays. Useful addition for platforms w/o dedicated work rescheduling mechanisms	
zMaterialTracker / zMaterialID	Documents the usage of a specific material at a specific location and provides links to other information regarding the material. Useful addition for platforms w/o dedicated material tracking	
Other ZDMP Features		
ZDMP Application Builder & SDK	Quick and easy development of new customized zApps. Useful for other platforms that do not support an easy App Development on their own	
zApp Marketplace	Allows to sell and request zApps for specific purposes. Allows external platform to extend their App portfolio	
Human Collaboration	Supports human collaboration and HCI through exchange of information, audio/video calls, factory map visualisations etc. Useful addition for other platforms that do not provide human collaboration features on their own	
Prediction and Optimisation Designer	Quick and easy development of applications that rely on ML-models to solve problems. Useful addition for other platforms that do not provide visual modelling for machine learning models	
Security Designer	Automated and systematic identification of risks for the system. Useful addition for other platforms that do not provide a similar feature	

Figure 1: List of potentially relevant features for interlinking ZDMP with other platforms

1.1.2 High-level ZDMP Features

As identified in Figure 1, several zApps serve a specific use case or provide similar functionalities for different use cases. When taking the adaptability of these zApps to additional use cases and their overall interlinking rating into account, the list of full features can be classified into the high-level feature set shown in Figure 2. It allows an easier understanding for non-project staff.

The list of ZDMP features is always the same throughout all reports. It shows the ZDMP features in a “condensed” form to keep the table simple and more comprehensible. “Condensed” means, for example, that there are several zApps planned for the detection of shape deviations (width, height, shape, etc) depending on the use case. But it does not make sense to rate each shape deviation zApp separately because they all perform essentially the same function.

Also note that the table does not include all ZDMP (core) components because interlinking often does not make sense as discussed in Section 1.1.1. For example, there is no reason for an external platform to use ZDMP’s orchestration component for its own services and there is also no interface planned for this kind of interconnection in T6.5. Nevertheless, the components will take an indirect role when implementing the interlink but they are no “interlinking features” for an external platform per se.

ZDMP Feature	Covered zApps and zComponents
ML-based quality control	zAnomalyDetector, zProductVersionControl, zRemoteQC
Digital Twins: Monitoring and simulation of IoT devices	zDigitalTwin
Inventory and maintenance management	zAutomaticCall
Automatic material ordering	zAutomaticMaterialOrdering
(Automatic) work rescheduling	zRescheduler
Machine monitoring and parameter optimisation	zMachineMonitor, zMachineAnalytics, zParameterMonitor, zParameterAnalytics, zPowerManager, zCycleTimeManager
Manual and automatic Final Testing	zFeedbackMFT, zArtificialIntelligenceMFT, zFeedbackAFT, zArtificialIntelligenceAFT
Detection of product shape deviations	zSteelSheetWidthMonitor, zShapeTubeMonitor, zThicknessMonitor, zTilesConformity, zHorizontalWeldDetection, zVerticalWeldMonitor, zXRAYMonitor, zXRAYAnalytics, z3DGenerator
Detection of machine parts defects	zWiresMonitor, zWornOutBladeDectection
Material tracking and documentation of material specifications and usage including location tags	zMaterialTracker, zMaterialID
Quick and easy development of new customized zApps	ZDMP Application Builder & SDK
Automated and systematic identification of risks via Security Designer	Security Designer
Quick and easy development of applications that uses models to solve problems	Prediction and Optimisation Designer
Marketplace for requesting and selling custom applications	zApp Marketplace
Support for human collaboration and HCI (messaging, information exchange, factory visualisations)	Human Collaboration

Figure 2: High-level feature set of the ZDMP platform

1.2 External Platform Features

Interlinking external platforms with ZDMP also provides several benefits for ZDMP and its users. For instance, this includes access to additional IoT devices, applications, data sources and other core systems such as Manufacturing Execution Systems (MES) and Enterprise Resource Planning (ERP). Interlinking ZDMP with a platform a user already uses could increase the user's interest in also employing ZDMP and would provide him with a holistic experience.

1.2.1 External IoT Devices

Some 3rd party platforms may provide connectivity to IoT devices, which are not fully supported by ZDMP. This aspect is especially interesting if a device is needed to be accessible by ZDMP but only provides native support for a specific platform. For instance, this could be the case when the vendor of the IoT device provides its own IoT platform. By interlinking ZDMP with this platform, ZDMP users could also interact with the device and work with its data from within ZDMP.

1.2.2 External Applications and Marketplaces

Even though ZDMP provides users with the ability to develop their own zApps with the Application Builder, the required functionality could already be implemented in another application running on another platform. Interlinking ZDMP with this platform would allow a ZDMP user to just use the external application rather than developing a new zApp. Moreover, interlinking the ZDMP marketplace with the marketplace of an external platform would yield the benefits of cross-platform marketing of zApps.

1.2.3 External Data Sources

Another relevant feature for ZDMP provided by external platforms is their data. By interlinking the external platform with ZDMP, zApps could make use of the data generated and collected by the external platform. For instance, the data could be a used for the creation of machine learning models running on ZDMP.

1.3 Interlinking Issues

Interlinking ZDMP with other platforms to exchange data or to provide cross-platform access to platform-dependent applications can be very difficult and yield several problems and issues: Missing interfaces, Non-standard protocols and data formats, incompatible security concepts, lack of documentation, changing platform functionalities and specifications, and legal issues.

1.3.1 Missing Interfaces

First, a target platform must provide the interfaces to enable external sources to access its services and resources. If the necessary interfaces do not exist, any interlinking ambitions are often immediately condemned to failure. This is especially true if a 3rd party platform provider does not see a real benefit to justify the additional efforts to implement the missing interfaces. In case of interlinking with an open source platform, there is at least the chance to implement a plugin to realise the missing interfaces. However, this requires a fundamental understanding of the platform's code basis and typically a lot of development and implementation work.

1.3.2 Non-standard Protocols and Data Formats

Another problem that may affect the interlinking success are proprietary or non-standard communication protocols and data formats. To exchange data and information, both platforms need to talk the same language.

Not all target platforms may use standardised protocols and data formats such as MQTT and JSON. In this case, ZDMP would have to implement additional functionalities to transform the ZDMP-internal data representation into the format supported by the 3rd party platform and vice versa. This can be very time consuming and is prone to errors. Additionally, some data properties used by the 3rd party platform such as custom data types could be not fully compatible to ZDMP. Transforming this data thus could result in information loss.

But even if the platform uses standard protocols and data formats this does not necessarily means that the 3rd party implementation of this standard fully follows the corresponding specifications. Some platforms may not implement all features of a specification or may use some custom variations.

However, in the case of ZDMP, the Data Harmonisation component is available to manage the data (content) aspects of transformation which could be used to do this operation.

1.3.3 Incompatible Security Concepts

Interacting with a platform typically requires an authentication and an authorisation step. This may cause additional problems and issues for the interlinking process. For instance, the 3rd party platform may use an authentication mechanism, which is not directly supported by ZDMP. In this case, ZDMP would have to implement additional authentication mechanisms to realise the interconnection.

Moreover, the target platform may implement a security model, which cannot be fully mapped with ZDMP's internal security model. The target platform may also restrict access to specific resources, eg when accessing resources from external systems. This may result in some functionalities not being available limiting the capability of the cross-platform interconnection.

1.3.4 Lack of Documentation

The documentation of a platform's interfaces, file formats, and backend system is another crucial aspect for the interlinking process. Without adequate documentation, developers will encounter difficulties when using the target platform's interfaces and processing the data.

Solving these issues can be very time consuming, for example when reverse engineering is needed. Hence, a complete lack of documentation, especially when working with proprietary data formats, may impede the entire interlinking process.

Notably, a lack of documentation may also affect the significance of the findings presented in this interlinking study. Without sufficient details about a target platform, the interlinking benefits and especially the technical requirements cannot be assessed in full detail and often interesting facilities to link to are those that are rather 'protective' of providing even limited information except if you are already a paid customer.

1.3.5 Changing Platform Functionalities and Specifications

The functionality and specification of platforms may change over time. This may result in only partially working or even fully broken cross-platform interconnections. Also, some changes may remove entire features, which are fundamental for the interconnection. In these cases, the interconnection often cannot be restored. This may impact existing purchases / deployments of ZDMP components and zApps and so care should be taken, from marketing, technical interfaces, through to legal agreements, that the implications and mitigations are obvious / available.

1.3.6 Legal Issues

In addition to the technical issues outlined above, interlinking ZDMP with other platforms may also be affected by legal issues. The data exchanged between ZDMP and another platform, for example, may include personal data, which is subject to GPDR. Similarly, some data may be subject to IPR. Interlinking ZDMP with other platforms thus requires the implementation of mechanisms to protect this data against unauthorised access.

Further details regarding legal issues related to data management are discussed in the D026 and D027 documents (Regulation and Trustworthy System / Data Management Document).

1.4 Platform Selection

There are numerous platforms and solutions available to date, which theoretically could be interlinked with ZDMP for mutual benefits. Analysing all of them with respect to mutual benefits and technical feasibility of interlinking them with ZDMP, however, goes beyond the scope of this study. In this iteration of the T2.6 document, a selection of widely used or emerging platforms is focused upon including several open-source ones that are related to ZDMP's application domain.

Platform Logo[1]	Description
ADAMOS	ADAMOS is an open and manufacturer-neutral Industrial Internet of Things (IIoT) platform focused on the mechanical engineering industry. This application domain in combination with the ADAMOS partner network and its application marketplace makes it an interesting candidate for interlinking with ZDMP **Why selected:** Cross-platform marketing of zApps, large industry user base, access to partner network

[1] All logos shown in this table are courtesy of the corresponding platforms' websites.

Platform Logo[1]	Description
	MindSphere is one of the largest and most widely used IoT platforms in several domains such as manufacturing industry and energy management. It provides native support for Siemens IoT devices and features an application marketplace. Interlinking MindSphere with ZDMP would allow to complement the features of both platforms and would create an opportunity for cross-platform marketing of zApps **Why selected:** Cross-platform marketing of zApps, large industry user base, access to Siemens devices, access to energy management functions
	The Bosch IoT Suite is also one of the largest and most widely used IoT platforms in several application areas. An interconnection with ZDMP could open a new market for zApps with a large user base, while Bosch IoT users would benefit from additional functionality provided by ZDMP and its zApps **Why selected:** Cross-platform marketing of zApps, large industry user base, access to Bosch devices
	toii® is an Industrial Internet of Things (IIoT) platform developed by Thyssen Krupp. It provides native support for Thyssen Krupp devices including some legacy devices. An interconnection could enable ZDMP users to get access to these devices **Why selected:** Cross-platform marketing of ZDMP features, access to legacy Thyssen Krupp devices, offers opto-electric capabilities
	FIWARE For Industry is an Open Source platform for Smart Industries. It has a large user base and can be adapted to multiple use cases. An interconnection with ZDMP could allow both platforms to complement their capabilities and enable ZDMP to cross-market its zApps **Why selected:** Cross-platform marketing of ZDMP features, large industry user base, smart industry community access
	vf-OS is an open Operating System for Virtual Factories deployed in a cloud platform. It is one of the foundation technologies upon which ZDMP platform is built, making the interconnection with ZDMP a natural choice **Why selected:** Foundation Technology of ZDMP, Cross-platform marketing of ZDMP features

Platform Logo[1]	Description
	The eFactory project realises a federated smart factory ecosystem by interlinking smart factory platforms through an open and interoperable Data Spine. Integrating ZDMP and eFactory would allow ZDMP to access resources provided by multiple platforms and vice versa in a standardised way. Hence, the integration with eFactory is a planned action in the T6.5 Inter-platform Interoperability task **Why selected:** Cross-platform marketing of ZDMP features, access to multiple platforms, standardised interface for inter-platform interlinking
	DISRUPT is a cloud-based platform focusing on the manufacturing industry. It provides tools to increase flexibility and efficiency of production which could be interesting for ZDMP such as a Decision Support Toolkit and plant floor simulator **Why selected:** Cross-platform marketing of ZDMP features, access to functions complementing ZDMP features
	BEinCPPS is an Innovation Action in the field of Cyber-Physical Production Systems (CPPS). It provides an open source platform and covers some use cases, which are related to Zero Defects Manufacturing **Why selected:** Cross-platform marketing of ZDMP features, access to functions complementing ZDMP features

Figure 3: Selection of 3rd party platforms analysed in the interlinking study

1.5 Interlinking Report Templates

The results and findings of the interlinking study are presented in the form of reports for each individually analysed target 3rd party platform. Each report comprises the following sections:

- **Platform Profile:** This section contains a table showing characteristics about the target platform such as its application domain, launch date, and license model:

Example Platform	
Logo	
Website	www.example-platform.com
Domain	Electronics

Launch Date	1st January 2020
License	Commercial
Company	Example GmbH Street 123 12345 City Country

- **Description:** This section provides a general description of the platform and its background
- **Interlinking at a Business Level:** This section covers the mutual benefits of interlinking ZDMP and the target 3rd party platform on a business level. It presents an overview of the features of the platform and discusses, which of the ZDMP features, and which external platform features, are relevant for the respective platform counterpart and thus could be interlinked. The table below illustrates this with some fictitious examples of the "XYZ" ecosystem and where the column "Interlinking benefit" give a textual description of the usefulness of a feature for interlinking, while the coloured icons provide a visual rating according to the schema listed thereafter. A summary of this discussion including interlinking ratings for the individual features is shown as a table in Section 3.2:

Feature	Interlinking benefit	
ZDMP Features		
ML-based quality control	Useful extension for Example Platform's Analytics module, which does not feature Machine Learning	
Digital Twins: Monitoring and simulation of IoT devices	Monitoring is already covered by module X of the Example Platform but there is no simulation functionality	
Inventory and maintenance management	Already covered by Example Platform	
….etc		
External Platform feature (XYZ ecosystem)		
Access to devices connected to the Example Platform and their device data	Useful for ZDMP users that make use of both platforms	
Access to Example Platform Marketplace	Cross-platform marketing of zApps	
Example Platform Analytics	Already covered by ZDMP components	
….etc		

Key to above table	
Useful feature for interlinking	
Partially useful feature for interlinking	
Not useful for interlinking	

- **Interlinking at a Technical Level:** This part of the report deals with the technical requirements that must be fulfilled to interlink the features proposed in the business level analysis. It discusses, for instance, which protocols are needed to interconnect ZDMP with the target platform and which problems may arise when interlinking both platforms in general

2 Interlinking Study

This section presents the analysis reports for the selection of 3rd party platforms that have been assessed in the first iteration of this document. The first part of the reports covers the commercial platforms. The second part presents the findings for the analysed open-source platforms.

2.1 ADAMOS

2.1.1 Platform Profile

ADAMOS	
Logo	ADAMOS
Website	www.adamos.com
Domain	IIoT, Mechanical Engineering
Launch Date	1st October 2017
License	Commercial
Company	ADAMOS GmbH Landwehrstraße 55 64293 Darmstadt Germany

2.1.2 Description

ADAMOS (ADAptive Manufacturing Open Solutions) is an open and manufacturer-neutral Industrial Internet of Things (IIoT) platform focused on the mechanical engineering industry. It was founded as a strategic alliance of global market leaders in machinery and plant engineering as well as IT and software such as DMG Mori AG, Dürr AG, Carl Zeiss AG, ASM PT, and Software AG.

ADAMOS' core capabilities are the networking and management of devices on the Internet, data visualisation and real-time analysis, and the provisioning of application logic. Thereby it features a horizontal integration of applications from different vendors, which provide ADAMOS users with a seamless user experience. Moreover, ADAMOS provides an application marketplace to enable its users to search and buy applications based on their specific needs.

Besides these technical capabilities, ADAMOS provides a partner network to enable the joint development of new applications and to improve the cooperation in the mechanical and plant engineering industry to exploit opportunities and synergies.

2.1.3 Interlinking at a Business Level

As outlined above, ADAMOS has a large user base from the mechanical and plant engineering industry and cooperates with global market leaders and other partners in this sector. This community in combination with ADAMOS' application marketplace makes interlinking ADAMOS with ZDMP an interesting option from a business point of view.

It could enable ZDMP to establish partnerships in the mechanical engineering domain to exchange information and resources and would allow ZDMP to cross-market its zApps and other features to a broader range of users. ADAMOS in turn would benefit from applications specially tailored to the needs of Zero Defects Manufacturing. For these reasons, the interlinking with the ADAMOS platform is already a planned action in the ZDMP Task T6.5 Inter-platform Interoperability.

Other capabilities of the ADAMOS platform that should be considered are:

- **Device Management:** ADAMOS enables the management of machines and other devices over the Internet. It provides plug and play connectivity for several IoT gateway solutions and supports numerous machines, industrial connectivity, and LPWAN protocols
- **Remote Control:** Devices and machines registered in ADAMOS can be remotely controlled via built-in Remote Shell or Remote Access service. The former option provides a browser-based terminal emulation to issues commands to the connected assets. The latter allows users to access machines' graphical user interfaces through the browser based on VNC technology
- **Firmware and Configuration Management:** ADAMOS has a built-in firmware and software repository. It allows users to roll-out updates and pre-defined configurations to individual devices or to devices groups using bulk operations
- **Device Simulation:** ADAMOS enables users to simulate the behaviour of devices by creating artificial devices. Thereby the built-in simulator uses a playlist to send out predefined messages, which can be configured through predefined templates and a template editor
- **Data Visualisation**: ADAMOS provides browser-based data visualisation via predefined or custom dashboards. Additional browser-based visualisation tools can be implemented using the Web App Development SDK
- **Advanced Streaming Analytics**: ADAMOS allows to define smart rules to perform certain actions on occurrence of specific events such as sending alarms. More complex rules and other streaming analytics functions, for example using Machine Learning models, can be implemented with a native Event Processing Language
- **App Factory:** The ADAMOS App Factory describes the development environment for the members of the ADAMOS partner network. It provides applications and projects jointly developed by the ADAMOS partners that are tailored to specific use cases. For example, the Digital Workpiece application assigns data from different machines to a specific workpiece across several production steps
- **ADAMOS Hub:** The ADAMOS Hub provides users with manufacturer-independent access to applications from different providers. Through the horizontal integration of applications, the Hub enables users to manage these different applications and data at a central location. This also includes the management of data access rights

The benefits of interlinking these features with ZDMP and those provided by ZDMP with ADAMOS are discussed in Figure 4:

Feature	Interlinking benefit	
ZDMP Features		
ML-based quality control	Already covered by ADAMOS	🔴
Digital Twins: Monitoring and simulation of IoT devices	Interesting for interlinking even though ADAMOS already comes with built-in simulation functionalities. However, ADAMOS does not provide a complete Digital Twin functionality	🟢
Inventory and maintenance management	Already covered by applications available in the ADAMOS App Factor	🔴
Automatic material ordering	Interesting for interlinking because this feature is not provided by the ADAMOS	🟢
(Automatic) work rescheduling	Interesting for interlinking because this feature is not provided by the ADAMOS	🟢
Machine monitoring and parameter optimisation	Partially covered by ADAMOS through the device management and the web-based dashboards. However, ADAMOS does not feature parameter optimisation	🟡
Manual and automatic Final Testing	Not directly covered by ADAMOS. Potentially interesting for interlinking depending on the use case	🟢
Detection of product shape deviations	Not directly covered by ADAMOS. Potentially interesting for interlinking depending on the use case	🟢
Detection of machine parts defects	Already covered by applications available in the ADAMOS App Factor but may be useful depending on the use case	🟡
Material tracking and documentation of material specifications and usage including location tags	Already covered by applications available in the ADAMOS App Factor but may be useful depending on the use case	🟡
Quick and easy development of new customized zApps	Partially covered by ADAMOS through SDKs and APIs. However, there is no graphical Application Builder available.	🟡
Automated and systematic identification of risks via Security Designer	Interesting for interlinking because this feature is not provided by the ADAMOS	🟢
Quick and easy development of applications that uses models to solve problems.	Interesting for interlinking because ADAMOS does not provide the functionality to create Machine Learning models. It only allows to use existing models	🟢
Marketplace for requesting and selling custom applications	Already covered by ADAMOS	🔴
Support for human collaboration and HCI (messaging, information exchange, factory visualisations)	Interesting for interlinking because ADAMOS does not provide communication channels such as video and audio conferencing. However, some aspects are covered by ADAMOS through custom web-based dashboards	🟢
ADAMOS Features		
Access to devices connected to the ADAMOS platform and their device data	Useful for ZDMP users that make use of both platforms	🟢
Access to the ADAMOS Store / Hub (once publicly available)	Cross-platform marketing of zApps	🟢
App Factory	Access to applications and solutions specifically tailored to specific use cases and machines used for mechanical engineering	🟢
Remote Device Control	Already covered by ZDMP through Cumulocity	🔴

Feature	Interlinking benefit	
Firmware and Configuration Management	Already covered by ZDMP through Cumulocity	
Device Simulation	Already covered by ZDMP through the Digital Twin zApps and components	
Data Visualisation	Very useful because ZDMP does not provide a dedicated data visualisation module	
Advanced Streaming Analytics	Already covered by ZDMP	

Figure 4: Feature ratings for the interlinking of ZDMP and ADAMOS

2.1.4 Interlinking at a Technical Level

The ADAMOS Core represents the heart of the ADAMOS platform from a technical perspective. It consists of the following components or services, which are technically relevant for interlinking the platform with ZDMP:

- **Data Management:** ADAMOS implements a pre-defined and well-documented domain model for inventory objects such as machines and devices as well as transactional data such as sensor readings, events, and operations. It ensures the semantic meaning of the data. For example, differently labelled and encoded temperature measurements are mapped to a generic temperature type using Celsius as temperature unit. The domain model can also be extended if necessary. ADAMOS offers public and documented REST and MQTT APIs to enable to external systems to access the data. Through this, accessing and sending data as well as implementing a data transformation pipeline to map the data models of both platforms should be generally feasible with low to medium effort
- **Device Management:** As outlined above, the device management of the ADAMOS platforms supports many machine and industrial connectivity protocols. This includes, for example, OPC-UA, Canbus, and Modbus. Additionally, it allows to connect additional assets using LPWAN protocols such as LoRa and SIGFOX. These protocols are also supported by ZDMP. Interlinking devices connected to ZDMP and ADAMOS thus should be feasible if the devices use protocols supported by both platforms. Otherwise, a protocol transformation pipeline must be implemented, which may require some effort
- **Data Visualisation:** ADAMOS realises data visualisation via web-based dashboards, which are built-in the ADAMOS Web UI, and custom Web Apps. The latter can be developed using a Web App Development SDK provided by ADAMOS using web technologies such as Angular and React. Since the dashboards are an integral part of the ADAMOS UI, the only way of interlinking them with ZDMP would be to embed the ADAMOS UI in ZDMP's Portal. In contrast, the custom Web Apps are running as microservices on the ADAMOS platform using the platform APIs. Hence, these apps could be theoretically ported to ZDMP and its Application Run-Time. However, the success of this operation strongly depends on the individual requirements and attributes of the Web Apps
- **ADAMOS Hub / Store:** The ADAMOS Hub including the ADAMOS application store is currently in beta testing phase and not publicly available. An official market release is planned for the fourth quarter of 2020. For these reasons, there is also no technical documentation publicly available. At the time of writing, it is thus not possible to assess the feasibility of interlinking the marketplaces of ZDMP and ADAMOS

2.2 MindSphere

2.2.1 Platform Profile

MindSphere	
Logo	
Website	www.mindsphere.io
Domain	IoT
Launch Date	2016
License	Commercial
Company	Siemens Aktiengesellschaft Werner-von-Siemens-Straße 1 80333 Munich Germany

2.2.2 Description

MindSphere is an open cloud based IoT Operating System provided by Siemens. It is vendor-neutral and aims in connecting products, plants, systems, and machines from several domains.

The core functions of MindSphere are the networking of assets, the management, monitoring and analyses of these assets, and (real-time) data analytics including event processing and data visualisation. These functions are provided to users as Software-as-a-Service (SaaS) featuring a web-based user interface.

Additionally, these core capabilities can be extended through custom applications. This includes, for instance, applications that provide specialised functions for specific domains such as logistics, energy management or the health sector. Developers can create applications using MindSphere's APIs and development tools and offer them on a dedicated app marketplace called MindSphere Store.

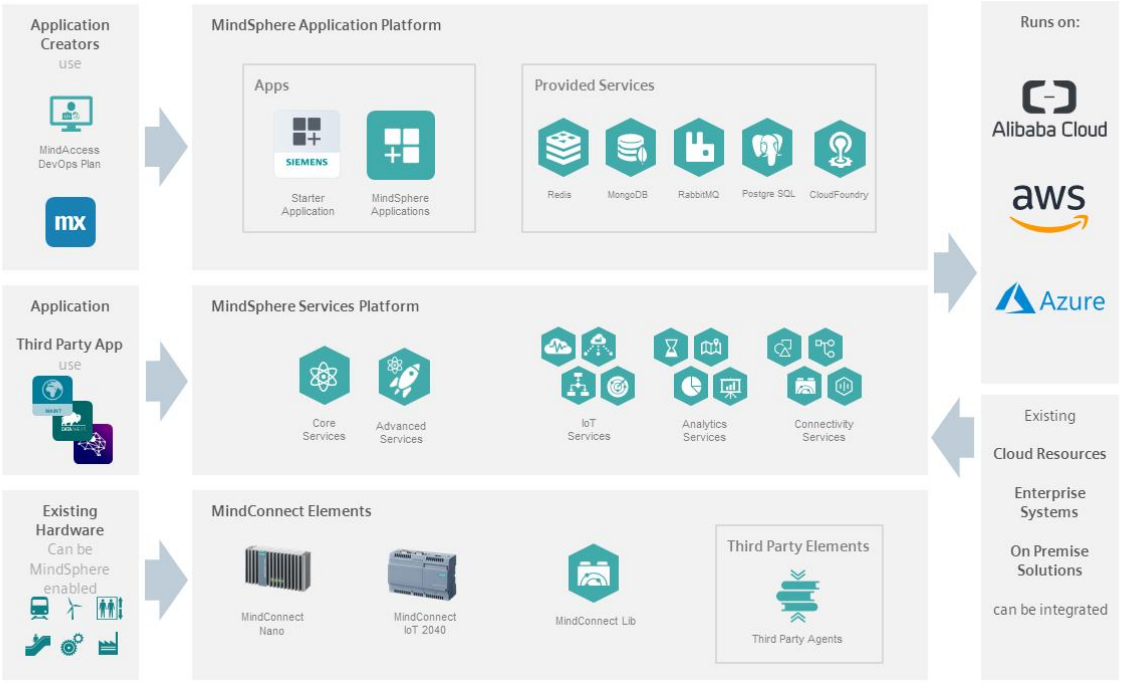


Figure 5: MindSphere architecture[2] (© Siemens)

2.2.3 Interlinking at a Business Level

MindSphere is one of the largest and most widely used IoT platforms. It has customers from several domains such as manufacturing, energy, finance, and health. Additionally, MindSphere is an open platform and provides an app marketplace, which allows third party developers to create and sell custom applications. Interlinking ZDMP with MindSphere thus could yield several benefits for both platforms.

From ZDMP's perspective, getting access to the MindSphere Store would enable ZDMP to sell zApps to a broader range of customers. Additionally, an interconnection would enable ZDMP users to make use of both platforms and provide them with additional functionality beyond the scope of Zero Defects Manufacturing such as energy management functions.

From the MindSphere side, an interconnection would allow the platform to extend its product portfolio with dedicated Zero Defects Manufacturing Applications, which are currently not available in this form in the MindSphere Store. This could be especially interesting for the industry users of MindSphere.

Other capabilities of Siemens' platform that should be considered are:

- **Device Connectivity:** MindSphere's MindConnect Elements provides a software library to connect devices and other systems to the MindSphere platform. Additionally, it provides plug and play support for different Siemens hardware
- **Remote Device Management:** MindSphere enables the remote management and monitoring of devices. This includes desktop sharing and control functionalities such as file transfer and session recording for troubleshooting and resolving technical issues

[2] Source: developer.mindsphere.io/concepts/concept-architecture.html last visited 27th May 2020

- **Energy Management:** MindSphere provides dedicated applications for energy management. They allow to monitor the power consumption and energy costs as well as the CO^2 emissions of the connected devices and machines
- **Data visualisation:** MindSphere and the applications available at the MindSphere Store provide several data visualisations served as Web Applications and the ability to create custom visualisations. This includes generic visualisations, for example for KPI and measurement monitoring, and specialised visualisation such as network and factory visualisations

The benefits of interlinking these features with ZDMP and those provided by ZDMP with MindSphere are discussed in Figure 6:

Feature	Interlinking benefit	
ZDMP Features		
ML-based quality control	Already covered by MindSphere	
Digital Twins: Monitoring and simulation of IoT devices	Already covered by MindSphere through applications offered at the MindSphere Store	
Inventory and maintenance management	Already covered by MindSphere and applications offered at the MindSphere Store	
Automatic material ordering	Interesting for interlinking because this feature is not directly provided by MindSphere	
(Automatic) work rescheduling	Interesting for interlinking because this feature is not directly provided by MindSphere	
Machine monitoring and parameter optimisation	Partially covered by applications available at the MindSphere Store but the automatic parameter optimisation would be a useful feature for interlinking	
Manual and automatic Final Testing	Not directly covered by MindSphere. Potentially interesting for interlinking depending on the use case	
Detection of product shape deviations	Not directly covered by MindSphere. Potentially interesting for interlinking depending on the use case	
Detection of machine parts defects	Partially covered by MindSphere and MindSphere Store applications. Specialised zApps for specific machine types could be nevertheless interesting for interlinking	
Material tracking and documentation of material specifications and usage including location tags	Not covered by the MindSphere and its applications. Potentially interesting for interlinking depending on the use case	
Quick and easy development of new customized zApps	Partially covered by MindSphere through the SDKs and APIs provided by MindSphere	
Automated and systematic identification of risks via Security Designer	Partially covered by MindSphere Store applications. However, interlinking would allow MindSphere to complement its existing functionality	
Quick and easy development of applications that uses models to solve problems.	Already covered by MindSphere	
Marketplace for requesting and selling custom applications	Already covered by MindSphere	
Support for human collaboration and HCI (messaging, information exchange, factory visualisations)	Partially covered by MindSphere and applications available at the MindSphere Store (eg factory visualisations). However, MindSphere does not provide communication channels such as video and audio conferencing	
MindSphere Features		
Access to devices connected to the MindSphere platform and their device data	Useful for ZDMP users that make use of both platforms	

Feature	Interlinking benefit	
Access to the MindSphere Store	Cross-platform marketing of zApps and access to additional applications (eg for energy management) to complement ZDMP's functionality	
Remote Devices Management	Already covered by ZDMP components	
Energy Management	Very useful because ZDMP only provides basic energy management capabilities through the zApp zPowerManager	
Data Visualisation	Very useful because ZDMP does not provide a dedicated data visualisation module	

Figure 6: Feature interlinking ratings for ZDMP and MindSphere

2.2.4 Interlinking at a Technical Level

The following MindSphere components are technically relevant for interlinking the platform with ZDMP:

- **MindSphere Connect Elements:** As outlined above, Siemens offers several gateway devices that provide plug and play support for MindSphere. Additional devices can be connected via 3rd party or custom software agents, which function as a middleware between the devices and the MindSphere platform. These software agents can be implemented using the Open Edge Device Kit provided by MindSphere. Alternatively, devices can be integrated through the MindConnect IoT Extension, which supports standard protocols such as MQTT, REST, and OPC-UA. Interlinking ZDMP device data with MindSphere and vice versa thus could be realised using standard already used by ZDMP.
- **MindSphere Services Platform:** The MindSphere Services Platform is the principal component for accessing the services provided by MindSphere. This includes, for example, services for querying device data and accessing events, which are relevant for developing applications based on MindSphere features. These services can be called through public APIs, which are either HTTP-bases or messaging-based. The HTTP-based APIs come with an OpenAPI specification, which describes the operations supported by the API. This is similar to ZDMP and allows to integrate MindSphere APIs directly through the T6.4 Services API Management. The messaging-based APIs come with an AsyncAPI specification. It describes the topics and messages supported by a service. These APIs could be interlinked with ZDMP through its T6.4 Message Bus component. However, if the exposed services provide all information required for interlinking a specific ZDMP or MindSphere platform feature must be individually checked for each feature.

2.3 Bosch IoT Suite

2.3.1 Platform Profile

Bosch IoT Suite	
Logo	
Website	www.bosch-iot-suite.com
Domain	IoT, Manufacturing industry
Launch Date	2016 (PaaS)
License	Commercial
Company	Bosch.IO GmbH Ullsteinstrasse 128 12109 Berlin Germany

2.3.2 Description

The Bosch IoT Suite is a cloud-ready software package for the development of Internet of Things (IoT) services and applications. It is part of the Bosch IoT Cloud and provides an open IoT platform for various application areas which can be classified as Platform-as-a-Service (PaaS). The core functions of the Bosch IoT Suite are the networking of devices on the Internet and the provision of application logic.

For developers, the Bosch IoT Suite provides tools that enable them to quickly implement various requirements. The tools offer functions for networking devices and users and for developing, implementing, and operating highly scalable applications on this basis. This also includes functions for the easy and reliable management of devices, machines, and gateways. Access is provided via a secure access management system. Other functions of the suite include the execution of software rollouts, the connection of services and third-party systems, and the analysis of data.

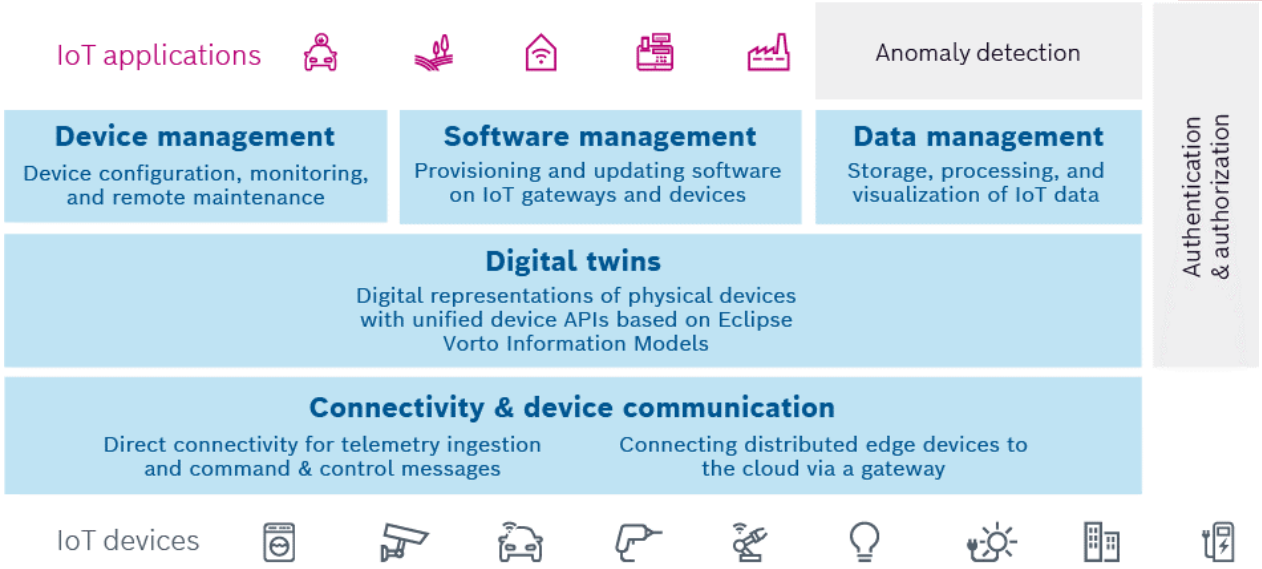


Figure 7: Bosch IoT Suite capabilities[3] (© Bosch)

2.3.3 Interlinking at a Business Level

Bosch IoT Suite is one of the largest and most widely used IoT platforms due to the presence of Bosch in the marketplace. From a business perspective, this makes interlinking the platform with ZDMP interesting. On the one hand, an interconnection could open a new market for zApps with a large user base. On the other hand, Bosch IoT users would benefit from the additional functionality provided by ZDMP and its zApps.

Other capabilities of Bosch's platform that should be considered include:

- **Device Connectivity:** The Bosch IoT Hub provides out-of-the-box connectivity for a large set of devices and supports standard protocols such as MQTT, AMQP 1.0, HTTP and LoRaWan
- **Digital Twin Management:** The Bosch IoT Things component provides a managed inventory of digital twins for IoT device assets. It allows to register, read, and update digital twins through open APIs. Additionally, it enables to query the digital twins according to their dynamic properties and static attributes and provides a fine-grained access control
- **Remote Device Management:** The Bosch IoT Remote Manager enables users to manage their devices throughout the device life cycle. It features the remote configuration of devices, device monitoring and the remote maintenance of devices
- **Managed Software Rollouts:** The Bosch IoT Rollouts component enables the management and rollout of software updates at a large scale such as firmware updates for IoT devices
- **Data analytics and anomaly detection:** The Bosch IoT Analytics service provides the functionality to detect anomalies based on historical data. Other features include data visualisation and semantic enrichment and aggregation of data
- **Data processing and visualisation:** The Bosch IoT Insights service enables users to process and visualise data in several ways. This includes, for example, the filtering, aggregation, decoding, and normalisation of data

[3] Source: www.bosch-iot-suite.com/capabilities-bosch-iot-suite last visited 27th May 2020

The benefits of interlinking these features with ZDMP and those provided by ZDMP with the Bosch IoT platform are discussed in the following table:

Feature	Interlinking benefit	
ZDMP Features		
ML-based quality control	Already covered by Bosch IoT	
Digital Twins: Monitoring and simulation of IoT devices	Already covered by Bosch IoT	
Inventory and maintenance management	Already covered by Bosch IoT	
Automatic material ordering	Interesting for interlinking because this feature is not provided by the Bosch IoT platform	
(Automatic) work rescheduling	Interesting for interlinking because this feature is not provided by the Bosch IoT platform	
Machine monitoring and parameter optimisation	Interesting for interlinking even though some features may already be partially covered by Bosch IoT through its device management and Bosch IoT insights. Especially the parameter optimisation could be useful.	
Manual and automatic Final Testing	Not covered by the Bosch IoT platform. Potentially interesting for interlinking depending on the use case.	
Detection of product shape deviations	Not covered by the Bosch IoT platform. Potentially interesting for interlinking depending on the use case.	
Detection of machine parts defects	Interesting for interlinking because this feature is only Partly covered by the device management of the Bosch IoT platform	
Material tracking and documentation of material specifications and usage including location tags	Not covered by the Bosch IoT platform. Potentially interesting for interlinking depending on the use case.	
Quick and easy development of new customized zApps	Partially covered by Bosch IoT through the SDKs and APIs provided by the Bosch IoT Suite. However, there is no dedicated Application Builder available.	
Automated and systematic identification of risks via Security Designer	Interesting for interlinking because this feature is not provided by the Bosch IoT platform	
Quick and easy development of applications that uses models to solve problems.	Already covered by Bosch IoT	
Marketplace for requesting and selling custom applications	Already covered by Bosch IoT	
Support for human collaboration and HCI (messaging, information exchange, factory visualisations)	Not covered by the Bosch IoT platform. Potentially interesting for interlinking depending on the use case.	
Bosch IoT Suite features		
Access to devices connected to Bosch's platform and their device data	Useful for ZDMP users that make use of both platforms	
Access to the Bosch IoT Marketplace	Cross-platform marketing of zApps	
Bosch IoT Analytics	Already covered by ZDMP components	
Bosch IoT Things (Digital Twins)	Core functionality already covered by ZDMP components. However, this would allow ZDMP users to use Bosch IoT digital twins in ZDMP, too	
Bosch IoT Rollouts (Managed firmware rollouts)	Already covered by ZDMP through Cumulocity	
Bosch IoT Insights	Very useful because ZDMP does not provide a dedicated data visualisation module	
Bosch IoT Remote Manager	Already covered by ZDMP through Cumulocity	

Figure 8: Feature interlinking ratings for ZDMP and Bosch IoT Suite

2.3.4 Interlinking at a Technical Level

The Bosch IoT Suite consists of several components or services, which are technically relevant for interlinking the platform with ZDMP:

- **Bosch IoT Hub:** The Hub is the core component of the Bosch IoT Suite for connecting IoT devices and builds upon an Open Source Software stack. It allows to send data from devices to the Hub and vice versa through standard protocols such as MQTT, AMQP 1.0, HTTP, and LoRaWan. This includes telemetry and event data as well as commands to trigger actions on the devices. External applications can get access to this data and send commands through a standard AMQP 1.0 messaging endpoint. This functionality provides a straightforward way to interlink ZDMP with Bosch IoT. ZDMP resources could be connected to Bosch's platform by "simulating" devices and sending data via one of the supported protocols. The integration of devices in the opposite direction can be established by implementing a ZDMP module that connects to the AMQP 1.0 endpoint provided by the Bosch IoT Hub
- **Bosch IoT Things:** Things component provides a managed inventory of digital twins for IoT device assets. External applications can interact with the digital twins via HTTP JSON APIs or by using connection-based methods such as WebSocket, AMQP and MQTT. There are also Java and JavaScript clients available enabling a convenient usage of the APIs. Additionally, Bosch IoT Things is based on the open source project Eclipse Ditto, which thus could also be used in ZDMP.
  Based on this wide range of connection possibilities and the usage of Eclipse Ditto, the integration of digital twin models provided by Bosch's platform with ZDMP should be straightforward to implement
- **Bosch IoT Insights:** The Insights service provides several ways to process and visualise data. New data can be ingested via a standard HTTPS API, which should make the technical interlinking part straightforward. The data processed with Insights can also be exported to standard formats such as JSON and CSV
- **Bosch IoT Marketplace:** The Marketplace allows customers to buy end-to-end IoT software and solutions that are based on the features of the Bosch IoT platform. In theory, external developers should be able to develop applications and sell them on the Marketplace. However, the technical details are unknown because of the lack of documentation available. The technical feasibility of interlinking the Bosch IoT Marketplace with ZDMP thus cannot be assessed now. This aspect will be revisited in a later iteration of this document if additional information becomes available

2.4 Thyssen Krupp toii

2.4.1 Platform Profile

Thyssen Krupp toii	
Logo	toii®
Website	www.thyssenkrupp-materials-iot.com
Domain	Energy and Utilities, Oil and Gas, Manufacturing, Industrial Automation
Launch Date	2017
License	Commercial
Company	Thyssenkrupp Materials IoT GmbH Thyssenkrupp Allee 1 45143 Essen Germany

2.4.2 Description

The Industrial Internet of Things (IIoT) platform toii® was developed to efficiently network all technical devices in a factory. Since Thyssen Krupp is a manufacturing company with a long history in building machines which includes older machines that may only be connected by legacy protocols of ThyssenKrupp.

There is only a limited amount of information available in public resources. This means also, even if this is a commercial platform, it is not listed in the business analysts' rankings of Forrester or Gartner. The same is true for research publications regarding market analysis. It is likely this is the case since the market activities of toii are bundled in the Thyssenkrupp Materials IoT GmbH, a 100% daughter company of the Thyssen Krupp group, only since May 2019[4].

However, ThyssenKrupp is a huge international player with a long history and high market volume on industrial engineering. The toii platform belongs to the "Material Services" line of Thyssen Krupp having a revenue of 13.9 billion euros in the business year 2018/19 and about 250.000 customers.

For many of their machines the toii platform may be the only possibility to connect those legacy system to a software platform at all. For example, the platform offers a module using opto-electric sensors to fetch control light signals of a machine where a detailed knowledge of that machine is essential.

[4] See www.thyssenkrupp.com/en/newsroom/press-releases/thyssenkrupp-materials-services-spin-off-paves-the-way-for-industry-4-0--15680.html last visited 25th of May 2020

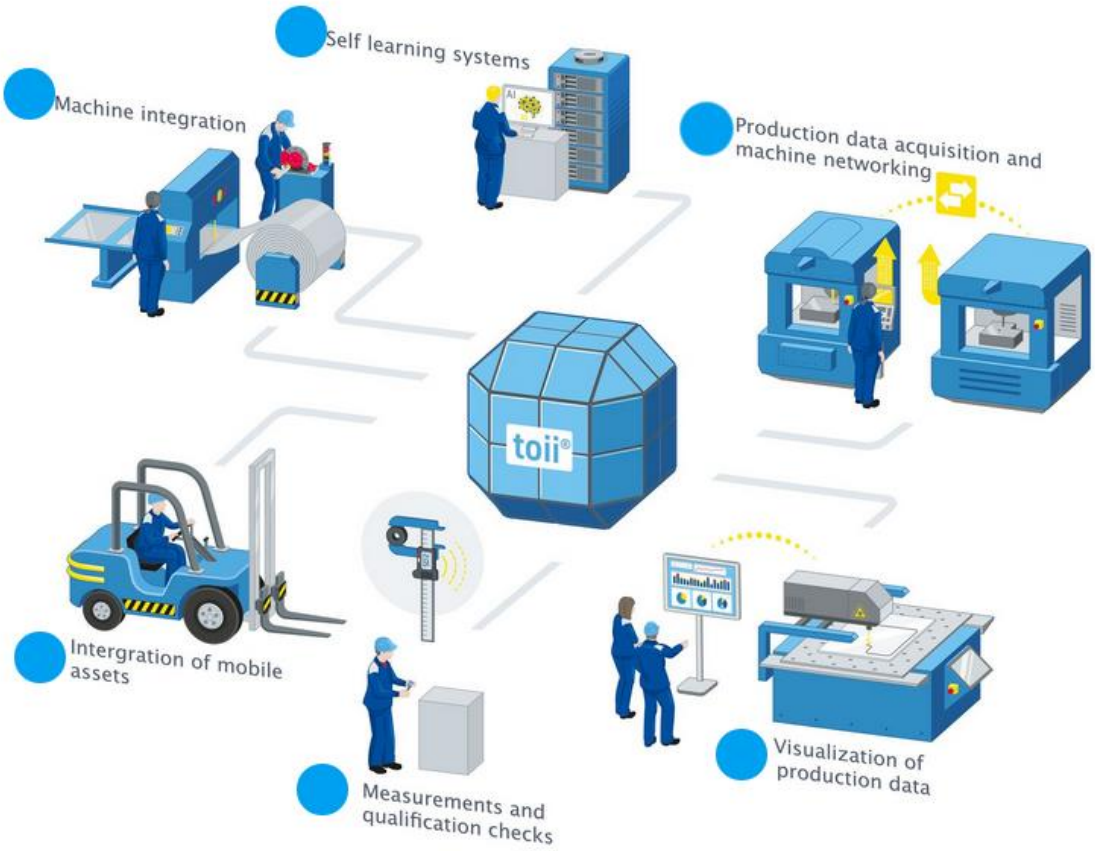


Figure 9: Thyssen Krupp toii overview[5] (©ThyssenKrupp)

2.4.3 Interlinking at a Business Level

The toii platform consists of a set of core modules that fulfil different purposes:

- **toii®.Collect:** This module collects the data from the machines. This includes simple devices without programmable logic controllers (PLCs) or older machines with user-defined interfaces to modern, IoT-capable machines and robots
- **toii®.Lights:** Light signals indicate the status of the analogue machine and convert it into digital data. The status of all machines can be viewed in a web browser and the data obtained can be used for initial analyses. A simple, effective, and cost-effective way to get started
- **toii®.Fusion:** Interprets and visualizes machine data collected via toii®.Collect, toii®.PDC, or toii®.Lights. The data are combined with external data and the manufacturing efficiency is visualized on dashboards. All relevant data can be viewed in any web browser
- **toii®.Control:** The integration module for the automation and control of all machines. The module automates processes and controls data flows in the factory. In this way, production-relevant data can be automatically and directly imported into the machine control system in real time without any delays

[5] Source: www.thyssenkrupp-materials-iot.com/en/toii.html last visited 27th May 2020

- **toii®.Think:** Smart data applications. This includes predictive maintenance algorithms supporting machine maintenance requirements, optimize production efficiency with the help of edge analytics, develop individualized processes or help to generate new business models with the data obtained
- **toii®.PDC:** The mobile module of the toii® platform. Data from permanently installed terminals or mobile devices is transferred to the platform via WLAN
- **toii®.Integrator:** External systems (third-party systems) such as manufacturing execution (MES) or enterprise resource planning (ERP) systems can be connected
- **Security:** Supports technologies such as TLS, OPC UA, or network architecture such as VLA

The benefits of interlinking these features with ZDMP and those provided by ZDMP with the toii platform are discussed in Figure 10:

Feature	Interlinking benefit	
ZDMP Features		
ML-based quality control	Already covered by toii platform for their own machines	🔴
Digital Twins: Monitoring and simulation of IoT devices	Interesting for interlinking because this feature is not provided by the toii platform	🟢
Inventory and maintenance management	Already covered by toii platform	🔴
Automatic material ordering	Interesting for interlinking even though some features may already be partially covered by toii platform through its Control module	🟢
(Automatic) work rescheduling	Interesting for interlinking even though some features may already be partially covered by toii platform through its Control module	🟢
Machine monitoring and parameter optimisation	Interesting for interlinking even though some features may already be partially covered by toii platform through its Control and Think module	🟡
Manual and automatic Final Testing	Not covered by the toii platform. Potentially interesting for interlinking depending on the use case	🟢
Detection of product shape deviations	Not covered by the toii platform. Potentially interesting for interlinking depending on the use case	🟢
Detection of machine parts defects	Interesting for interlinking because this feature is only partly covered by the Think module of the toii platform	🟢
Material tracking and documentation of material specifications and usage including location tags	Not covered by the toii platform. Potentially interesting for interlinking depending on the use case	🟢
Quick and easy development of new customized zApps	No public documentation available. However, there is no dedicated Application Builder mentioned in the concepts and overview	🟡
Automated and systematic identification of risks via Security Designer	Interesting for interlinking because this feature is not provided by the toii platform	🟢
Quick and easy development of applications that uses models to solve problems	Not covered by the toii platform. Potentially interesting for interlinking depending on the use case	🟢
Marketplace for requesting and selling custom applications	Not covered by the toii platform. Potentially interesting for interlinking depending on the use case since they may focus on existing customers	🟡
Support for human collaboration and HCI (messaging, information exchange, factory visualisations)	Not covered by the toii platform. Potentially interesting for interlinking depending on the use case	🟢
Toii Features		

Feature	Interlinking benefit	
Access to devices connected to toiis's platform and their device data toii®.Collect	Useful for ZDMP users that make use of both platforms	
toii®.Lights	Very useful because ZDMP does not provide a dedicated module with opto-electric capabilities	
toii®.Fusion	Core functionality already covered by ZDMP components	
toii®.Control	Very useful because ZDMP does not provide a dedicated module to access a machine control system. Depends on the use case (mainly for Thyssen Krupp machines)	
toii®.Think	Already covered by ZDMP data analyses and machine learning components	
toii®.PDC	Already covered by ZDMP depending on the use case	
toii®.Integrator	Already covered by ZDMP (mainly tasks 5.1 and 6.5)	

Figure 10: Feature interlinking ratings for ZDMP and toii

2.4.4 Interlinking at a Technical Level

The ThyssenKrupp toii consists of several modules. In the centre of the system is a so called "omnichannel" module. Since more detailed information is not available it can only be assumed that this is a messaging system with unclear capabilities beside the support of OPC UA. All other technical information is not available on public resources.

2.5 FIWARE SMART INDUSTRY

2.5.1 Platform Profile

FIWARE SMART INDUSTRY	
Logo	
Website	https://www.fiware.org/community/smart-industry
Domain	Cyber-Physical Production Systems
Launch Date	2016 (FIWARE Foundation)
License	Open Source
Company	FIWARE Foundation Franklinstrasse 13A 10587 Berlin Germany

2.5.2 Description

FIWARE is an initiative of the European Union that, since 2012, promotes an Open Source platform for the development of applications and solutions directly linked, at that time, to the Smart City. After the successful and well-received finalisation of the project, the FIWARE Foundation was created in 2016 to enable the platform to continue beyond its initial source of funding from the European Union and the project partners.

Today, several companies are supporting it through the association. The Community of FIWARE technology adopters has grown significantly especially due to start ups and SMEs. There is a win-win situation to make its open source component ecosystem be very active, thus making this platform one of the most extended and used in Europe and even the world.

This is all based in the FIWARE framework of open source components, which can be integrated together and with other third-party platform components to build smart solutions faster and easier. It has shown its potential in diverse fields and applications. For example, there is a FIWARE Community for Smart Industry, which is the one of special interest for interlinking with ZDMP. At its core, the FIWARE NGSI API enables the integration of components and provides the interoperability and replication of these smart solutions. FIWARE Smart Industry is compliant with existing industry architectures such as the RAMI4.0 (Reference Architecture Model Industrie 4.0), the IDS (Industrial Data Space) Reference Architecture or the IIRA (Industrial Internet Consortium Reference Architecture), which are also references also for ZDMP project.

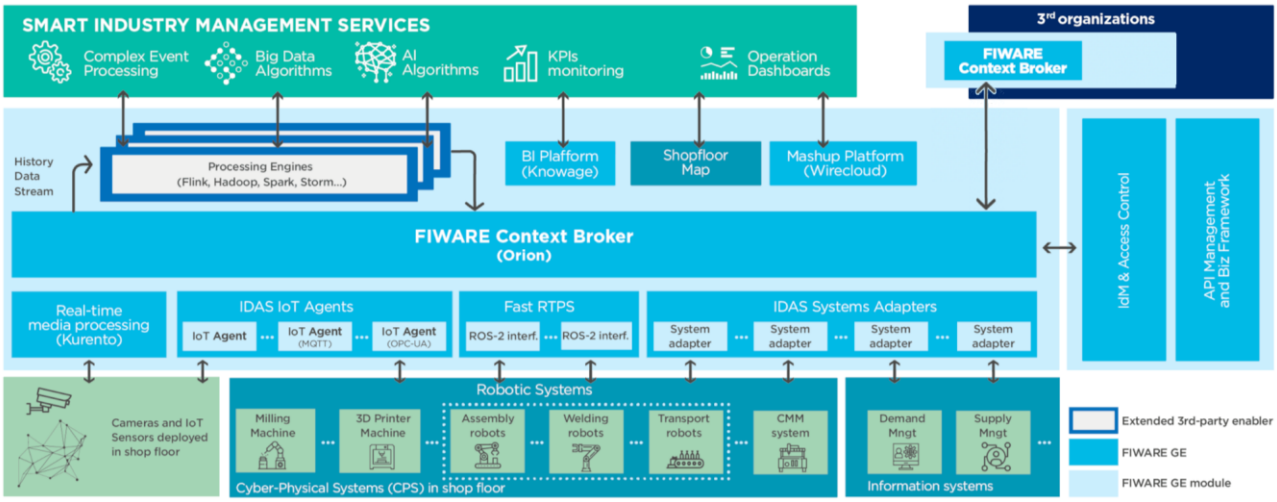


Figure 11 Architecture and modules of FIWARE Smart Industry[6] (© FIWARE)

2.5.3 Interlinking at a Business Level

Because the FIWARE modules and components cover from top to bottom a whole Industry 4.0 application, and therefore is customizable to fit any use case, it is difficult to find any aspect where there is no direct overlapping with ZDMP.

Under the umbrella of FIWARE Smart Industry, some relevant success stories that depict the possible relation with ZDMP project are:

- **Zero Defect Manufacturing:** Secure data exchange between factory machines: improving predictive maintenance and enabling Data Economy concept
- **MASAI:** Data integration software for manufacturing systems for collecting data from a variety of IoT devices in the manufacturing domain not entirely covered by existing proprietary solutions
- **Facility Enabler:** An Internet of Everything platform, for collecting, integrating, and analysing scattered data coming from heterogeneous data providers. It enables multi-domain data integration, harmonisation, and multi-device interoperability
- **Pd.M. in Automotive:** A solution for Predictive Maintenance allowing continuous monitoring of the welding process, where data is then processed by analysis algorithms, to detect unexpected parameter behaviour and optimize maintenance interventions
- **FIWOO:** IoT platform based on FIWARE components. It can integrate devices and sensors and make decisions and solve complex problems based on that data and context information. Used in the food manufacturing industry, in the context of FLEXINFOOD project

Nevertheless, FIWARE states a part of its success is the integration with third parties' platforms, so it is a viable candidate to find missing or complementary features for ZDMP. FIWARE community is also open to integrating new open source modules coming from other activities such as project into their ecosystem. This means that an open collaboration can be established if ZDMP is able to develop promising software modules that can help FIWARE broaden its catalogue, and vice versa, ZDMP can use modules that allow going the extra mile and providing features that were not initially in the scope of the project or supported by any current use case. Of special interest for FIWARE can be the designer tools, for instance to design apps that use ZDMP models running with data processing

[6] Source: www.fiware.org/community/smart-industry last visited 27th May 2020

software that is also compatible with FIWARE, allowing to produce KPI dashboards or visualizations that can be reused.

Feature	Interlinking benefit	
ZDMP Features		
ML-based quality control	Can add improved multivariate analysis algorithms to the FIWARE Smart Industry Management services repository	🟢
Digital Twins: Monitoring and simulation of IoT devices	Can add improved Digital Twin monitoring to the FIWARE Smart Industry Management services repository (Operation dashboards and KPI)	🟢
Inventory and maintenance management	Probably not needed as FIWARE has several modules, and ZDMP related apps and modules would need many modifications	🔴
Automatic material ordering	Probably not needed as FIWARE has several modules, and ZDMP related apps and modules would need many modifications	🔴
(Automatic) work rescheduling	Task Management can be of interest for the Smart Industry Management services repository	🟢
Machine monitoring and parameter optimisation	Machine monitoring may need an IoT Agent compatible with Data Acquisition from ZDMP	🟢
Manual and automatic Final Testing	Can add value to potential use cases	🟢
Detection of product shape deviations	Already a successful use case in FIWARE Smart Industry	🔴
Detection of machine parts defects	Already a successful use case in FIWARE Smart Industry	🔴
Material tracking and documentation of material specifications and usage including location tags	Orion Context Broker, at the core of FIWARE platform, can store metadata and context information for each item. Being a core module, it is not likely to be changed without significant impact	🔴
Quick and easy development of new customized zApps	Designer and development tools can be a good addition to FIWARE	🟢
Automated and systematic identification of risks via Security Designer	Designer and development tools can be a good addition to FIWARE	🟢
Quick and easy development of applications that uses models to solve problems.	Designer and development tools can be a good addition to FIWARE	🟢
Marketplace for requesting and selling custom applications	FIWARE has its own catalogue for open source modules, although other parts are commercial (the modules developed by third parties that contain / support part of the platform)	🔴
Support for human collaboration and HCI (messaging, information exchange, factory visualisations)	Can add improved Factory visualisation to the FIWARE Smart Industry Management services repository and add human collaboration enhanced module	🟢
FIWARE Features		
IDAS IoT Agents and System Adapters	These modules provide the necessary translation of protocols to integrate different data sources into Orion. Since Orion is not used in ZDMP, these modules are not relevant for interlinking	🔴
FIWARE Context Broker Orion	This core module manages the messaging and data bus, this is the exchange of data and metadata. It is a replacement of many ZDMP components and using it would require many technical changes	🔴
Access Control and API Management	Replacement of similar ZDMP components, but already compatible with Orion	🔴
BI platform, Mashup	These modules can help develop zApps faster and compatible with FIWARE	🟢

Feature	Interlinking benefit	
Processing engines from third parties' adapters	ZDMP uses some of these processing engines. Therefore, by using these adapters, zApps can be integrated with Orion easily	
Big Data, AI algorithms, KPI monitoring, etc	These algorithms can be used to process data from ZDMP sources and use cases, enhancing the catalogue of analysis tools of the zApps	

Figure 12: Feature interlinking ratings for ZDMP and FIWARE

2.5.4 Interlinking at a Technical Level

As can be seen in Figure 11, at the core of FIWARE applications lays the Orion Context Broker. As stated in the FIWARE documentation, Orion is the main and only mandatory component of any platform or solution developed with FIWARE. It provides a fundamental function: Managing context information, consulting it, and updating it. This means this module takes care of all the data exchange in the platform, and therefore at some point, an enabler that can connect with Orion is needed to use FIWARE solutions.

The following are technically relevant for interlinking:

- **Communication protocols:** The communication with Orion is based on the NGSI protocol, which means these adapters take the form of X-to-NGSI or NGSI-to-X translators. Nevertheless, the catalogue of available enablers covers a wide range of protocol requirements: MQTT and OPC-UA are usable, and it is not difficult to adapt REST APIs to NGSI (which is, basically, another REST API), which can help reduce the effort needed to connect devices, machines and other systems on the floor plant. On the other hand, the scenario is similar for the processing engines, just that they play the part of consumers of data instead of sources. Several process engines can be integrated already with Orion with third party enablers, such as the popular Spark or Hadoop, but also by using enablers to translate
- **Information Models**: The NGSI protocol also specifies how data needs to be modelled in the payload exchanged. This defines the data and metadata format, and each enabler or the previous bullet needs to address this differently. This technical challenge should be addressed by the T5.3 Data Harmonisation task
- **Data source discovery and catalogue:** On the core of ZDMP platform field level, the T5.1 Data Acquisition hosts a Device and data source manager, where zApps and users are able to search for data sources lists and required parameters to query those sources. This is also true for FIWARE, which means that devices should register also, in case Orion is needed, through the different enablers and the device manager used by FIWARE
- **Security aspects:** ZDMP integrates security at its core, by using the Authorisation, authentication, and secure communication components. The exchange of data through the platform components, the zApps, but also with third parties' software, should integrate the security mechanisms provided by T5.2 task. FIWARE also features an Access Control Module, which plays the same role as the Security Command Centre in ZDMP. Both solutions must be synchronized or at least use only one of them
- **Runtime Environment:** FIWARE modules are available as Docker images, which can be integrated and executed in the ZDMP orchestration and Kubernetes deployment

2.6 vf-OS

2.6.1 Platform Profile

vf-OS – virtual factory Operating System	
Logo	
Website	www.vf-os.eu
Domain	Manufacturing industry
Launch Date	31st October 2019
License	Open Source
Consortium	13 organisations from 6 European countries

2.6.2 Description

As will be detailed in the following subsections, vf-OS is one of the foundation technologies upon which the ZDMP platform is built. It establishes such a relationship between ZDMP and vf-OS that a single entity has emerged to take care of the exploitation of the results of the two projects: i4FS (Industry 4 Factory Solutions).

The vf-OS Platform is the result of a Research and Innovation Action project funded within the European Commission's H2020 program. It aims to contribute to the state-of-the-art in Factories of the Future by providing new research results, concrete applications, and demonstrations of the technological advancements in concrete use cases and environments. The project was not limited to providing theory but delivered the technological means to realise these concepts in software.

vf-OS is described an Open Operating System for Virtual Factories deployed in a cloud platform. It supports a multi-sided market ecosystem for providing a range of services to the connected factory of the future to integrate better manufacturing and logistics processes. The core functionalities of vf-OS are:

- **Virtual Factory System Kernel:** A specific set of libraries and infrastructure for vf-OS applications to be built upon which interact with each other. The vf-OS Kernel is the core of the operating system, responsible for providing key system-wide vf-OS resources and providing a set of specific services, which are open and accessible. The kernel executes vf-OS processes and applications while using the available computational / system resources in the most optimal manner
- **Virtual Factory Device Drivers and Open APIs:** A set of modules that virtualise a factory's real assets and connect them to their virtual images in the vf-OS. Plug-and-Play mechanisms and device drivers are being developed for seamless / open access and smart virtualisation of the factory resources. Open APIs, interconnection modules and drivers serve as seamless and secure interoperability mechanisms between the factory and the vf-OS applications

- **Virtual Factory Middleware and Databus:** A set of modules for integrating data from arbitrary sources, including, but not limited to CPS, smart objects, RFID, and wireless sensor networks. Cloud-based data storage (but also On Premise) are used to avoid vendor lock-in issues and the failure of the entire system. Also, consideration is given if a specific Cloud-based data store is not available anymore. Accessibility of data is facilitated through connectors and wrappers
- **Open Application Development Kit:** A complete and fully open Applications Development Kit addressed to the community with the aim of guarantee the growth of the specific applications running in vf-OS for covering all industrial sectors and concrete industrial scenarios including for those beyond the project. It allows third parties to develop their own applications and facilitate their integration into the vf-OS Platform thus widening and opening this way the development of specific third parties and specialised applications
- **Cloud Manufacturing Framework:** A Cloud Platform allocating the core business functionalities of vf-OS, including the marketplace and monetisation means as well as the ability to demand, advertise, and lease / purchase manufacturing Applications and third-party services. Users utilise this to request functionality, software developers introduce new applications running in vf-OS based on these requirements, service providers provide services (eg hosting), and users download / purchase and run the built applications either in-cloud or on-premise
- **Virtual Factory Components:** The individual technical components to build the functionalities of vf-OS are modular and provide open interfaces. Therefore, they can be easily integrated into other systems as well as incorporate future components, can integrate other technologies developed within current and future factories of the future projects, and can be used together with existing software systems within companies. In addition, the Open Applications Development Kit provides methodologies and interfaces to develop the individual applications

The exploitation of vf-OS outcomes is supported by the following concepts:

- **Open Access:** vf-OS and all of its components are by default open source enabling complementors (software developers, services providers, etc) to permanently improve the vf-OS components and interact with the Virtual Factory Platform and develop Apps using the Open Applications Development Kit (vf-OAK)
- **Sustainable Marketplace and App Store:** vf-OS takes advantage of the great success of the mobile apps business model that are currently being provided for systems such as Google Play or the Apple Store; transferring this approach to the manufacturing sector based on the application framework and the information infrastructure created
- **Joint Exploitation of Project Partners:** Joint exploitation of the project outcomes helps establish the RTD of vf-OS as a cloud platform and loosely coupled services. The joint exploitation of all partners has been formalised through a joint exploitation agreement that ensures the sustainability of project outcomes beyond the project lifetime
- **Spin-off Company:** As part of the project level exploitation plan and as a sustainability model for the furtherance of the project results, project partners have established a start-up company to exploit the project's technical outcomes, know-how and data-centric services. As will be described in the following subsection this is the same entity that takes care of the exploitation of ZDMP results.

2.6.3 Interlinking at a Business Level

As mentioned earlier, vf-OS is one of the foundational proven technologies upon which the ZDMP platform is built. vf-OS offers a general-purpose manufacturing orientated cloud platform supporting a multi-sided market ecosystem. This ecosystem provides a range of services for the connected factory of the future, allowing manufacturing companies to develop and integrate better manufacturing and logistics processes. On the other hand, ZDMP builds upon such platform, specializing in Zero Defects-oriented product and process quality issues of the manufacturing process.

This leads to a strict relationship between the two projects not only on a technical level (as will be shown in the next subsection), but from a business level. The relationship between ZDMP and vf-OS is such that a single entity has emerged to take care of the exploitation of the results of the two projects: i4FS (Industry 4 Factory Solutions).

Its aim is to market the developments carried out by the two projects, in other words, to market a toolkit composed of components for easily building and testing factory-orientated applications, a store for publishing them and an execution platform for deploying and monitoring these factory-orientated applications (i4Apps). Concisely, to monetisation initial Research / Innovation through a, so-called, multi-sided marketplace such as the Apple iTunes or Google Play.

i4FS primary route to market will be its online platform and marketplace aimed at manufacturers, especially SMEs, and allowing customer-supplier (ie software/technology provider) interaction. Regarding the marketing strategy, since ZDMP is still on-going, i4FS marketing strategy will continue with the ZDMP project after its start during the vf-OS project.

The initial i4FS shareholders in the business come from seven companies (partners in vf-OS and / or ZDMP) who operate in and across this field – from software developers through to zero defect technology providers.

i4FS will provide / market:

- A marketplace where factory applications can be purchased and downloaded, either via License or subscription, or requested to developers
- A development environment to allow software and manufacturing technology providers to build applications and other assets such as drivers or APIs, respectively, more easily and cost effectively and them sell them on the marketplace
- Initially generic applications will be provided along with a later specialism in zero-defect applications. Dependent on demand further specialisms may be entered in to – for example Circular Economy related manufacturing applications

Figure 13 discusses the interlinking of ZDMP and vf-OS platform features in detail:

Features	Interlinking benefit	
ZDMP Features		
ML-based quality control	ZDMP has multivariate analysis tools that could provide quality control to the vf-OS platform	
Digital Twins: Monitoring and simulation of IoT devices	vf-OS lacks a specific digital twin implementation	
Inventory and maintenance management	Maintenance calendar vApps only partially cover maintenance management issue and are specific to the pilot case. Probably vf-OS could take advantage of this ZDMP feature	

Features	Interlinking benefit	
Automatic material ordering	Partially covered by vf-OS through the vfProductValidation vApp. It manages the process of ordering and receiving products at a construction site	
(Automatic) work rescheduling	ZDMP work rescheduling may provide a useful value	
Machine monitoring and parameter optimisation	Interesting for interlinking. No specific component found in vf-OS marketplace. Specific adapters provided by ZDMP Data Acquisition may prove of value	
Manual and automatic Final Testing	Not specifically covered by the vf-OS platform. Could be interesting for interlinking	
Detection of product shape deviations	Not specifically covered by the vf-OS platform. Could be interesting for interlinking	
Detection of machine parts defects	Not specifically covered by the vf-OS platform. Could be interesting for interlinking	
Material tracking and documentation of material specifications and usage including location tags	Not specifically covered by the vf-OS platform. Could be interesting for interlinking	
Quick and easy development of new customized zApps	Already covered by vf-OS through its Application Development Toolkit	
Automated and systematic identification of risks via Security Designer	Not covered by vf-OS. Interesting for interlinking	
Quick and easy development of applications that uses models to solve problems.	Already covered by vf-OS	
Marketplace for requesting and selling custom applications	Like ZDMP, vf-OS has its own marketplace. From an interlinking point of view what is of interest lies in the possibility to cross-distribute apps among the two marketplaces	
Support for human collaboration and HCI (messaging, information exchange, factory visualisations)	vf-OS has its own human collaboration environment, the vf-OS engagement Hub	
vf-OS Feature		
Access to devices connected to vf-OS and their device data	Useful for ZDMP users that make use of both platforms	
Access to the vf-OS Marketplace	Cross-platform marketing of zApps	
Visualization tools	Some available tools may be applicable to ZDMP (depending on use case)	
vf-OS Assets: Drivers, APIs, Enablers and External Service Provision	Interesting possibility to cross distribute specific assets (eg drivers or other) across the two platforms	
Engagement Hub	ZDMP has its own Human Collaboration environment	
OAK Toolkit	ZDMP has its own Application Builder	
I/O Toolkit	ZDMP has its own Data Acquisition component. Some drivers and adapters for specific devices and data sources can be of interest for interlinking	
Virtual Factory Kernel	Though vf-OS is one of the technical building blocks for ZDMP, the project has its own kernel architecture	

Figure 13: Feature interlinking ratings for ZDMP and vf-OS

2.6.4 Interlinking at a Technical Level

As mentioned in the previous subsection, the vf-OS project is a foundation point for ZDMP and therefore, several parts of the ZDMP platform are developed starting from some of its components or based on its concepts, and some of the components are reused or adapted as part of ZDMP development activities.

In both platforms, the same component model is used, and platform components and applications are developed and are available as Docker images, so they provide their own environment and tools and only a running Docker environment is required. Docker is a virtualisation platform, which allows the user to run lightweight containers with any software component. These containers wrap a complete filesystem, which can be customised by the user as with any other system. As the containers are not bound to the hardware, relocation, testing, and later scaling of the software components is much easier.

Docker has many advantages to be used as containerisation technology:

- It enables to build a container image and use that same image across every step of the deployment process
- Docker manages to reduce deployment to seconds
- Docker containers are configured to maintain all configurations and dependencies internally
- Docker can be used in any OS and in a multi-cloud platform
- Docker makes sure each container has its own resources that are isolated from other containers
- From a security point of view, Docker ensures that applications that are running on containers are completely segregated and isolated from each other, granting complete control over traffic flow and management

Moreover the ZDMP Marketplace - a platform component with a similar business model of Google Play or the Apple App Store which allows end users to search for, compare, and buy applications and services targeting users from the manufacturing sector - is implemented through components that are based on the vf-OS Marketplace components supplied and supported by project partner ASCORA.

This common architectural framework shared by the two projects is expected to lead to a high-level of technical compatibility of applications developed on top of the two platforms. Apps previously developed in the context of vf-OS, even when not specifically addressing Zero Defects issues, will provide useful general-purpose functionality for any manufacturing actor exploiting the ZDMP platform, while ZDMP Apps will enrich the general application ecosystem available to vf-OS users. The above-mentioned Marketplace will form the basis for the Marketplace for the above mentioned i4FS, which will then host applications from both ZDMP and vf-OS.

2.7 eFactory

2.7.1 Platform Profile

eFactory - European Connected Factory Platform for Agile Manufacturing	uropean Connected Factory Platform for Agile Manufacturing
Logo	
Website	www.efactory-project.eu
Domain	Manufacturing industry
Launch Date	Planned for 31st December 2022
License	Partly Open Source (Federated platform services), partly licensed
Consortium	30 organisations from 10 different countries

2.7.2 Description

The eFactory project realises a federated smart factory ecosystem by primarily interlinking four smart factory platforms, from the FoF-11-2016 cluster, through an open and interoperable Data Spine. The federation of the four base platforms is complemented by industrial platforms, collaboration tools and smart factory systems. These are specifically selected to support connected factories in lot-size-one manufacturing.

The project demonstrates the power of federation through three embedded large-scale pilots, focusing on lot-size-one manufacturing and sustainable value networks in diverse sectors, while a cross sectorial circular economy pilot is also incorporated. The results of

the pilots are openly made available as lessons learned and best practices. The creation of the European smart factory ecosystem is supported by offering interested companies technical and financial support. A dedicated budget is allocated to offer financial support to companies who are interested in using the eFactory platform to enhance their businesses. The project is primarily composed of SMEs who can quickly react and adopt innovative solutions, while experience and market reach of big players such as Airbus and Siemens is also leveraged.

2.7.3 Interlinking at a Business Level

The federated eFactory platform delivers enhanced value and reduces the barrier to innovation by providing seamless access to services and solutions that are currently dispersed. In parallel the platform provides the necessary infrastructure, tools and support for novel service creation and validations by third parties. Further, by fostering healthy competition in the smart factory ecosystem, the eFactory platform will ensure that the needs of the evolving smart manufacturing industry are met for the long term. The eFactory federation is offered to the manufacturing and logistic companies as an open platform to: Use the offered functionality, experiment with innovation approaches and develop custom solutions based on specific needs.

eFactory is by design, an open market infrastructure for European manufacturing. It sees itself as a catalyst for an ecosystem of commercially viable, but smaller, platforms that partly compete and partly cooperate to deliver value to their customers. Such an ecosystem must inevitably be federated, and it must over time develop governance mechanisms that ensure stable growth and avoid the development of gross imbalances.

eFactory provides the following capabilities:

- **eFactory Data Spine:** An interoperability layer that interlinks digital platforms, automation and enterprise systems, CPS, IoT objects and cloud services through an interoperable data-exchange mechanism (see the technical level interlinking section)
- **Federated Platform services**: A collaboration infrastructure that streamlines communication across digital platforms, automation systems and applications through the interoperable Data Spine. It provides core services including:
    - Security (User management, Single Sign-On, privacy, governance, etc),
    - Market ready or reference implementations of the smart factory and Industry 4.0 tools from project partners
    - A multi-sided Marketplace Framework that supports cross-platform utilisation of tools and services to enable the uptake of the latest solutions and link solution providers as well as users across multiple platforms and sectors

The eFactory platform aims to bring new user communities (and their requirements) to the federated smart and connected factory ecosystem. The project organises an open call for experimentation in 2020. It is not only aimed at individuals, SMEs, and large industry, but also towards digitisation hubs and other European platform initiatives. A plan for large scale experimentation will elaborate the key offerings and the support features available for open experimentation.

As remarked in the description, eFactory participates together with ZDMP in the FOF platform cluster 4DMP under the scope of the “DT-ICT-07-2018-2019: Digital Manufacturing Platforms for Connected Smart Factories” topic. This cluster strategy will enable the three projects, to reach a broader audience and enhance its impact at national

and international levels with an action plan to achieve a higher impact whilst considering the resources available and each project specificities.

The Cluster Strategy is based on collaborative topics that are of common interest to the cluster's projects. These topics were carefully selected to potentiate the cooperation amongst all cluster projects. The selected topics cover different areas and are perfectly aligned with DT-ICT-07-2018-2019 four pillars:

- Platform Building
- Large-scale Piloting
- Ecosystem Building
- Standardisation

The first pillar is a technical pillar where issues such as common reference architectures, interoperability frameworks, open source platforms or B2B data sharing should be addressed in a common way. A Catalogue or Handbook of Open Source components that could be shared also can play a key role within this pillar. The Largescale piloting pillar addresses common approaches, business KPIs, digital maturity or joint skills, methodologies, and tools for pilot's conduction, and cooperation on open calls. Considering the specificity of some of the previous topics they will be separately addressed. Platform and ecosystem building will naturally lead to an active cooperation on market analysis and business models amongst the cluster projects. The pillars will be the focus of cooperative dissemination activities covering research and events. These dissemination activities will enhance the impact of the cluster projects beyond what is established in their individual impact strategy. Standardisation will be addressed as a key cooperative topic to identify potential new domains for specific standards, push them forward, and enhance the application of existing ones.

Several features of ZDMP and eFactory could be interlinked for mutual benefits:

Features	Interlinking benefit	
ZDMP Features		
ML-based quality control	Though may be already covered by other platforms connected to eFactory, the ZDMP implementation could also prove useful in the federated platform	
Digital Twins: Monitoring and simulation of IoT devices	Though may be already covered by other platforms connected to eFactory, the ZDMP implementation could also prove useful in the federated platform	
Inventory and maintenance management	Though may be already covered by other platforms connected to eFactory, the ZDMP implementation could also prove useful in the federated platform	
Automatic material ordering	Though may be already covered by other platforms connected to eFactory, the ZDMP implementation could also prove useful in the federated platform	
(Automatic) work rescheduling	Though may be already covered by other platforms connected to eFactory, the ZDMP implementation could also prove useful in the federated platform	
Machine monitoring and parameter optimisation	Though may be already covered by other platforms connected to eFactory, the ZDMP implementation could also prove useful in the federated platform	
Manual and automatic Final Testing	Though may be already covered by other platforms connected to eFactory, the ZDMP implementation could also prove useful in the federated platform	
Detection of product shape deviations	Though may be already covered by other platforms connected to eFactory, the ZDMP implementation could also prove useful in the federated platform	

Features	Interlinking benefit	
Detection of machine parts defects	Though may be already covered by other platforms connected to eFactory, the ZDMP implementation could also prove useful in the federated platform	
Material tracking and documentation of material specifications and usage including location tags	Though may be already covered by other platforms connected to eFactory, the ZDMP implementation could also prove useful in the federated platform	
Quick and easy development of new customized zApps	Each federated platform has its own app development mechanism	
Automated and systematic identification of risks via Security Designer	Not clear whether ZDMP security designer could be applied at federated level	
Quick and easy development of applications that uses models to solve problems.	Each federated platform has its own app development mechanism	
Marketplace for requesting and selling custom applications	eFactory has its own multi-sided Marketplace Framework that supports cross-platform utilisation of tools and services	
Support for human collaboration and HCI (messaging, information exchange, factory visualisations)	Human collaboration tools could be open to users of other eFactory-federated platforms to explore synergies with other platforms	
eFactory feature		
eFactory Data Spine	Interesting for communication with other platforms	
Federated Platform Services	Some platform services could provide added value to ZDMP	
Marketplace	ZDMP has its own Marketplace, but access to eFactory marketplace could allow a wider distribution of zApps	
Matchmaking	Interesting to provide ZDMP with access to federated search, recommendation, and matching services	

Figure 14: Feature interlinking ratings for ZDMP and eFactory

2.7.4 Interlinking at a Technical Level

The eFactory platform is offered to users through a unified Portal with value-added features to hide the complexity of dealing with different platform and solution providers. The platform offers unified access to a vast number of interoperable tools and services. This includes but is not limited to:

- Digital solutions for factory connectivity
- Distributed workflow design and execution
- Distributed production planning
- Shop-floor monitoring and alerting
- Digital Twins
- Risk management
- Data analytics

Adoption of common interoperability standards and security protocols allow seamless interactions and data exchange between multiple tools and services, while preserving security and privacy concerns.

The eFactory ecosystem is based on a federated model, which consists of distributed platforms, tools, and components provided by several partners. The main elements in the eFactory federation are:

- **eFactory Data Spine:** This is the central entity or gluing mechanism in the eFactory federation. The Data Spine provides the interoperability infrastructure that initially

interlinks and establishes interoperability between the four base platforms: COMPOSITION, DIGICOR, NIMBLE, and vf-OS. It adheres to common industry standards and follows the micro-services pattern to enable the creation of a modular platform. Therefore, it can be easily extended beyond interconnecting the base platforms to 'plug' new external platforms in and interlink them with the existing platforms. the eFactory platform architecture, shown in the following Figure 15, highlights the platform agnostic nature of the Data Spine ie. it is evident from the high-level architecture that as far as interactions with the Data Spine are concerned, there is no distinction between the eFactory platform and the base platforms or any other platforms (external and third party). Thus, the Data Spine would be independent from the rest of the eFactory platform. This hypothetically means that even if the eFactory platform were 'switched-off' in the future, the Data Spine would not have to be 'switched-off' with it and therefore would continue to support an interconnected ecosystem.

- **eFactory Platform:** This is a digital platform that provides unified access to dispersed (IoT, digital manufacturing, data analytics, blockchain, distributed workflow, business intelligence, matchmaking, etc) tools and services through a Web-based portal. The tools and services brought together in the eFactory platform are the market ready or reference implementations of the Smart Factory and Industry 4.0 tools from project partners. The collection of enhanced versions of such tools and services from the base or external platforms deployed together as microservices would constitute the eFactory platform. These micro-services are made accessible through the eFactory Portal using the Single Sign-On (SSO) functionality offered by the eFactory ecosystem.
- **Base Platforms:** The four base platforms (COMPOSITION, DIGICOR, NIMBLE, and vf-OS) in eFactory are funded by the European Commission's Horizon 2020 program within the Collaborative Manufacturing and Logistic Cluster (FoF-11-2016). These base platforms are interlinked through the Data Spine that offers seamless interoperability of distributed tools and services by integrating, aligning, and enhancing the open APIs of the existing platforms o External Platforms: In addition to the four base platforms, the eFactory ecosystem enables interlinking of other platforms and open-source tools that address the specific needs of connected smart factories. The external platforms that joined the eFactory ecosystem at the beginning of the project are: ValueChain's iQluster platform5 and SMECluster's Industreweb platform.
- **Pilots and Experiments:** These are the components and systems that will interact with the eFactory ecosystem (including the eFactory Platform and the Data Spine) during the project.

Notably, one of the four platforms interlinked in eFactory is the vf-OS platform which is one of the foundational technologies upon which the ZDMP platform is built. This means that several parts of the ZDMP platform are developed starting from some of its components or based on its concepts, and some of the components are reused or adapted as part of ZDMP development activities. This is an aspect that will have a positive impact on technical interlinking ZDMP with eFactory.

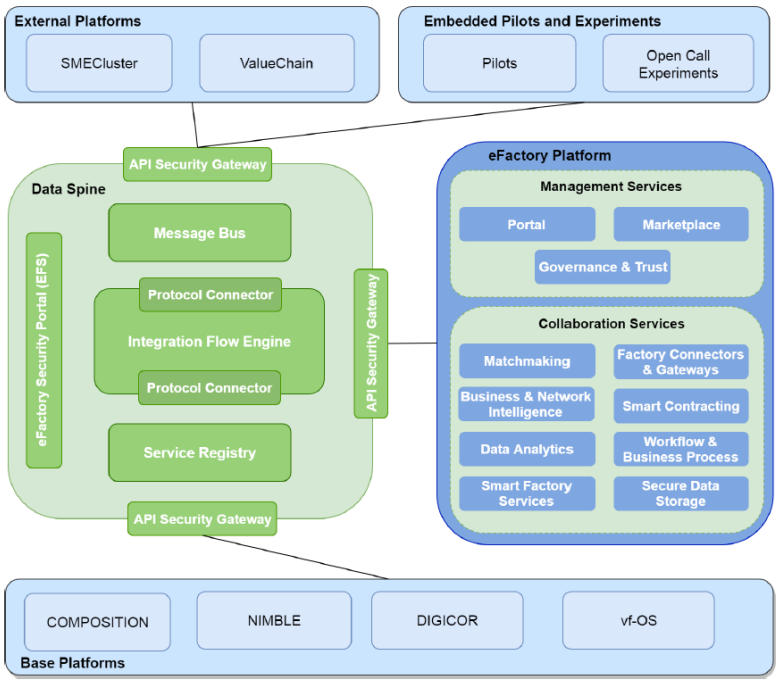


Figure 15: eFactory Architecture[7]

2.8 DISRUPT

2.8.1 Platform Profile

DISRUPT	
Logo	
Website	www.disrupt-project.eu
Domain	Manufacturing industry
Launch Date	August 2019
License	Partly Open Source, partly licensed
Consortium	9 organisations from 6 European and associated countries

2.8.2 Description

DISRUPT is a cloud-based platform focusing on the manufacturing industry by providing tools to increase flexibility and efficiency of production. It enables factories to adapt faster to the ever-increasing volatility of demand, especially in the consumer durables, electronics, and automotive industry.

[7] Source: www.efactory-project.eu/post/copy-of-efactory-architecture-views last visited 27th May 2020

From a technological perspective, DISRUPT envisions each element of production to be controlled via the IoT by its virtual counterpart. The collected data will be analysed to detect complex events that trigger automated actions.

By combining modelling, simulation, and optimisation, DISRUPT is enhancing decision support over a secure and flexible platform that will allow engineers from different disciplines and different skills to collaborate in developing services.

From the business side, the outcome of DISRUPT is focused on the segments:

- **Durables and Electronics:** Production reconfiguration, scaling and optimisation services for production planning. Support of manufacturing decisions for process (re-) design, production, and capacity planning by integrating modelling, simulation, and optimisation components
- **Automotive**: Ecosystem-aware and event-enabled production planning and control evaluating different scenarios and alternatives in cases such as contemporary manufacturing environment, late-cycle changes, the use of unqualified and nonstandard parts, unexpected plant floor events, low supplier involvement and the lack of adequate decision support
- **IoT and CPS**: Modular, decentralised approach to implementing Cyber Physical Systems and Internet of Things for automated plant floor event handling and self-adjustment in Industry 4.0

2.8.3 Interlinking at a Business Level

DISRUPT aims to deliver a reference platform that will provide a framework that enables building applications and tools and offering services or even machines that address specific business use cases. Through this approach, developers and machine providers are made an integral part of the organisation's ecosystem, enabling collaboration and rapid application development processes, while facilitating decision makers in the adoption of proposed changes.

The platform is offering capabilities in the following sections:

- Interoperability
- Virtualisation
- Decentralisation
- Real-time Capability
- Service Orientation
- Modularity

DISRUPT proposes a holistic approach to ICT-enabled manufacturing by integrating data analytics, complex event processing and cyber-physical operations empowered by decision support tools. It incorporates not only the structure of the plant floor but also the manufacturing chain and the characteristics of the production processes from cradle to grave and how each part of the corresponding ecosystem interacts with the others.

The major features or tools of DISRUPT are including the access to devices connected to the platform and their device data, a decision support toolkit, advanced analytics tools, a plant floor simulator, and a production scheduler and ramp up tool.

In general, in all the three focused segments (Durables and electronics, Automotive, IoT and CPS) the tools share a common concept to support different types of end-users with specific tools fulfilling different needs depending on the user role (see Figure 16).

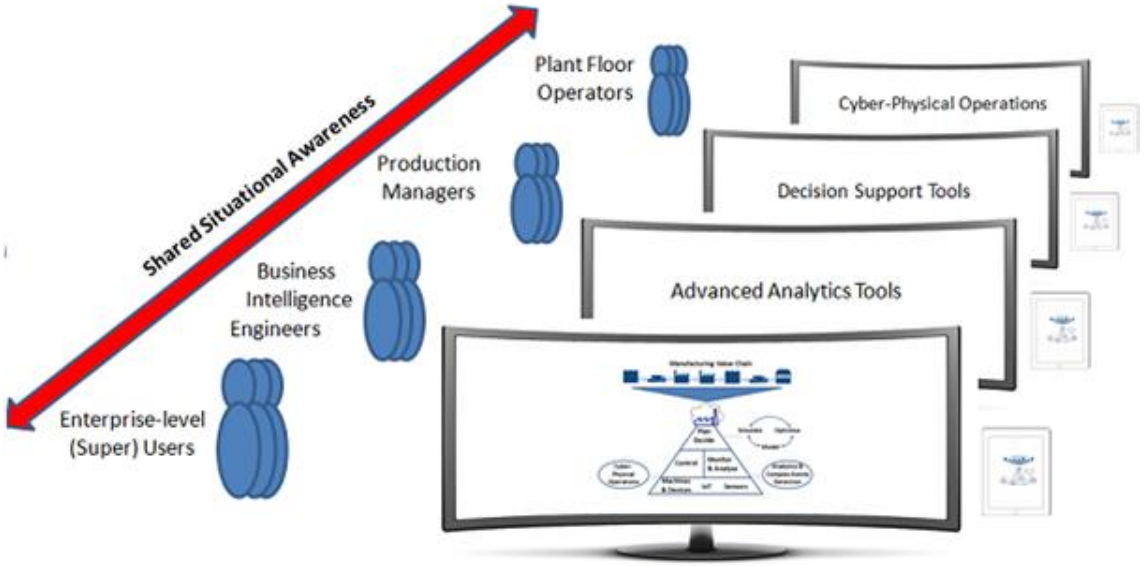


Figure 16: Disrupt user groups and tools[8]

The benefits of interlinking these features with ZDMP and those provided by ZDMP with the DISRUPT platform are discussed in the following table:

Feature	Interlinking benefit	
ZDMP Features		
ML-based quality control	Already covered by the DISRUPT platform (for specific use cases)	
Digital Twins: Monitoring and simulation of IoT devices	Interesting for interlinking because this feature is not provided by the DISRUPT platform	
Inventory and maintenance management	Interesting for interlinking because this feature is not provided by the DISRUPT platform	
Automatic material ordering	Interesting for interlinking because this feature is not provided by the DISRUPT platform	
(Automatic) work rescheduling	Already covered by the DISRUPT platform	
Machine monitoring and parameter optimisation	Interesting for interlinking even though some features may already be partially covered by the DISRUPT platform through its connections to CPS systems	
Manual and automatic Final Testing	Already covered by the DISRUPT platform in its targeted three domains	
Detection of product shape deviations	Already covered by the DISRUPT platform in its targeted three domains	
Detection of machine parts defects	Interesting for interlinking because this feature is only partly covered by the DISRUPT platform	
Material tracking and documentation of material specifications and usage including location tags	Already covered by the DISRUPT platform	
Quick and easy development of new customized zApps	Partially covered by the DISRUPT platform through the cloud controller using standards such as JMS and MQTT. However, there is no dedicated Application Builder available	
Automated and systematic identification of risks via Security Designer	Already covered by the DISRUPT platform	
Quick and easy development of applications that uses models to solve problems	Already covered by the DISRUPT platform	

[8] Source: www.disrupt-project.eu/about/expected-outcome last visited 27th May 2020

Feature	Interlinking benefit	
Marketplace for requesting and selling custom applications	Not covered by the DISRUPT platform. Potentially interesting for interlinking depending on the use case.	
Support for human collaboration and HCI (messaging, information exchange, factory visualisations)	Partially covered by the DISRUPT platform. Potentially interesting for interlinking depending on the use case	
DISRUPT Features		
Access to devices connected to DISRUPT platform and their device data	Useful for ZDMP users that make use of both platforms	
DISRUPT Decision Support Toolkit	Additional feature for production managers	
DISRUPT Advanced Analytics Tools	Already covered by ZDMP components	
DISRUPT platform plant floor simulator	Core functionality already covered by ZDMP components. However, this would allow ZDMP users to use Disrupt digital twins / simulator in ZDMP, too	
DISRUPT platform production scheduler and ramp up tool	Additional feature for production managers	

Figure 17: Feature interlinking ratings for ZDMP and DISRUPT

2.8.4 Interlinking at a Technical Level

DISRUPT consists of several technical layers as shown in Figure 18. The virtualisation layer represents the central layer of DISRUPT. It includes two modules, which are relevant from a technical perspective when interlinking ZDMP with DISRUPT:

- **Data Collection Framework (DCF):** This module represents DISRUPT's interface to the Physical Layer, ie the connected IoT devices and Enterprise Information Systems such as ERPs and MES
- **Cloud Controller:** This module represents the heart of the DISRUPT platform. It acts as the central interfaces between the different DISRUPT platform components and manages communication between them. This functionality is provided through a message bus system, which supports communication via standard protocols such as JMS and MQTT, and standard formats such as JSON

To be able to integrate ZDMP with software components of the DISRUPT platform and vice versa, a communication to the Cloud Controller's Message Bus must be established. Since this Bus system uses standard protocols and formats already supported by ZDMP and there are also no specific requirements in terms of security, interlinking both platforms should be a easy to achieve.

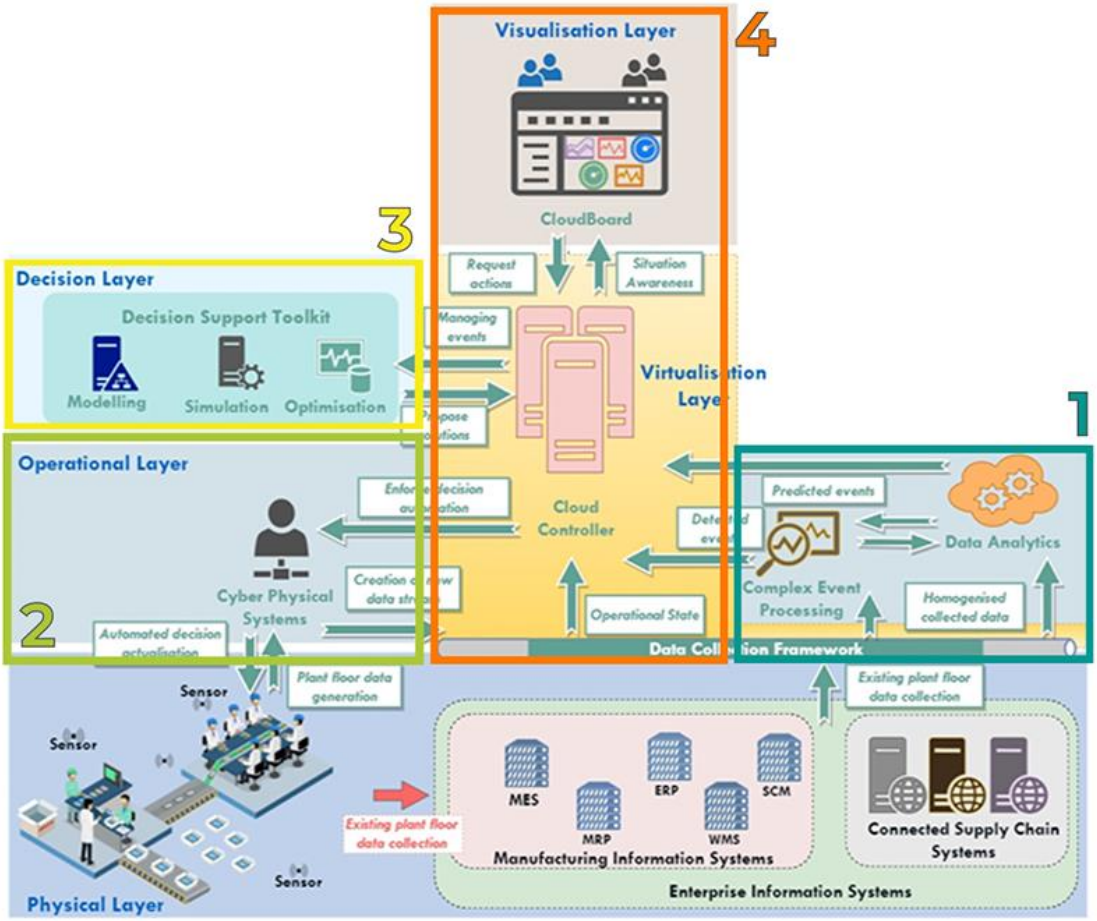


Figure 18: The DISRUPT architecture[9]

[9] Source: www.disrupt-project.eu/about/technologies last visited 27th May 2020

2.9 BEinCPPS Platform

2.9.1 Platform Profile

BEinCPPS	
Logo	
Website	www.beincpps.eu
Domain	Cyber-Physical Production Systems
Launch Date	31st October 2018
License	Partly Open Source, partly licensed
Consortium	23 organisations from 8 European countries

2.9.2 Description

BEinCPPS is a European Commission Innovation Action in the field of Cyber-Physical Production Systems (CPPS). It aims to integrate and experiment a CPPS-oriented, Future Internet-based machine-factory-cloud service platform.

At first the platform was tested intensively in five selected candidates from the Smart Specialisation Strategy Vanguard regions (Lombardia in Italy, Euskadi in Spain, Baden Württemberg in Germany, Norte in Portugal, Rhone Alpes in France). Afterwards, it was extensively tested in all European regions, by involving local competence centres and manufacturing SMEs. The final aim of this project is to improve the adoption of CPPSs all over Europe.

The BEinCPPS project is based on three pillars: Open source platforms, experimentation facilities and ecosystem, and Innovation Management tools / methodology. Regarding the relevance for the ZDMP project, the open source platform is the part of interest.

This three-layered (machine-factory-cloud) platform is based on state-of-the-art R&I advances in the fields of Internet of Things, Future Internet, and CPS / Smart Systems. It can bi-directionally interoperate data pertaining to the machine, the factory, and the cloud levels.

For each of these layers, the project offers a BEinCPPS Open Platform for CPPS with the following capabilities:

- **Field Level**
  - Micro Complex Event Processing for CPPS
  - TSN Enabled 4DIAC Real Time Environment for Distributed Automation Systems
  - WSN (Wireless Communication) for CPPS
- **Factory Level**

- CPPS Messaging Services
- CPPS Publishing Services

- **Cloud Level**
  - Dynamic Complex Event Processing for CPPS
  - 3D Visualisation Services
  - Task Orchestration for CPPS
  - Assets Registry for CPPS

Figure 19: BEinCPPS Platform components[10]

The provided platform and its components have been used in different fields of application and use cases, highlighting the following:

- Portable testing unit for statistical quality check
- CPS-based Pick-by-X system for worker assistance
- Cyber-physical gauging systems for checking fixtures

[10] Source: www.beincpps.eu

- CPS-based logistics system for flexible production
- Smart and autonomous moulding for high precision

2.9.3 Interlinking at a Business Level

BEinCPPS market orientation is directed towards the use of innovative technologies to improve cyber-physical production systems, which means it aims to cover as many applications and use cases as possible. During the project, several business use cases were assessed. Some of them fall directly in the scope of Zero Defects Manufacturing. This includes, for instance, the portable testing units for quality check or the checking of fixtures for plastic parts manufacturing, to reduce the quantity of failed pieces or items produced.

Although the results are encouraging, the reality is that it can be beneficial to extend and complement the platform developed in BEinCPPS with ZDMP zApps, especially those oriented specifically to analytics and anomaly detections.

The platform already proposed some components to address the field level monitoring (collecting data) and exchanging information by supporting several protocols and communication paradigms (IoT Middleware and device management). It also includes some visualisation and data analysis components, but they may be too specific for the project selected use cases, or too general for the regular user, who would need training and a lot of time to adapt the component to his / her needs.

Therefore, zApps can extend and integrate with an already deployed BEinCPPS instance of components to extend the range of use cases. This would benefit both platforms, as they can interact and share data / experience and reach a wider number of users and applications.

It is also relevant noticing the solutions for the design and development stages provided by BEinCPPS, which could complement the design tools for modelling, characterizing, and developing uses case in collaboration with ZDMP.

ZApps could be seen as another set of “components” on the top part of the platform diagram shown in Figure 19. Regarding the zApps that could be marketed between ZDMP and this 3rd party platform, the table below shows a list of potential candidates. The nature of the BEinCPPS platform allows a high degree of zApp reusability and integration, although technical challenges for adapting zApps to core components of BEinCPPS platform could be required.

Features	Interlinking benefit	
ZDMP Features		
ML-based quality control	ZDMP has multivariate analysis tools that can enhance quality control in BEinCPPS installations, adding new algorithms showing better defect detection	
Digital Twins: Monitoring and simulation of IoT devices	This feature complements the components from BEinCPPS, that lacks Digital Twin implementation	
Inventory and maintenance management	Partly covered by the pick-by-X and Logistics for flexible production use cases of BEinCPPS	
Automatic material ordering	This feature is missing in BEinCPPS, so it can provide a direct benefit	
(Automatic) work rescheduling	Partly covered by the pick-by-X use case of BEinCPPS	
Machine monitoring and parameter optimisation	Especially the parameter optimisation output can be used by the CPPS embedded components to improve machine operation in runtime	

Features	Interlinking benefit	
Manual and automatic Final Testing	Already a use case in BEinCPPS platform	
Detection of product shape deviations	Already a use case in BEinCPPS platform	
Detection of machine parts defects	This feature is partly covered in use cases, although is focused on conveyor belts and transport of pieces between work desks, or plastic injection moulds.	
Material tracking and documentation of material specifications and usage including location tags	Partly covered by the pick-by-X and Logistics for flexible production use cases of BEinCPPS	
Quick and easy development of new customized zApps	Useful to widen the range of applications and use cases	
Automated and systematic identification of risks via Security Designer	Interesting for BEinCPPS, as it lacks security designer	
Quick and easy development of applications that uses models to solve problems.	Interesting for BEinCPPS, as it lacks an application builder	
Marketplace for requesting and selling custom applications	BEinCPPS already has an own marketplace / catalogue. The benefit can come from the possibility of the third party to request / download zApps, not selling them	
Support for human collaboration and HCI (messaging, information exchange, factory visualisations)	BEinCPPS has its own information exchange components and visualisation, although they can be integrated with complementary / enhanced with ZDMP dedicated components	
BEinCPPS Features		
CPPS Embedded	The features covered by these assets of BEinCPPS can complement the physical level (devices and machines in the floor plant) with specialized run time environment and context event processors in application where data acquisition require such features	
CPPS Communications	Can provide communication protocol stacks that ensure deterministic and synchronized data flow for hard and soft real time application at field level	
IoT Middleware and device management	Already covered by ZDMP components	
Ecosystem collaboration	Already covered by ZDMP components	
Human – machine interaction	Already covered by ZDMP components	
Event data processing	Already covered by ZDMP components	

2.9.4 Interlinking at a Technical Level

To be able to integrate zApps with software components of the BEinCPPS platform, several aspects should be considered:

- **Required protocols:** BEinCPPS components have defined protocols for exchanging information among them, but also could be used to communicate with 3rd parties, in this case, ZDMP zApps. Both platforms use (and plan to use) common protocols that are widely adopted, such as MQTT, AMQP or OPC-UA. It could be also possible to integrate through dedicated APIs or use other standards supported by FIWARE IoT Agents and ORION Context Broker, as they are used as core components in the IoT Middleware and device management layer.
- **Information Models:** Apart from the protocols of choice to exchange information, it is needed to agree on how the data in interpreted and represented. BEinCPPS uses several standardized solutions such as IPSO Smart Object, OMA LWM2M, but it is

still a challenge to be able to interpret correctly data coming from different sensors, machines, and vendors. This technical challenge should be addressed by the T5.3 Data Harmonisation task.

- **Data source discovery and catalogue:** On the core of ZDMP platform field level, the T5.1 Data Acquisition hosts a Device and data source manager, where zApps and users are able to search for data sources lists and required parameters to query those sources. For some zApps, this step is needed to start collecting and analysing data, so any data source exposed by a BEinCPPS platform-based use case, would need to register its data sources prior to working with the zApps.
- **Security aspects:** ZDMP integrates security at its core, by using the Authorisation, Authentication, and Secure Communication components. The exchange of data through the platform components, the zApps, but also with 3rd parties' software, should integrate the security mechanisms provided by T5.2 task. Therefore, to use BEinCPPS components to provide data to zApps, those devices or software components must request credentials to the Authorisation and Authentication components of ZDMP, set the required roles, and install the provided certificates if needed to open secure encrypted channels (for example, a TLS socket for MQTT publishing).
- **Runtime Environment:** BEinCPPS IoT Middleware and device management are available in Docker images, which can be integrated and executed in the ZDMP orchestration and Kubernetes deployment.

3 Summary

This section summarises the findings presented in Section 2. It provides a summary of the most useful ZDMP features for interlinking with 3rd party platforms and outlines the most useful features for ZDMP offered by other platforms. Moreover, it elucidates the overall technical feasibility of interlinking ZDMP with the assessed external platforms.

3.1 ZDMP Feature Interlinking Summary

As outlined in Section 1.1, ZDMP offers several features that may be useful for 3rd party platforms. However, some features are already covered by some external platforms or are too specific to match the 3rd party platform's scope.

The individual ratings of the ZDMP features from the perspective of the assessed external platforms are summarised in Figure 20. Thereby, column "Total Rating" provides an average rating of a feature based on the individual ratings obtained per external platform.

ZDMP Feature	ADAMOS	MindSphere	Bosch IoT Suite	Thyssen Krupp toii	vf-OS	eFactory	DISRUPT	BEinCPPS	Total Rating
ML-based quality control	🔴	🔴	🔴	🔴	🟢	🟢	🔴	🟢	🟡
Digital Twins: Monitoring and simulation of IoT devices	🟢	🔴	🔴	🟢	🟢	🟢	🟢	🟢	🟢
Inventory and maintenance management	🔴	🔴	🔴	🔴	🟢	🟢	🟢	🟡	🟡
Automatic material ordering	🟢	🟢	🟢	🟢	🟡	🟢	🟢	🟢	🟢
(Automatic) work rescheduling	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟡	🟢
Machine monitoring and parameter optimisation	🟡	🟡	🟢	🟡	🟢	🟢	🟢	🟢	🟢
Manual and automatic Final Testing	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🟢
Detection of product shape deviations	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🟢
Detection of machine parts defects	🟡	🟡	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Material tracking and documentation of material specifications and usage including location tags	🟡	🟢	🟢	🟢	🟢	🟢	🔴	🟡	🟢
Quick and easy development of new customized zApps	🟡	🟡	🟡	🟡	🔴	🔴	🟡	🟢	🟡
Automated and systematic identification of risks via Security Designer	🟢	🟡	🟢	🟢	🟢	🟡	🔴	🟢	🟢
Quick and easy development of applications that uses models to solve problems.	🟢	🔴	🔴	🟢	🔴	🔴	🔴	🔴	🟡
Marketplace for requesting and selling custom applications	🔴	🔴	🔴	🟡	🟡	🔴	🟢	🔴	🟡
Support for human collaboration and HCI (messaging, information exchange, factory visualisations)	🟢	🟡	🟢	🟢	🔴	🟢	🟡	🔴	🟡

Figure 20: Summary of the ZDMP feature interlinking ratings for all assessed platforms

According to the results obtained for the individual 3rd party platforms, the most useful ZDMP features for interlinking are those specialised for Zero Defects Manufacturing. Most platforms do not provide dedicated tools for the detection of shape deviations or machine defects. Other relevant features are the applications for automatic ordering of material, material tracking, automatic work rescheduling, and machine parameter optimisation. The human collaboration functions and the Security Designer could be useful to extend the functionality of the assessed 3rd party platforms.

In contrast, Machine Learning-based quality control, Inventory and Maintenance Management, and Digital Twins are less relevant features for interlinking because they are already covered by several platforms. Similarly, most platforms already offer their own application marketplace. Hence, using the ZDMP marketplace for selling 3rd party platform apps is also less important. The same applies to the Application Builder provided by ZDMP.

Overall, the study shows that all 3rd party platforms would benefit from interlinking with ZDMP in one way or another.

3.2 External Platform Feature Interlinking Summary

3.2.1 Most Relevant Features

All assessed 3rd party platforms provide several features, which could be beneficial for ZDMP when interlinking both platforms. The following list highlights the most relevant features, which are provided by several platforms, and summarises their benefit for ZDMP:

- **Access to devices and data:** Interlinking ZDMP with other platforms would allow ZDMP users to access devices and data connected to other platforms. This provides several benefits. For example, external data could be a useful input for Machine Learning models and ZDMP users could access and control external devices directly from within ZDMP instead of using multiple systems. This could also increase the acceptance of ZDMP by potential customers.
- **Access to proprietary and legacy devices:** Many IoT platform providers also produce and sell their own IoT devices. For example, this includes Bosch, Siemens, and Thyssen Krupp. Sometimes, these devices use proprietary protocols and software, which makes it hard to connect these devices to other platforms such as ZDMP. In general, one can assume that devices produced by an IoT provider typically work best with in its own platform environment. Hence, interlinking ZDMP with these platforms could provide ZDMP with a straightforward way to access these devices.
- **App Marketplaces:** Several platforms serve a marketplace for applications that can be used in combination with the platform and to extend its functionality. This includes, for instance, ADAMOS, MindSphere, Bosch IoT Suite, vf-OS, and eFactory. The latter even realises a federated application marketplace for multiple platforms. Interlinking ZDMP's marketplace with the store of other platforms would allow ZDMP the cross-platform marketing of zApps and would enable both platforms to extend their functionalities and their product portfolio.
- **Data Visualisation:** Some platforms feature dedicated data visualisation capabilities. Since ZDMP does implement general purpose visualisation tools, interconnecting these external visualisation tools with ZDMP would provide ZDMP users with additional dedicated visualisation capabilities.

The following table highlights, which of the assessed platforms support these features:

Platform feature	ADAMOS	MindSphere	Bosch IoT Suite	Thyssen Krupp toii	FIWARE	vf-OS	eFactory	DISRUPT	BEinCPPS
Access to devices and data	✓	✓	✓	✓	✓	✓	✓	✓	✓
Access to proprietary and legacy devices		✓	✓	✓					
App Marketplace	✓	✓	✓		✓	✓	✓		
Data visualisation	✓	✓	✓			✓			

3.2.2 Other Relevant Features

Besides the features described above, some platforms also provide individual features that could be relevant for ZDMP to complement its functionalities. For example, this includes access to use case specific applications through ADAMOS, the energy management applications of MindSphere, and the Decision Support Toolkit of DISRUPT. A full list of these features is shown in Figure 21:

Platform feature	Interlinking benefit	
ADAMOS		
Access to applications (App Factory)	Access to applications and solutions specifically tailored to specific use cases and machines used for mechanical engineering	🟢
MindSphere		
Energy Management	Especially useful because ZDMP only provides basic energy management capabilities through the zApp zPowerManager	🟢
Bosch IoT Suite		
Digital Twins (Bosch IoT Things)	Core functionality already covered by ZDMP components. However, this would allow ZDMP users to use Bosch IoT digital twins in ZDMP	🟡
Thyssen Krupp toii		
Opto-electric capabilities (toii.Lights)	Especially useful because ZDMP does not provide a dedicated module with opto-electric capabilities	🟢
Machine Control (toii.Control)	Especially useful because ZDMP does not provide a dedicated module to access a machine control system. Depends on the use case (mainly for Thyssen Krupp machines)	🟡
FIWARE SMART INDUSTRY		
BI platform, Mashup	These modules can help develop zApps faster and compatible with FIWARE	🟢
Processing engines from third parties' adapters	ZDMP uses some of these processing engines. Therefore, by using these adapters, zApps can be integrated with Orion easily	🟢
Big Data, AI algorithms, KPI monitoring, etc	These algorithms can be used to process data from ZDMP sources and use cases, enhancing the catalogue of analysis tools of the zApps.	🟢
vf-OS		

vf-OS Assets: Drivers, APIs, Enablers and External Service Provision	Interesting possibility to cross distribute specific assets (eg drivers or other) across the two platforms	
I/O Toolkit	ZDMP has its own Data Acquisition component. Some drivers and adapters for specific devices and data sources can be of interest for interlinking	
eFactory		
eFactory Data Spine	Interesting for communication with other platforms	
Federated Platform Services	Some platform services could provide added value to ZDMP	
Matchmaking	Interesting to provide ZDMP with access to federated search, recommendation, and matching services	
DISRUPT		
DISRUPT Decision Support Toolkit	Additional feature for production managers	
DISRUPT platform plant floor simulator	Core functionality already covered by ZDMP components. However, this would allow ZDMP users to use Disrupt digital twins / simulator in ZDMP, too	
DISRUPT platform production scheduler and ramp up tool	Additional feature for production managers	
BEinCPPS		
CPPS Embedded	The features covered by these assets of BEinCPPS can complement the physical level (devices and machines in the floor plant) with specialized run time environment and context event processors in application where data acquisition require such features	
CPPS Communications	Can provide communication protocol stacks that ensure deterministic and synchronized data flow for hard and soft real time application at field level	

Figure 21: Summary of the feature interlinking ratings per assessed 3rd party platform

3.3 Overall Technical Feasibility

Most of the assessed platforms use standardised communication protocols and data formats. A comprehensive documentation of the relevant interfaces is also available for most platforms. Through this and ZDMP components such as T5.3 Data Harmonisation, interlinking ZDMP with these platforms should be possible in principle. An exception to this is Thyssen Krupp's toii platform because of the lack of publicly available documentation.

However, the real effort of interlinking ZDMP features with another platform and vice versa strongly depends on the individual requirements of the features and components that should be interlinked. For example, publishing a zApp on the MindSphere store may require several adaptions to the zApp to make it compatible, while providing an external platform with access to a ZDMP feature exposed via REST API through the T6.4 Services API Management is straightforward action.

4 Conclusion

Inter-platform linking and the interoperability with external platforms is a central aspect of ZDMP. It can yield many benefits for both platforms such as cross-platform marketing of applications, cross-platform access to devices and data, and completing the features of both platforms.

As the interlinking study presented in Section 2 shows, all assessed platforms would receive some benefit through an interlink with ZDMP. Especially the dedicated Zero Defects Manufacturing Applications such as the shape deviation detection zApps or those featuring the detection of machine defects provide functionalities, which the assessed 3rd party platforms are typically lacking. Other relevant features include applications for the automatic ordering of material, material tracking, machine parameter optimisation, and functions for human collaboration.

On the other hand, ZDMP could benefit from the device connectivity and data visualisation capabilities provided by external platforms and their application marketplaces. An interlink could provide ZDMP with access to additional devices and data visualisation tools, enable cross-platform marketing of zApps, and to reach a larger user basis. Some platforms also provide some unique features such as the energy management capabilities of Siemens MindSphere, which would complement the functionality of ZDMP.

Based on these findings, the most interesting candidates for interlinking with ZDMP are ADAMOS, MindSphere, Bosch IoT, eFactory, and vf-OS. They all come with their own marketplaces and the commercial platforms have large user bases, which allows ZDMP to market zApps on other platforms and to reach more customers. Interlinking with ADAMOS, eFactory, and vf-OS (via eFactory middleware) is already part of the DOA and planned actions for Task T6.5 Inter-Platform Interoperability. An interlink to MindSphere and Bosch IoT could be considered as well.

From the technical perspective, establishing an interlink between ZDMP and the assessed platform should be possible in principle. ZDMP as well as the assessed 3rd party platforms use standard communication protocols and data formats and the required documentation of the interfaces is also available for all platforms but Thyssen Krupp's toii. Hence, the technical feasibility of interlinking ZDMP with toii cannot be reliably assessed at the time of writing. In general, the technical feasibility and the required effort for interlinking features strongly depends on the individual requirements of the features. This aspect thus must be carefully considered when planning and implementing interlinks in Task T6.5 Inter-Platform Interoperability.

This document represents the first iteration of a living deliverable. A second version is scheduled for M30 and the third and final iteration for M48. With each iteration, the findings of the interlinking study will be revisited based on the most recent development state of ZDMP and the 3rd party platforms. Future iterations may also extend the study regarding additional platforms if necessary.

Annex A: History

Document History	
Versions	V0.0.1: • Initial document structure and template V0.0.3: • Updated document template to ZDMP template v1.07 • Added partner inputs V0.1.0: • First document draft including the first three project & platform interlinking analysis reports V0.2.0: • Added additional platform analysis reports • Added overview section V0.3.1: • Added additional platform analysis reports • Extended overview section • Added feature rating tables to the reports • Updated partner logos V0.4.5: • Added additional platform analysis reports • Updated overview section • Added summary and conclusion sections V1.0: • Final version for M18 submission V1.0A: • Final version for M18 submission
Contributions	ICE: • Stuart Campbell ITI: • David Todoli SAG: • Martin Heß • Marc Dorchain SOFT: • Christian Melchiorre

Annex B: References

None

ZERO DEFECTS
Manufacturing
Platform
ZDMP

www.zdmp.eu