Project Acronym:	CAPP-4-SMEs
Project Title:	Collaborative and Adaptive Process Planning for Sustainable Manufacturing Environments
Theme FoF.NMP.2012-6:	Knowledge-based tools and approaches for process planning and integrated process simulation at factory level
Grant Agreement No:	314024
Work Package 8:	Project Management
Task 8.1:	Administrative Management
<u>Deliverable D8.2:</u>	**<u>Project Management and Final Report</u>**
Date of the latest version of Annex I against which the assessment will be made:	2012-09-06
Periodic Report:	1st ☐ 2nd ☑
Period Covered:	From 2014-6-01 to 2015-11-30

Responsible Organisation:	**KTH**
Document Type:	Report
Document Version:	V1.0
Document Preparation Date:	2015-11-15
Document Due Date:	2016-02-29

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Project co-funded by the European Commission within the 7th Framework Programme		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
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CO	Confidential, only for members of the consortium (including the Commission Services)	

[1] Usually the contact person of the coordinator organisation as specified in Art. 8.1. of the grant agreement

Versioning and contribution history

Version	Organisation	Comment	Date
V0.1	KTH	Initial draft of final report (D8.2)	2015-11-01
V0.9	KTH	90% complete final report	2015-11-15
V1.0	KTH	Final version of the final report	

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SELF-DECLARATION

(Scanned copy of the declaration duly filled in and signed by the project coordinator)

I, as scientific representative of the coordinator of this project and in line with the obligations as stated in Article II.2.3 of the Grant Agreement declare that:

- The attached periodic report represents an accurate description of the work carried out in this project for this reporting period;
- The project (tick as appropriate):
  - ☑ has fully achieved its objectives and technical goals for the period;
  - ☐ has achieved most of its objectives and technical goals for the period with relatively minor deviations;
  - ☐ has failed to achieve critical objectives and/or is not at all on schedule[2].
- The public website is up to date.

[2] If either of these boxes is ticked, the report should reflect these and any remedial actions taken.

- The financial statements which are being submitted as part of this report are in line with the actual work carried out and are consistent with the report on the resources used for the project (section 3.6) and if applicable with the certificate on financial statement.
- All beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs, have declared to have verified their legal status. Any changes have been reported under section 5 (Project Management) in accordance with Article II.3.f of the Grant Agreement.

Name of scientific representative of the Coordinator: Lihui Wang
Date:
Signature of scientific representative of the Coordinator:

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List of Abbreviations

AHP	Analytical Hierarchy Process
CAPP	Computer-Aided Process Planning
EFB	Execution Function Block
ERD	Entity-Relationship Diagram
EuP	Directive of eco-design of Energy using Products
FB	Function Block
GA	Genetic Algorithm
GRNET	Greek Research and Technology Network
HBMO	Honey-Bee Mating Optimisation
HBMO-SA	Hybrid Honey-Bee Mating Optimisation and Simulated Annealing
HCI	Human-Computer Interaction
HMI	Human Machine Interface
IAAS	Infrastructure as a Service
MAM	Machine Availability Monitoring
MFB	Meta Function Block
OFB	Operation Function Block
OP	Operation Planning
OTAP	Over the Air Programming
PAAS	Platform as a Service
PO	Project Officer
PTA	Project Technology Advisor
SA	Simulated Annealing
SAAS	Software as a Service
SP	Supervisory Planning
WP	Work Package

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Executive Summary

Product development and manufacturing activities are the primary economical pillars of the EU, and over 90% manufacturing activities attribute to Small- and Medium-sized Enterprises (SMEs). Current markets are characterised by turbulence and mounting demands for highly customised products. Customers require higher quality, faster delivery, and shorter times between successive generations of products. Value chains and cooperation between companies especially SMEs are increasingly project-specific, customer-centric and flexible, and manufacturing jobs are diversified and urgent. Meanwhile, sustainable product regulations and incentives have being taken effect, and manufacturers should, at the design and process planning stages, consider the multi-faceted requirements of manufacturing processes to ensure flexibility, competitiveness and sustainability throughout product lifecycles. It therefore requires SMEs to be able to efficiently configure and re-configure their manufacturing processes to facilitate product customisation and alteration in order to adapt much quickly to the changing global market and sustainable requirements.

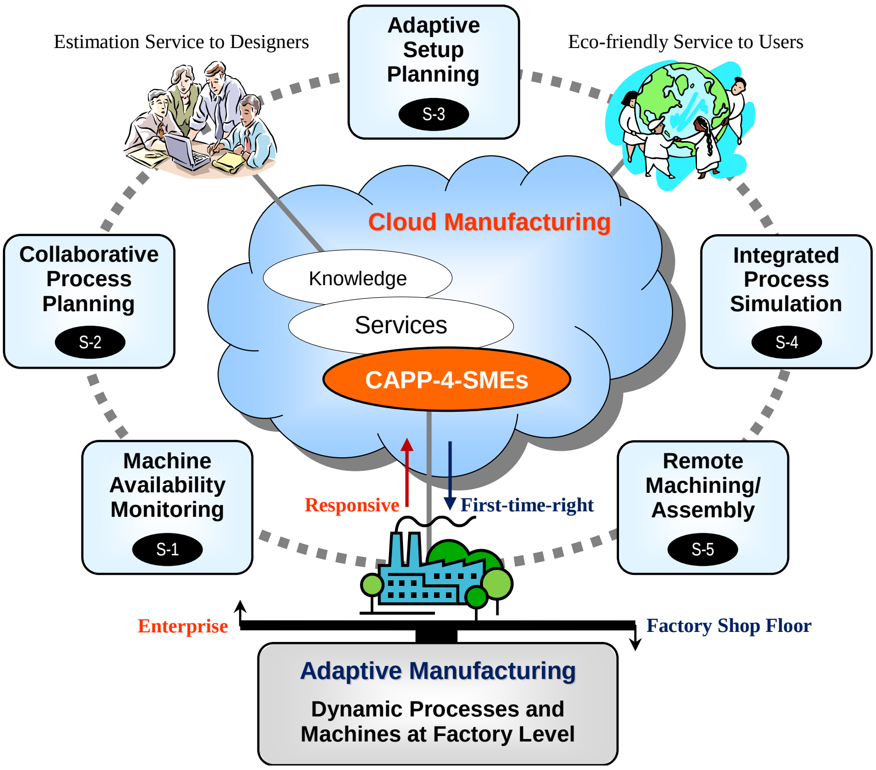


Figure 1. Project overview

Innovative knowledge-based Computer-Aided Process Planning (CAPP) is a key enabler to minimise cost, improve adaptability, responsiveness, robustness, and sustainability of manufacturing processes. This CAPP-4-SMEs project, planned for 36-month duration and 435 person-months, is aimed at enhancing the competitiveness of European companies, particularly SMEs, in sustainable manufacturing environment by:

- developing a series of innovative and adaptive process planning services to support SMEs to simulate, evaluate, plan and optimise their dynamic and complex manufacturing processes and execution systems in collaborative value chains, in a bid to achieve efficiency, cost-effectiveness, robustness, sustainability, smartness and user intervene-friendliness during process planning;

- developing a knowledge-based and efficient simulation service to support multi-criteria manufacturability evaluation from the beginning of product lifecycle so as for SMEs to achieve first-time-right in terms of accuracy and reliability for customised product processes as well as improved overall energy profiles to comply the tougher eco-regulations;
- applying event-driven function block technology for on-board adaptive process control functions at machine level through process plan embedding, smart algorithm invocation and bi-directional communication for SMEs to achieve real-time responsiveness, adaptability and overall resource effectiveness;
- introducing a monitoring service for up-to-date machine availability and utilisation to ensure that decision making for planning and optimisation become resource-aware and well informed; and
- adopting Cloud and service-oriented computing approaches, which are the new-generation supplement, consumption, and delivery model for the over-the-Internet provision of dynamically scalable resources and utility computing, as a service platform to support SMEs to move away from developing and maintaining resource-intensive and standalone CAPP systems and migrate to portable CAPP services accessible and configurable over the Internet.

The CAPP-4-SMEs Consortium is comprised of 11 partners (4 universities, 1 multi-national manufacturing company and 6 SMEs) from 5 European countries (Sweden, UK, Greece, Germany and Spain). The complementary expertise of the academic and industrial European partners in the project enables knowledge sharing, dissemination and exploitation of scientific findings, industrial applications and technical know-hows across the EU in international dimension. Technical innovations have be achieved through collaborative RTD activities oriented towards industrial applications for factories of the future.

Industry-relevant demonstration has be developed in the project as an important element for result validation using real-world cases from SMEs distributed in the EU. Targeting to showcase huge reduction in resource consumption, improvement in process robustness and accuracy, and increase in productivity by reduced cycle times under more reliable and efficient manufacturing conditions, the demonstration activities based on the innovative RTD outcomes of the project are be geared to exploit future commercialisation opportunities throughout the extensive industrial networks of the Consortium, and to generate greater impacts in broader areas of the EU.

1 Project Objectives

The concept and aim of the proposed research is to enhance the competitiveness of European companies, particularly SMEs, in the modern manufacturing environment by:

- developing a series of innovative and adaptive process planning services to support SMEs to simulate, evaluate, plan and optimise their dynamic and complex manufacturing processes and systems in collaborative value chains, in a bid to achieve efficiency, cost-effectiveness, robustness, sustainability, smartness and user intervene friendliness during process planning;
- developing a knowledge-based and efficient simulation service to support multi-criteria manufacturability evaluation from the design stage so as for SMEs to improve the overall energy profiles imposed by tougher eco-regulations from the beginning of the product lifecycle;
- introducing a monitoring service for up-to-date machine availability and utilisation to ensure that decision making for planning and optimisation become resource-aware and well informed;
- adopting Cloud and service-oriented computing approaches (that is the new generation supplement, consumption, and delivery model for the over-the-Internet provision of dynamically scalable resources and utility computing) as the platform of the aforementioned services to support SMEs to move away from developing and maintaining resource-intensive and standalone CAPP systems and migrate to be Cloud and service-oriented solution accessible and configurable over the Internet; and
- applying event-driven function block technology for on-board adaptive decision making at machine level through process plan embedding, smart algorithm invocation and bi-directional communication for SMEs to achieve real-time responsiveness, adaptability and overall resource effectiveness.

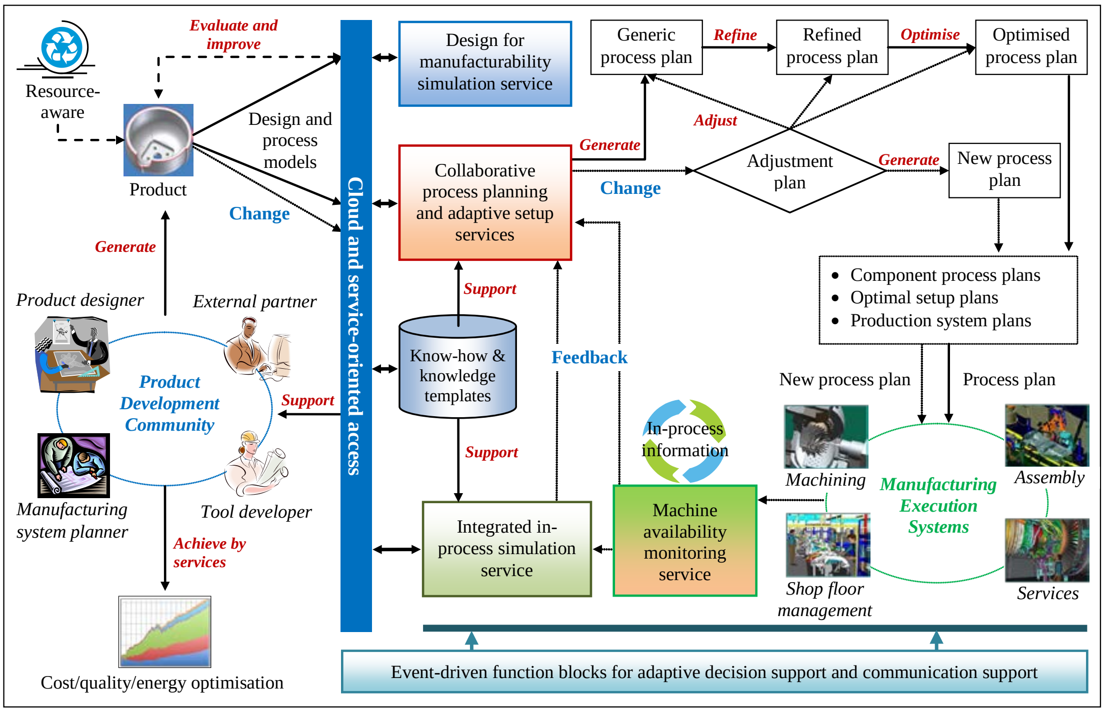


Figure 2. Services and information/decision flows of CAPP-4-SMEs

This overall, project-level, aim can be subdivided into the following objectives that link directly to the core work packages (WPs) of CAPP-4-SMEs:

- **Objective 1:** To design and develop a service-oriented platform for Cloud manufacturing, where relevant monitoring, planning, optimisation and execution control services can be provided;
- **Objective 2:** To monitor and predict machine utilisation and availability, locally or remotely, so that the decision making for planning and optimisation etc. become resource-aware and well informed;
- **Objective 3:** To develop a web-enabled and knowledge-based tool for dispersed engineering teams to create non-linear process plans collaboratively, using the services of Cloud manufacturing;
- **Objective 4:** To generate setups adaptively based on the available machines, their configurations and capabilities, by sharing real-time in-process monitoring information from Objective 2; and
- **Objective 5:** To provide an integrated process/setup simulation environment to optimise parameters for reduced cycle time and resource consumption, and increased quality and productivity.

The aforementioned objectives are each assigned to one RTD WP to be achieved in the three project-years. The five WPs and three additional WPs are: WP1 *Cloud Manufacturing Services Platform*; WP2 *Machine Availability Monitoring*; WP3 *Collaborative Process Planning*; WP4 *Adaptive Setup Planning*; WP5 *Integrated Process Simulation*; WP6 *Job-Shop Machining Demonstrators*; WP7 *Dissemination and Exploitation*; and WP8 *Project Management*. Within the project all the technical WP and related objectives are achieved on time and in good quality.

2 Work Progress and Achievements

Most of the technical developments from WP1, 2,3,4 and 5 were achieved in the project period 1, and reported in the project mid-term review report. Thus in this section, brief progress reports are presented regarding WP1-5, and the contents focuses on new findings and outcomes. More details can be found in D8.1 CAPP-4-SMEs WP8 Mid-Term Report and related deliverables, respectively [1].

2.1 Progress overview and contribution to the research field

The eight WPs are allocated to the four phases, as shown in Figure 3, together with their interdependencies. Although the WPs are mainly shown in sequential order, it does not mean that one WP should start only after the previous one finishes. The interdependencies are more **logical rather than temporal**. During project execution, most WPs overlap with each other with slightly different starting dates. This allows feedbacks among WPs for handshaking and functions improvement. During the project lifecycle, WP8 provides consistent support to other WPs to ensure smooth implementation and integration.

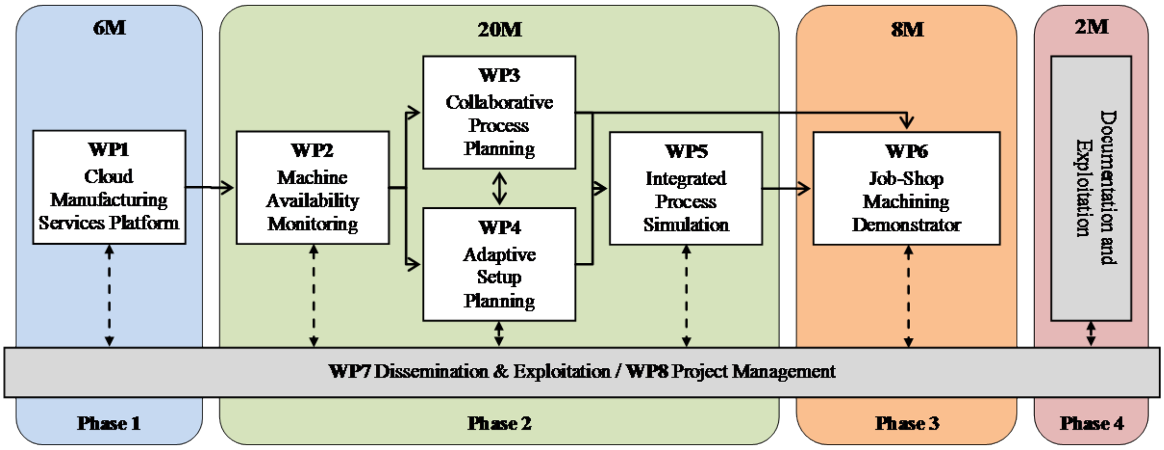


Figure 3. Work packages in different phases and their logical interdependencies

In general the output of CAPP-4-SMEs project is successful and promising solutions for the manufacturing industry. As shown in Figure 4, the total cycle time for process planning is shortened due to the faster speed of each planning stage. Moreover, with the trust worthy data from the shopfloor, the feasibility of CAPP-4-SMEs solution is higher than conventional solutions, thanks to the monitoring modules.

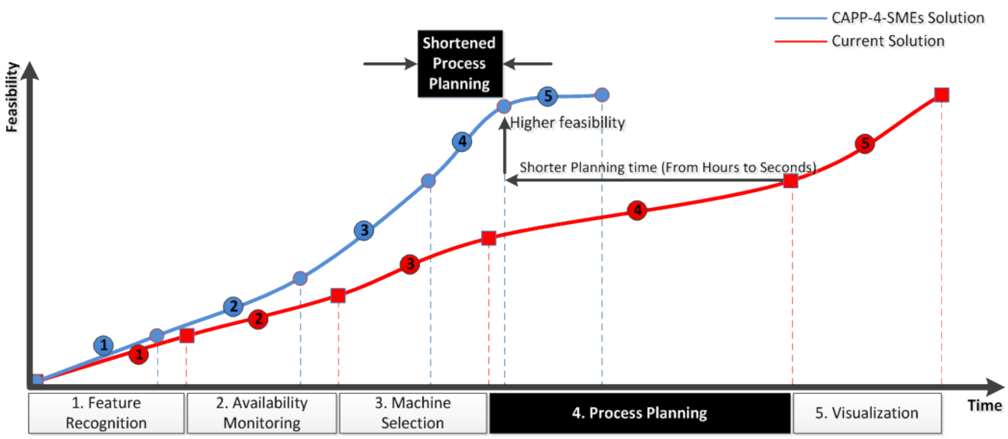


Figure 4. Shorter cycle time and higher feasibility

Additionally, the CAPP-4-SMEs solution also supports the manufacturing industry with higher adaptability. When there are changes on the shopfloor, e.g. broken of tools, maintenance of machines, the process planning module is able to respond quickly based on the new scenario and machine availabilities. Traditionally, changing machines needs hours or even days of work to re-do the process planning, to make it suitable for the new machines. In CAPP-4-SMEs solution, the respond time can be shortened from hours to seconds, with high adaptability.

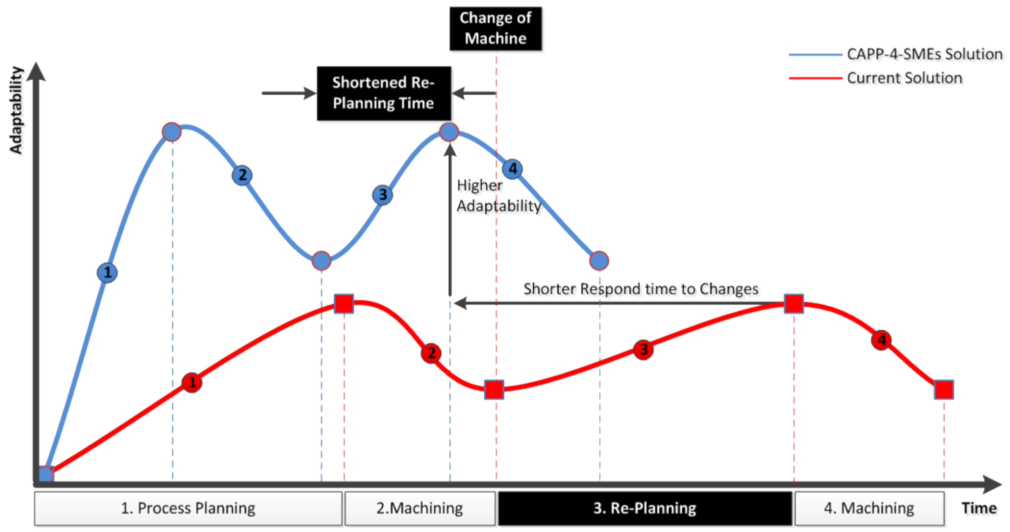


Figure 5. Faster respond to changes

In what follows, the brief description and progress of each WP is summarised. While more detailed progress and achievements can be found in separate reports as deliverables, they may not publicly available. Therefore, *certain repetition is purposely included* here to provide a comprehensive review to general public.

2.2 WP1 — Cloud manufacturing services platform

Work Package Number	*1*	**Start date**		*M1*		
Work Package Title	Cloud manufacturing services platform					
Activity Type	*RTD*					
Participant Name	**KTH**	**COV**	**LMS**	**CU**	**SAN**	**PROD**
Person-months	0.3/0/5	18.74/5.12/17	2.97/0/3	4/4/7	2.17/1.07/8	6.07/0/6
	ICT	**FT**	**AF**	**CAM**	**PKT**	
	1.5/0.5/2	3.31//4	2/1/2	0.2/1.4/2	2/2.5/2	

2.2.1 Objective

WP1 is to design and develop a service-oriented platform for Cloud manufacturing, where monitoring, planning, optimisation and execution control services can be provided.

2.2.2 Description of work

The challenges to be addressed in this WP include protocol design to support real-time communication between machines and services, smart controller design for dynamic changes in manufacturing environments and reliable integration of services. Detailed work plan and task breakdown to address the challenges are listed below.

T1.1: State-of-the-art technology requirements (COVUNI) - *Completed*

This task focuses on surveying the currently available Cloud and service-oriented infrastructure, interfaces and APIs for all stakeholders, in order to facilitate the advance in building a flexible and plug-n-play architecture for easily expandable software platforms. A survey of available architectures and systems concerning service definition, entity modelling and module interaction was performed. COVUNI is mainly responsible for this task, with the participation of CU, KTH and LMS.

T1.2: User requirement analysis and test case design (CU) - *Completed*

A detailed study of user requirements in the collaborative process planning architecture was performed, identifying the major factors that affect the efficiency and quality of the architecture. Based on the requirements and specifications, a set of test cases were defined for the architecture, as well as for the integrated services as a whole. Unit tests, interoperability tests, as well as stress tests will be provided to platform developers for validation of the work performed. CU is leading this task, coordinating the work of COVUNI, SAN and SME end-user partners.

T1.3: Architecture design and implementation (COVUNI) - *Completed*

Using input from the above tasks, the early and final architecture was designed and implemented, respectively, including machine/service communication protocol design, smart controller and service provider design, interface design for process planning services and function block-based functions, and service deployment into the Internet for remote invocation. The architecture will be tested based on T1.2. COVUNI is coordinating this task, with participation from CU, KTH and LMS.

T1.4: Service integration and testing (COVUNI) - *Completed*

The first step towards the integration of the functional services into the architecture is the consolidation of the input from individual functional services. This task will provide both the generic guidelines for the development of the functional services, as well as the exact integration tests for the early and final services and platform. The following aspects will be addressed and defined within the implementation and integration methodology:

- The implementation aspects of the integration interfaces. Special effort will be provided in order to ensure the openness and extensibility of the platform
- The GUIs and adaptability requirements
- The way to practically deal with the smooth content flow between the different services in the environment.

2.2.3 State-of-the-art technology requirements (Task 1.1)

Reflecting task 1.1, a thorough study on State-of-the-art technology requirements was taken and summarised in the approved deliverable D1.1. Literature Review on *Collaborative Manufacturing Systems* is also completed based on 76 literatures. The topic of analysis includes:

- Cloud and future Internet technologies
- Cloud technologies for manufacturing applications
- Function block-driven process planning
- Machine availability monitoring

The originality and innovation of the CAPP-4-SMEs approach are identified also in the field of machine availability monitoring. In the domain of data acquisition, analysis and visualisation, the following advances beyond state of the art are envisioned.

The advanced embedded multi-sensory systems will address the need for intelligent sensors with capabilities of noise reduction, multi-parameter monitoring and online data sharing. In combination with data retrieval directly from the machines' controllers, the information fusion service will leverage the data and provide meaningful information to process planning and simulation modules. CAPP-4-SMEs will implement sensor systems with multiple sensing abilities (acoustic emissions, vibrations, proximity sensors, etc.), miniature size and light weight, low power consumption, long range and high data transmission rate, large on-board memory, fast on-board data processing, low cost, and high reliability. All the aforementioned characteristics are necessary since they are specifically advantageous to machine availability applications. In general, sensor systems will have sensing elements, on-board analogue-to-digital converters, on-board memory, embedded micro-controllers, data transmission, and a power source or supply. The connection between internal and external devices will be performed with wireless data transmission interfaces.

An advanced intelligent engine is capable of performing fault detection and degradation capturing. Symbolic Dynamic Filtering (SDF) is considered for fault detection and deviation from the nominal conditions among other methods. SDF is a statistical pattern recognition method for studying dynamical systems that is characterised by its robustness to measurement noise and spurious signal and by its adaptability to low resolution sensing due to the coarse graining in space partitions [2]. In particular, reference time series, stored in the repository, and time-series acquired by the sensors are compared and analysed with SDF.

Degradation capturing is performed with the use of life expectancy models (remaining useful life) and ARIMA models are considered for that matter.

The envisioned innovations regarding visualisation technologies are described hereafter. CAPP-4-SMEs is expected to visualise results in an intuitive and remote manner on performance indicators such as energy consumption and remaining useful life utilising advanced visualisation technologies. Visualisation tools such as smartphones and industrial screen are considered, which are low cost, and easy to be handled by engineers even in shop floor environment.

In addition, a **survey of related EU and national projects was also achieved in comparison with CAPP-4-SMEs project**. The innovations of CAPP-4-SMEs in relation to some key projects related to process planning and machine monitoring are summarised below.

Table 1. Innovations of CAPP-4-SMEs in relation to other European projects

Project	Relevant Results	CAPP-4-SMEs Innovation
KoBaS Knowledge Based Customised Services for Traditional Manufacturing Sectors Provided by a Network of High Tech SMEs; FP6-2002-NMP-2	This project aims at the development of a set of tools to enable the quick customisation of solutions in order to provide advanced task and process planning, machine configuration, maintenance, training and management support, based on techniques such as Virtual Reality, 3D & Discrete Events Simulation, Knowledge Based Systems and Finite Element Analysis.	CAPP-4-SMEs envisages to perform collaborative and adaptive process planning through the monitoring data directly from equipment. Such maintenance data will be distributed within different levels, equipment, end-users and OEMs.
LOTPIM Predictive Maintenance System For Industrial Machinery Based On Induction Motor Current Analysis, Wireless And Self- Power Technologies; FP6-SME	This project aimed at implementing a predictive maintenance system specialised to machines analysing motor's current. However, LOTPIM did not developed a system facilitating the visualisation of the results, utilising user friendly technologies such as augmented reality.	CAPP-4-SMEs envisages to collect a more versatile monitoring information from equipment as performing maintenance planning and maintenance analytics within equipment level. Moreover, CAPP-4-SMEs envisages to develop visualization of the results among the different users levels.
MOSYCOUSIS Intelligent Monitoring System based on Acoustic Emissions Sensing for Plant Condition Monitoring	This project aims at the development of a predictive maintenance system based on acoustic emissions phenomenon. Acoustic emissions phenomenon can come from systems under movement.	CAPP-4-SMEs envisages the development of an advanced monitoring infrastructure with the usage of multi-sensory installations to capture a wide spectrum of data.

Manufacturing CAPP systems have been evolving over time to meet changing customers' requirements and emerging technologies. It is envisaged that the next generation CAPP system would not only have access to product data, process data, and resource data, but also has the additional ability to create a capability-adjusted process plan based on an actual resource capability instead of the nominal resource information. Hence, there is a need for the ability for online tracking of resource utilisation, multi-objective decision support for planning and simulation, and on-board execution control at different locations, seamlessly and collaboratively.

2.2.4 User requirement analysis and test case design (Task 1.2)

User requirements are essential for the decision of the aim and structure of CAPP-4-SMEs solutions. It also helps on deciding the actual software structure as this depends on the needs and expectations of the user as well as the availability of tools and software.

This subsection reports the interviews that have been performed with two companies: PowerKut and Prodintec to provide a *Requirements Analysis* for the project. The first two interviews targeted the CAD/CAM users' and manufacturers' view and investigate the typical process steps of making a part. The semi-structured interviews also tried to investigate the requirements for process optimisation and user expectations (*Improvement and Company Interests*).

2.2.4.1 *Comparison and analysis of the requirements interviews*

When comparing what were mentioned during both interviews, it appears that although both companies are SMEs producing machined parts, they do not have identical approaches in their decision process and in their process planning. However, they reached a common agreement when it comes to the requirement suggestions.

In summary, a future Cloud based system would need to support Windows-based systems at least at the user's end. A Microsoft oriented environment was recommendable. However, the hardware environment is diverse.

2.2.4.2 *Case studies*

Three sets of potential parts have been proposed. The choice came from the end user partners, as they are the representatives for potential users of the final CAPP-4-SMEs system. The aim of the design of the parts was to:

- demonstrate the challenges posed by real-world applications
- show different stages of complexity of real-world parts based on standard CAD geometries
- provide a set of data in form of CAD data (partially including tolerances) and CAM tool paths
- provide a communication platform to discuss the decision processes for making these parts
- provide a test bed for the development of the software

As shown is Figure 4, the parts had to be non-sensitive with regards to confidentiality while being realistic enough to demonstrate the complexity of real-world parts.

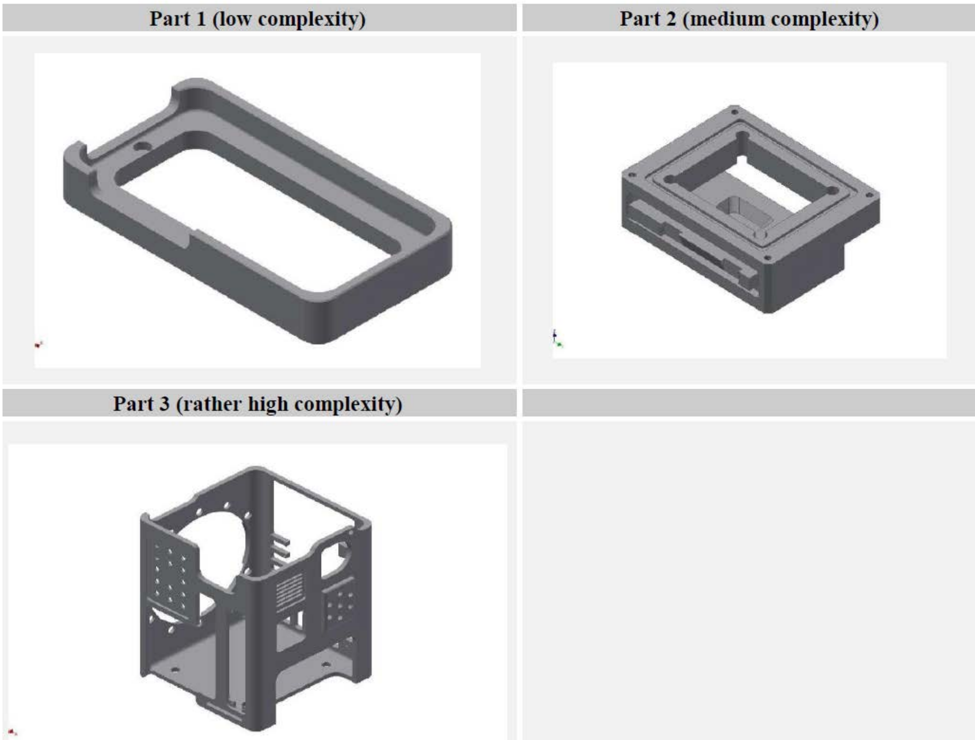


Figure 6. Case studies, parts provided by Prodintec

2.2.5 Architecture design and implementation (Task 1.3)

Based on inputs from literature reviews and user requirement analysis in previous sections, the early architecture of CAPP-4-SMEs system was designed. Existing architectures for collaborative CAPP systems can be classified into three types: thin server + strong client, strong server + thin client, and peer-to-peer. In the first architecture, clients are equipped with whole system functions and some communication facilitators. A server plays as an information exchanger to broadcast design and manufacturing files or commands generated by a client to other clients during a collaborative design process. In the second architecture, the data structures in clients are lightweight and they primarily support visualisation and manipulation functions (selection, transformation, changing visualisation properties of displayed parts, etc.). The main planning/optimisation activities are carried out in a common workspace in the server side. A thin/strong representation in client/server respectively has been proposed to enhance the performance of the system effectively [3, 4]. The third architecture, including [5], and Inventor collaborative tool™, supports the sharing and manipulation of services or modules of a system by other systems.

Given the targeted user groups of the CAPP-4-SMEs system, the second architecture has been chosen and designed based on open-source software. The entire system is shown in Figure 5. Completed blocks are highlighted while others are ongoing. This system consists of three primary layers: (1) a Client Tier to enable product visualisation, manipulation of design parts and machine monitoring over Web browsers; (2) an Application Tier to support function-blocked based process planning, machine monitoring and dynamic scheduling residing in the server side; and (3) a Data Tier to store relevant databases including feature-based models, machine and cutter databases in the server side. The implementation of the 3-tier system architecture is illustrated in Figure 6.

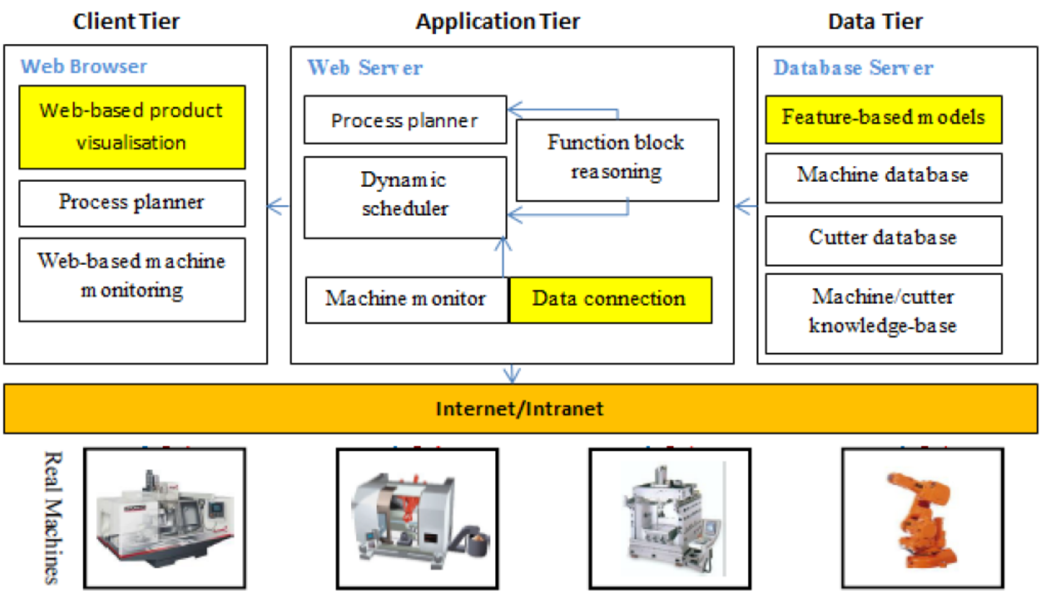


Figure 7. Conceptual design of system architecture

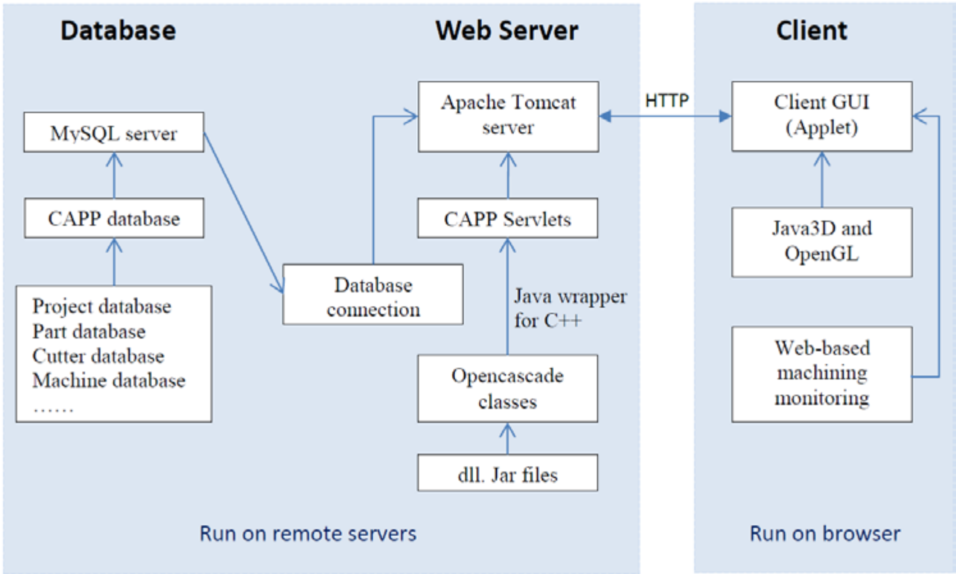


Figure 8. Implementation of the architecture

2.2.6 Service integration and testing (Task 1.4)

2.2.6.1 *Event-based mechanism for distributed objects*

An event-based mechanism based on a multiple-layer inheritance structure is used to wrap the exchanged information in a structural and extensible way to take advantages of object-oriented concept. In the first layer, a super-class of events, which inherits the "Serialisable" class of the Java language, is defined and its sub-classes in the other two layers are automatically "Seriablisable". The event classes in the second layer extend the super class and are classified as the following three types mainly:

- Input event in a client. This event wraps the input information in a client and is dispatched to a server for modelling or a service for analysis;
- Object event for a designed part. This event wraps the designed part generated from the collaborative server and sent back to the clients for visualisation and manipulation;
- Analysis event for a designed part. This event is generated by a manufacturing analysis service to bind the generated analysis information for a request from a client.

2.2.6.2 *Functional components in the distributed architecture*

A front-end client embedded in a Web browser provides users with functions for visualising design models, invoking process planning services, connecting database, and displaying results. Primarily, the module consists of five functions: (i) a 3D visualisation environment for manipulating design models, (ii) a 2D visualisation environment for manipulating the optimisation data generated by the process planning services, (iii) an interface to a look-up service with the registered process planning services for identification and authorisation, (iv) an interface to a distributed feature-based design system to exchange design models and relevant information for visualisation and analysis, and (v) an interface to a database to retrieve and store information.

The main applet frame is composed of four sections: the menu/toolbars, the 3D visualisation, display, the machining tree and feature definition buttons as is shown in Figure 7.

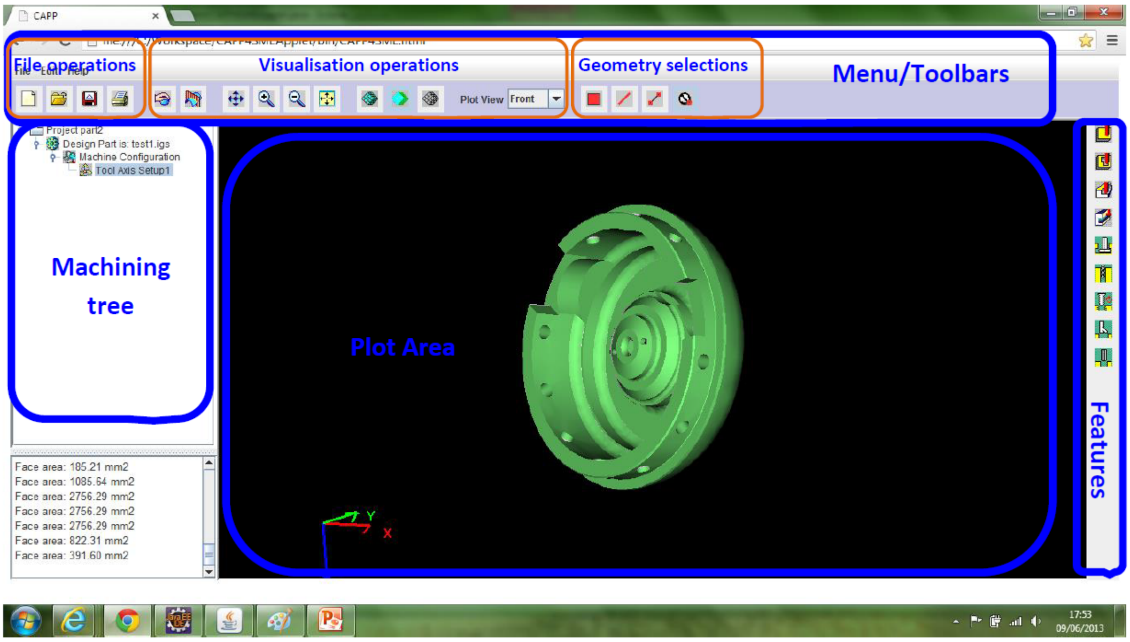


Figure 9. Web-based user interface

2.2.7 Summary

In the entire system, an event-based mechanism enables high-performance communication between functional modules, users and systems. The integrated system can effectively support a dispersed team for carrying out collaborative process planning activities. The multiple-layer inheritance structures designed for the communication events and the integration strategy for manufacturing analysis services ensure the system to be extensible and scalable.

The system is developed via multiple methods, e.g. Java, HTML, and so forth. A common user interface is also deployed which integrates the development modules from all WPs, i.e. WP1, 2, 3, 4 and 5.

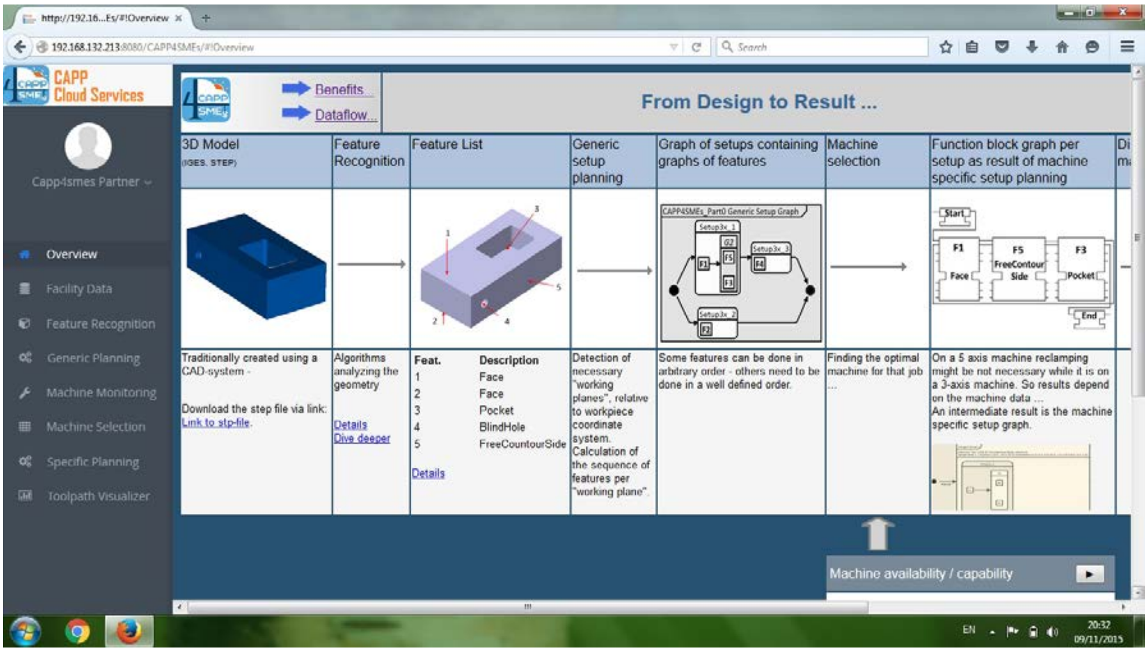


Figure 10. Cloud-based CAPP system via common web browser

2.3 WP2 — Machine availability monitoring

Work Package Number	*2*	**Start date**			*M7*	
Work Package Title	Machine availability monitoring					
Activity Type	*RTD*					
Participant Name	**KTH**	**COV**	**LMS**	**CU**	**SAN**	**PROD**
Person-months	1.8/0/12	8.53/16.28/7	14.89/1.5/17	2.5/4/5	1.07/0.40/7	4.13/2.21/6
	ICT	**FT**	**AF**	**CAM**	**PKT**	
	0/0/0	1.33/0/2	0.5/1/2	0.2/2.6/2	2/2/2	

Objectives:

To monitor and predict machine utilisation and availability, locally or remotely, so that the decision making for planning and optimisation etc. become resource-aware and well informed.

Description of work:

This WP is responsible for developing functions for real-time resource monitoring of availability of machines by continuously checking job execution status on each machine, and for prediction of available time windows of the machines based on the current job completion rate and schedule. In a networked production environment, it is also possible to obtain a holistic view of machine utilisation and to identify any bottlenecks by comparing it against the machines' capacity. The up-to-date information of machine utilisation will be useful for process planning and setup planning (WP3 and WP4) to make well-informed decisions according to the real-world situation. It also facilitates integrated process simulation (WP5) so that optimal process/setup plans can be generated for the right resources at the right time with high throughput. Together with the execution control, this WP bridges the gap between the real world and the cyber world, making Cloud manufacturing services practical and useful to real-world applications and adaptable to unforeseen changes. The challenges to be addressed in this WP include real-time constraint over the Internet and non-open architecture CNC controllers when striving to collect and share information instantly.

T2.1: Interfacing CNC controllers for on-site data collection (LMS) - *Completed*

This task is responsible for on-site on-machine data collection in real time. The data collected are sent to an app server in the Cloud for processing. Machine built-in sensors and CNC controllers are being integrated with the services platform. Communication protocols will be cross-examined to meet the real-time constraint of data transmission over the Internet. This task is led by LMS.

T2.2: Function block-based remote execution monitoring (KTH) - *Completed*

In the Cloud manufacturing environment, remote monitoring of machining process may be infeasible due to security protection or the lack of sensor networks. Under such circumstance, function blocks can be used to achieve the purpose of machine availability monitoring by checking the execution status of the function blocks. This task embeds an event-driven monitoring algorithm in each function block that represents a part of a process plan. Once a machining job (a set of function blocks) is dispatched to a chosen machine, the embedded algorithm can be triggered to monitor the execution status of the job, and indirectly the availability of the machine. KTH is leading this task.

T2.3: Real-time visualisation for monitoring over the Internet (LMS) - *Completed*

Once the information from T2.1 and T2.2 are received, the information will be presented and visualised intuitively to end users. This task takes care of the real-time visualisation of the sensory data for remote monitoring. To best utilise the limited network bandwidth, 3D models are used for viewing purpose. The models will be connected to and driven by the sensor data to provide a holistic view of a real production environment. A 2D view will be developed for more complex situations. The task is coordinated by LMS, with active participation of KTH and CU.

T2.4: Information-fusion service to end users (LMS) - *Completed*

Sensory data from varying sources often possess different meanings. If not used properly, the data may result in misleading information. In order to convey the right information to the right user at the right time, an information-fusion service must be provided in this task by pulling varying sensor data together for a content-specific purpose, e.g. machine utilisation or energy efficiency of a given machining process. Such service will provide added values to optimal process planning and simulation. LMS is in charge of the task with participation of CU and COVUNI.

T2.5: Development of a service-oriented web-based monitoring system (LMS) - *Completed*

This task is responsible for developing an integrated prototype system that can be plugged in to the Cloud manufacturing services platform of WP1. The prototype shall have a web user interface, and can direct users' requests to the app server for sensor or function block data collection, in addition to monitoring machine availability. The task is led by LMS, supported by COVUNI and KTH.

2.3.1 Requirements for the machine monitoring module

Five main topics are investigated in order to implement a machine availability monitoring module: data acquisition, sensory systems, data processing, data fusion, integrated platforms and finally visualisation techniques. For data acquisition, data must be retrieved from a milling machine with the use of a sensory system or through the controller interfacing. Machine availability, tool availability and prediction of machine availability window are the main outputs of the monitoring system. The next field of investigation is data processing. Data processing techniques should be implemented for processing data in order to transfer it subsequently from the machine to a cloud environment to be analysed. Moreover, machine, tool, fixture specifications have to be incorporated in the monitoring module not only for internal use but also for integration and data exchanges. Finally, visualisation techniques for visualising monitoring results regarding the machine's status, energy consumption, machine availability window are investigated in order to perform a usable and friendly graphical user interface for the end users, as shown in Figure 9.

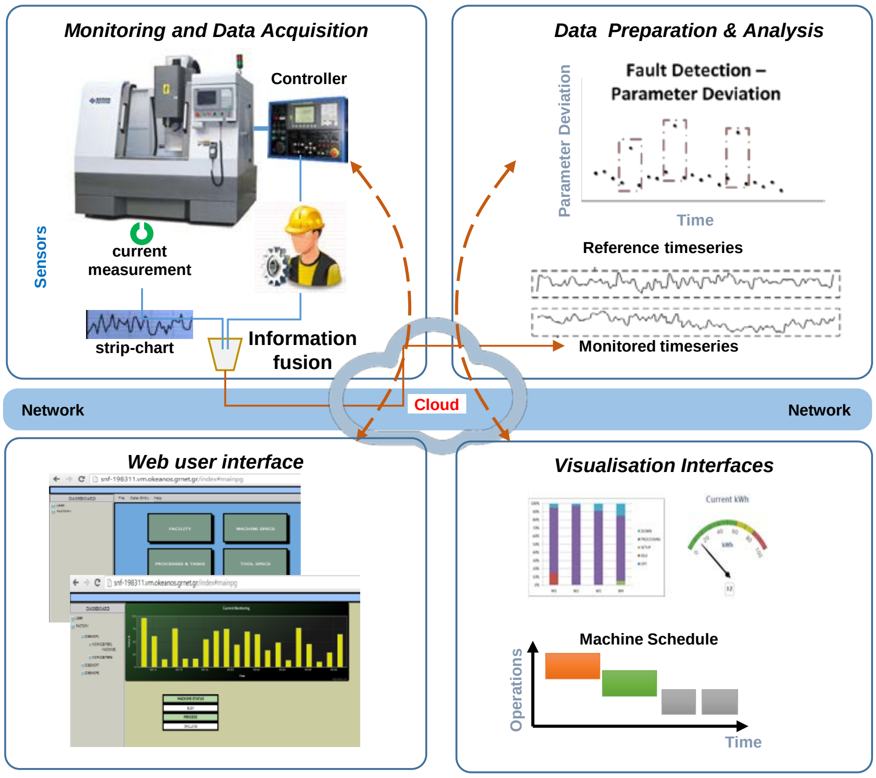


Figure 11. Main requirements of machine availability monitoring

2.3.2 Specifications of the module and overall architecture

The overall architecture of the machine availability monitoring system consists of six main parts. Data acquisition is the first one, where data can be retrieved from a milling machine through sensors, controllers and human input. Alternative way is the integration of the monitoring system with an external scheduling system, as shown in Figure 10.

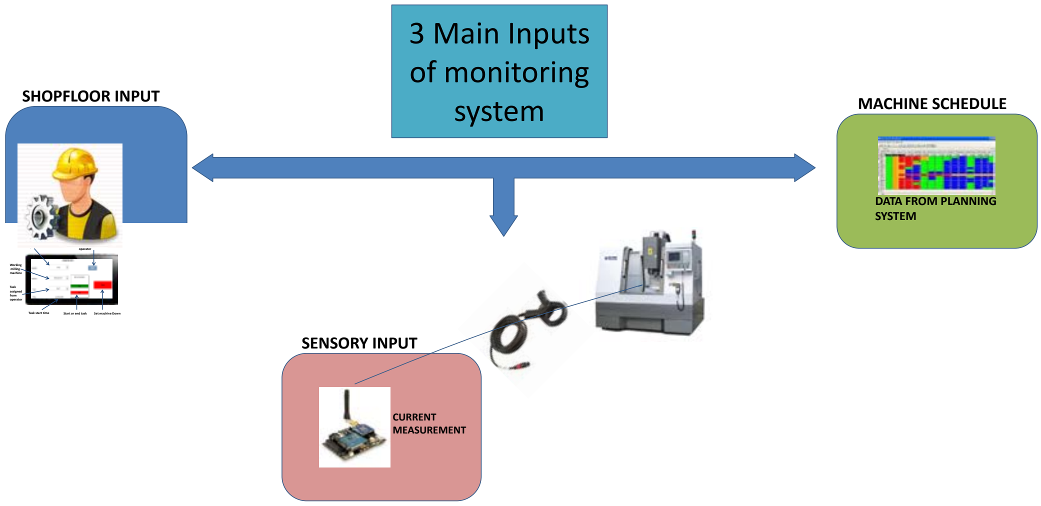


Figure 12. Three main inputs of the monitoring system

The second step includes monitoring the retrieved data, using Waspmote and Raspberry Pi devices. Waspmote is an open source wireless sensor platform for implementation of low consumption modes which allows the sensor nodes to be completely autonomous. Raspberry Pi is a credit-card sized computer that collects all the data from the Waspmote and sends it to a

Cloud database. The data is subsequently analysed, prepared and processed through algorithms inside the Cloud environment and then the results are visualised in a user-friendly web interface, as shown in the overall architecture of WP2 in Figure 11.

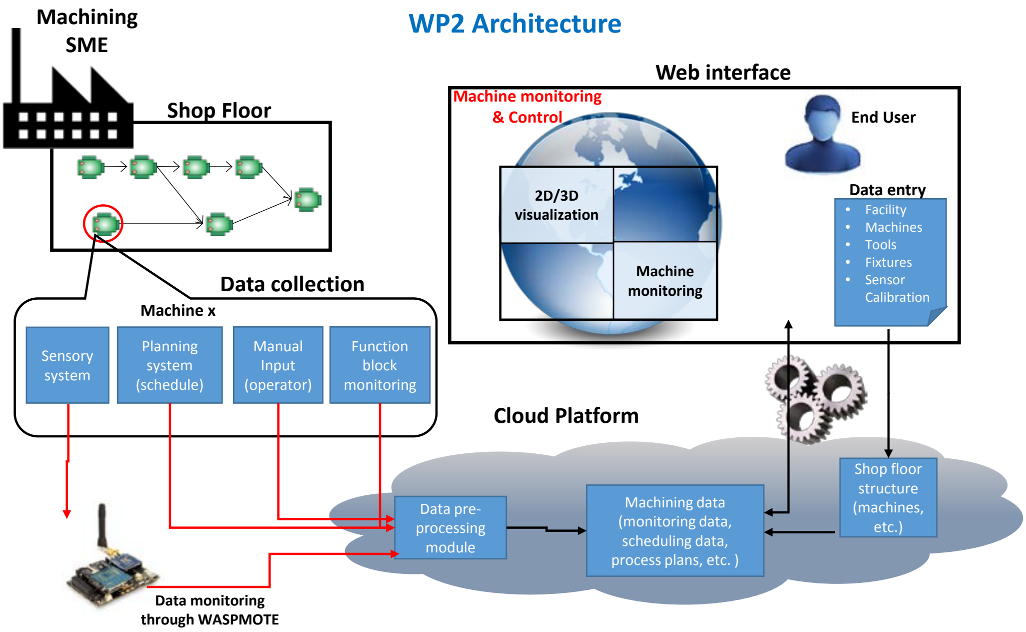


Figure 13. WP2 overall architecture

2.3.3 Data collection (Task 2.1)

At the time of compilation of this subsection, the sensor used is a current sensor. As part of task 2.1, data acquisition and monitoring of the machine in real time is necessary. Thus, sensor implementation was established to meet real-time constraint of data transmission over the Internet. Apart from sensors, a machine operator is necessary for other tasks, such as data acquisition from schedule and co-workers, which are not possible without the operator. For monitoring purposes, the data acquired from *current* measurements are categorised to give the availability of a machine. The measurements taken from the sensors are 'translated' to the users for specific purposes. Our approach (in Figure 12) is based on the availability of a machine. Processing, non-processing and down are the different status of the machine. If the machine is non-processing, the machine is available and new tasks can be added to the machine. Otherwise, new tasks have to wait until the machine becomes available.

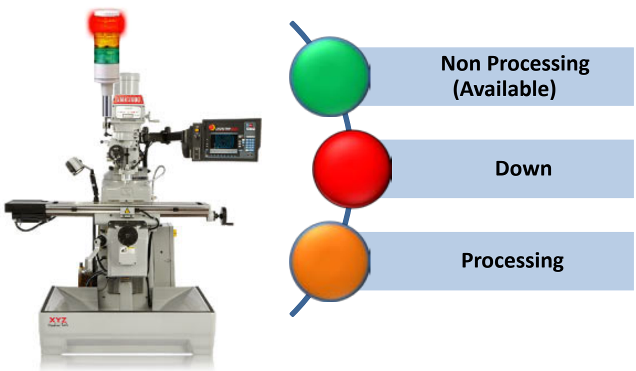


Figure 14. Machine statuses

The main outputs of the system are machine current status, machine availability window, machine utilisation and machine power consumption. The machine status is derived from the information fusion technique using the inputs of the system. Machine utilisation is then calculated from the following equation [6]:

$$\text{Utilisation} = \frac{Processing\ Time}{Available\ time} \text{ (in \%)}$$

Moreover, power consumption is calculated. Power measurements were performed in 5 machines for each mode of the machine. Finally, machine availability window is calculated based on the machine schedule, gathered from a shop-floor production planning system.

2.3.4 Information fusion (Task 2.4)

Sensory data from varying sources often possess different meanings. If not used properly, the data may result in misleading information. In order to convey the right information to the right user at the right time, an information-fusion service must be provided in this task by pulling varying sensor data together for a content-specific purpose. The methodology used here is shown in Figure 13.

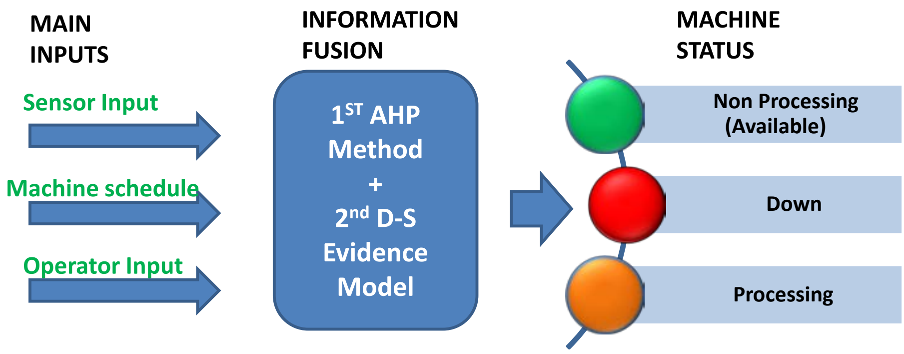


Figure 15. Decision fusion for machine status

First, the AHP method is used to decompose the problem into a hierarchy of criteria and alternatives. Five criteria are defined here: precision, synchronisation, flexibility, error probability and prediction capability. Precision refers to the error rate of the chosen method and synchronisation refers to the ability of the method to track real time changes of the machine operating mode. Flexibility indicates each method's monitoring capability. Error probability is the reliability of the chosen method and prediction capability is the ability to obtain an indicator for the machine future status.

Second, the Dempster-Shafer theory is applied. It uses a number in the range [0,1] to indicate belief in a hypothesis given a piece of evidence. This number is the degree to which the evidence supports the hypothesis. The impact of each distinct piece of evidence on the subsets of Θ is represented by a function called a basic probability assignment (bpa). A bpa is a generalisation of the traditional probability density function; the latter assigns a number in the range [0,1] to every singleton of Θ such that the numbers sum to 1. Using 2^{Θ}, the enlarged domain of all subsets of Θ, a bpa denoted *m* assigns a number in [0,1] to every subset of Θ such that the numbers sum to 1.

The AHP results are used to assign each method a subjective probability of being reliable by representing each method's evidence by a belief function that gives a corresponding degree of belief to the machine operating status.

2.3.5 Function block-based execution monitoring (Task 2.2)

According to Task 2.2, an event-driven monitoring algorithm in function block is integrated in the machine availability monitoring module. Figure 14 illustrates how the function block-based module interacts with a machine and presents information to viewers.

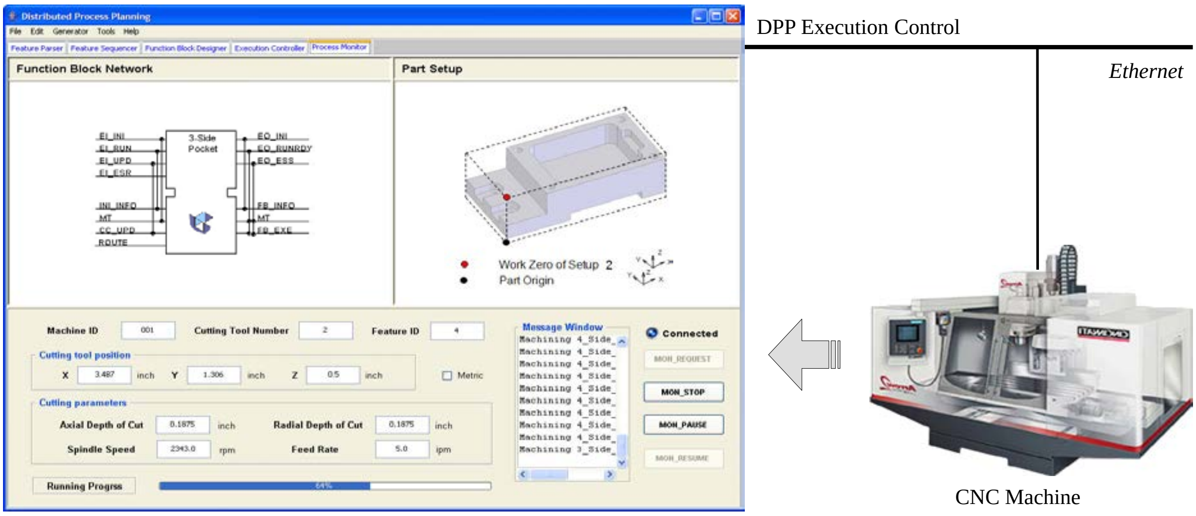


Figure 16. Function block process monitoring

The integrated machine availability monitoring module provides the collaborative process planning module (WP3) and adaptive setup planning module (WP4) with information regarding the machine specification, machine kinematics, tool specification and available tools for each machine.

2.3.6 System implementation

Machine condition monitoring is the process of monitoring the condition of a machine with the intent of predicting mechanical wear and failure. It is dominated by three different types of sensors: accelerometers, tachometers, and proximity probes. The information measured by various sensors is used to feedback control, condition monitoring and fault diagnosis. With the output of the sensor, the real-time detection of machine faults can be achieved. In WP2, an inductive clamp is used as a sensor supported by a sensor board called Waspmote [7].

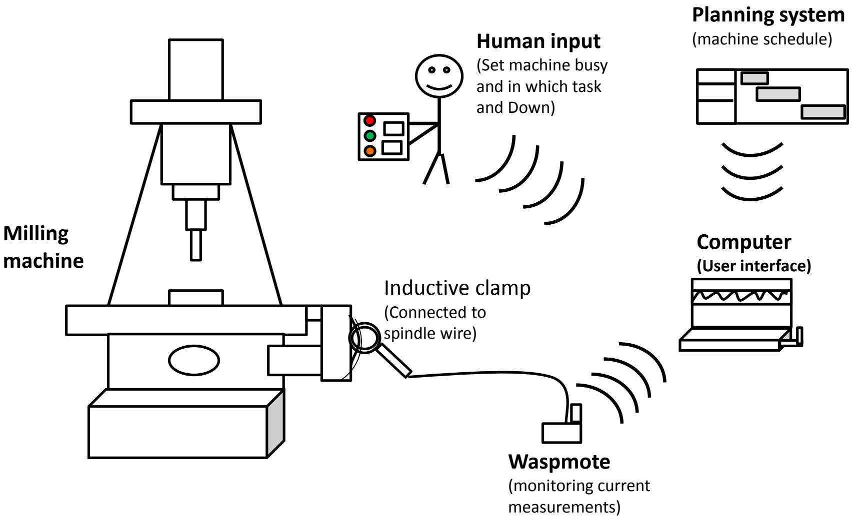


Figure 17. Experimental installation

Figure 15 shows the experimental installation, including a milling machine, an inductive clamp (a current sensor) and a Waspmote (sensor board). The current sensor was connected to the spindle wire through the inductive clamp to measure the current of the spindle. Continuously, the sensor board sends data to a computer via wireless network connection. In parallel, the operator has the capability to send information directly to the computer regarding which task is running in which machine or to set the machine status *down* due to different failure and breakage.

2.3.7 Visualisation – web user interface (Task 2.3, Task 2.5)

A web user interface is where interaction between humans and computers occurs. In our case, the user can input data concerning the facility and its machines, machining tasks, tools and fixtures. For visualisation purpose, a user interface was implemented as shown in Figure 16.

Figure 18. System information

In addition to the facility information, a user can choose to monitor a specific machine. As shown in Figure 17, the green light is for available machines, red for defining that the machine is down and yellow for processing machines.

Figure 19. Main outputs of a machine

2.3.8 Summary

In WP2, a prototype for machine availability monitoring is implemented. Subsequent development and documentation are be summarised in D2.2 “Prototype for web-based real-time monitoring”.

Three main inputs are considered in the prototype. Sensory input from current sensors, machine schedule through a planning system, and input from the shop floor through machine operators. The data collection for a milling machine, the data acquisition, the data processing, information fusion and finally the visualisation of the results are the five main fields that were investigated in this WP and comprise the outcomes of the first prototype of machine availability monitoring. A set of user interfaces is readily available for data entry, results visualisation and manipulation of monitoring parameters. The outputs of WP2 are the essential inputs for process planning and setup merging. The Machine Availability Monitoring module will be further integrated with the function block monitoring module, and the sensory system will be enhanced through the addition of visual sensors. The task of interfacing CNC controllers will also be further investigated; a CNC controller simulation system will be integrated with the monitoring module, providing the necessary data for estimating processing time or predicting tool breakage or machine collision. Finally, the prediction of machine availability windows will be further investigated, in terms of its accuracy improvement.

2.4 WP3 — Collaborative process planning

3 Work Package Number		3	Start date		M7
Work Package Title	Collaborative process planning				
Activity Type	*RTD*				
Participant Name	KTH	COV	LMS	CU	SAN	PROD
Person-months	12.3/69.04/18	6.26/1.08/7	2.24/7.66/10	0/6/5	3.48/0.75/6	4.97/1.59/6
	ICT	FT	AF	CAM	PKT	
	2.5/1.5/4	3.31//4	0/0/0	0.2/2.1/2	0/0/0	

Objective:

To develop a web-enabled and knowledge-based tool for dispersed engineering teams to create non-linear process plans collaboratively, using the services of Cloud manufacturing

Description of work:

This WP is responsible for developing the core functionality of process planning, as a service-oriented knowledge-based tool of CAPP-4-SMEs. In order to deal with factory-level uncertainty such as tool shortage, machine breakdown, missing fixtures, job delay, rush order, etc., a process plan is better to have built-in flexibility and adaptability that can adjust itself to a change in a timely manner. Two enabling technologies are used for system implementation: machining features and function blocks. The major challenges of this WP are collaborative decision making, robustness of algorithms, and how to design function blocks and interface with CNC controllers to replace G-code. Details of work breakdown in tasks and the role of partners are listed below:

T3.1: Service-oriented browser/server architecture design (KTH) - *Completed*

This task is to design a sub-system architecture for the collaborative process planning module that enables CAPP services via a standard web browser. Core decision-making logics will be placed in a secure app server in the Cloud. The architecture must comply with and be plugged in to the services platform of WP1. Seamless information sharing and synchronisation among end users is the major challenge towards multi-party collaboration. The task is led by KTH with support from COVUNI.

T3.2: Web-based supervisory planning (KTH) - *Completed*

This task is to analyse the design data of a component, prepare a list of machining features, sequence the features according to datum references and manufacturing constraints, and generate a machine-neutral non-linear process plan. This functionality will be web-based, with reasoning support and knowledge references from the services platform. This task will also develop a thin-client web user interface to facilitate supervisory planning and deploy resultant decision algorithms in the app server.

T3.3: Design and development of a function block designer (KTH) - *Completed*

Function blocks are used extensively in CAPP-4-SMEs to carry a non-linear process plan all the way to a CNC controller for part machining. Each function block needs to be properly defined in terms of internal algorithms, execution control mechanism, and I/O events and variables. A dedicated web-based iconic function block designer will be developed by KTH. The designer will also allow function block re-design or modification, and store defined function blocks in a shared library for reuse.

T3.4: Job dispatching and execution control (KTH) - *Completed*

On top of the services platform of WP1, this task will implement a user portal for job dispatching and execution control/monitoring. The portal must interface with WP2 and WP4 to obtain availability info of machines and final optimal setup plans. This task will also research on appropriate communication method to effectively connect with closed-architecture machine controllers.

T3.5: Controller-level runtime operation planning (KTH) - *Completed*

The functionality of on-board operation planning is novel in this project and crucial to intelligent CNC machining. This task addresses the challenge by developing a prototype that facilitates event-driven algorithms execution for generating detailed operation plans for open-architecture controllers or last-minute G-code generation for legacy controllers. Smart algorithms for on-board on-time local optimisation will be developed jointly with CU, SAN, FT and CAM.

While the first four tasks are to implement new services for the common platform, the last task is to deploy an add-on module to machine controllers. In the case of legacy controllers, a front-end computer will be used to host the module for runtime operation planning.

3.1.1 Process planning and execution (Task 3.1, 3.2)

A process plan generally consists of two parts: *generic* data (machining method, machining sequence, and machining strategy) and *machine-specific* data (tool data, cutting conditions, and tool paths). A two-layer hierarchy is, therefore, considered suitable to separate the generic data from those machine-specific ones in Cloud-DPP, as shown in Figure 18.

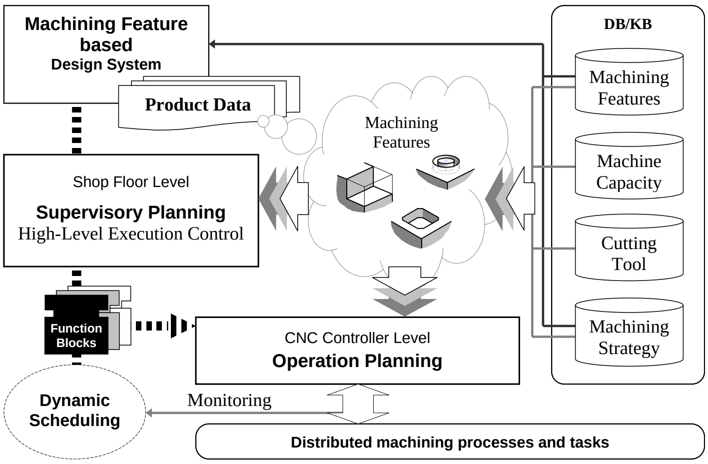


Figure 20. Concept of distributed process planning

The services provided by Cloud-DPP are divided into two groups and accomplished at two different levels: shop-level *supervisory planning* and controller-level *operation planning*. The former focuses on product data analysis, machining feature decomposition, setup planning, machining process sequencing, jig/fixture selection, and machine selection. The latter considers the detailed working steps for each machining operations, including cutting tool selection, cutting parameters assignment, tool path planning, and control code generation. Between supervisory planning and operation planning, scheduling functions can be integrated by means of function blocks. Because of the two-level structure, the decision-making in Cloud-DPP becomes distributed in terms of (1) timing (supervisory planning *in advance* vs. operation planning *at runtime*) and (2) location (supervisory planning in *one* office workstation vs. operation planning by *many* machine controllers). The separation of decisions also makes the high-level process plans generic and portable to alternative machines. In other words, since a final process plan is generated adaptively yet at runtime by CNC controllers, there is no need to generate redundant alternate process plans, resulting in much reduced unnecessary re-planning effort and machine waiting time.

The Cloud-DPP is not limited to the task of process planning. It also covers process plan dispatching and execution monitoring at shop floor and machine levels. Such functionalities are designed into the system architecture as shown in Figure 19, where supervisory planning, execution control and operation planning are the three major components. The execution control looks after the dispatching of jobs while interfacing with scheduling and monitoring modules to retrieve the latest information on the availability of resources and status of machines.

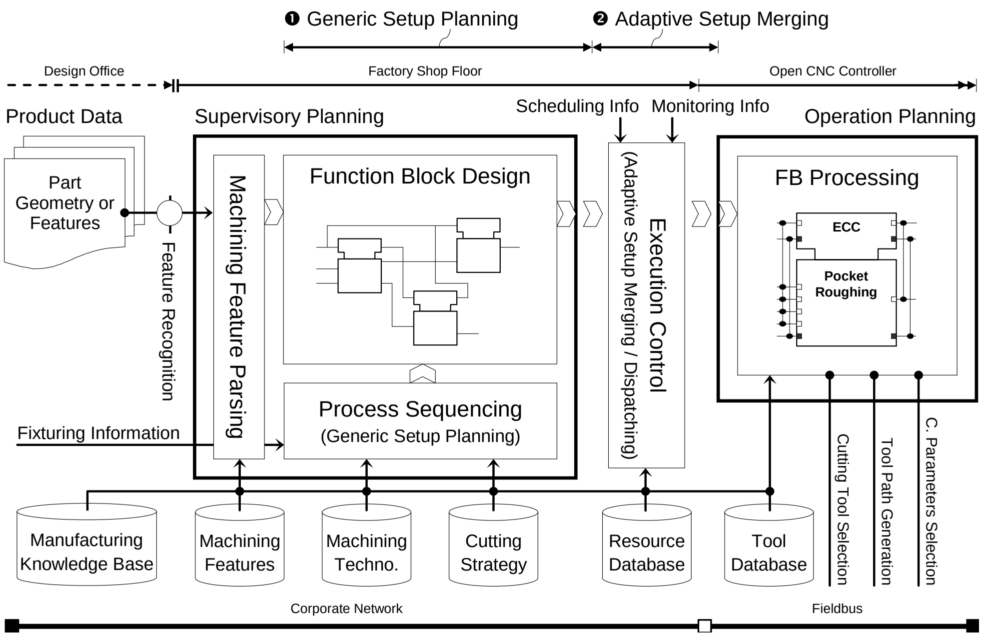


Figure 21. System architecture of Cloud-DPP

During supervisory planning, a generic setup plan can also be created by grouping machining features according to their tool access directions. The generic setup plan is for 3-axis machines as they form the basic configuration of machine tools on a typical machining shop floor. Necessary setup merging for 4- or 5-axis machines is conducted during the execution control and before setup dispatching to best utilise the capability of the higher-end machines.

3.1.2 Design and development of a function block designer (Task 3.3)

A Function Block Designer (FBD) is implemented in Java to facilitate process planning engineers during collaborative process planning. The objective is to develop a web-based system for multiple users to share information while fulfilling their duties of collaborative process planning. Enabled by the cloud technology, geographically dispersed team members can thus share knowledge and run-time machining status through a web user interface, location-transparently. The FBD consists of a basic function block designer, a composite function block designer, a function block network designer, and simulation of the function block network. As the name suggests, each designer performs a specific function. The data sharing between the four co-designers are realized through interfaces, via the FBD, with special functions for data communication.

3.1.2.1 *Function Block Design*

The concept of function blocks is described in the IEC-61499 specification [8], as an emerging IEC standard for distributed industrial processes and control systems, particularly for PLC control. It is based on an explicit event-driven model and provides for data flow and finite state automata-based control. It is relevant to the process planning in machining data encapsulation and process plan execution. The event-driven model of a function block gives an NC machine more intelligence and autonomy to make decisions collaboratively on how to adapt a process plan to match the actual machine capacity and dynamics. It also enables dynamic resource scheduling, execution control, and process monitoring. Figure 20 illustrates the internal structures of a basic (left) and composite (right) function blocks. A basic function block can have multiple outputs and can maintain internal hidden state information. This means that a function block can generate different outputs even if the same inputs are applied. This fact is of vital importance for automatic cutting parameters modification, after a function block has been dispatched to a machine, by changing the internal state of the function block. For example, a function block of *pocket-milling* can be used for *roughing* and *finishing* at the same machine or at different machines, with different cutting parameters and tool paths, by adjusting the internal state variables of the function block to fine-tune the algorithms in use.

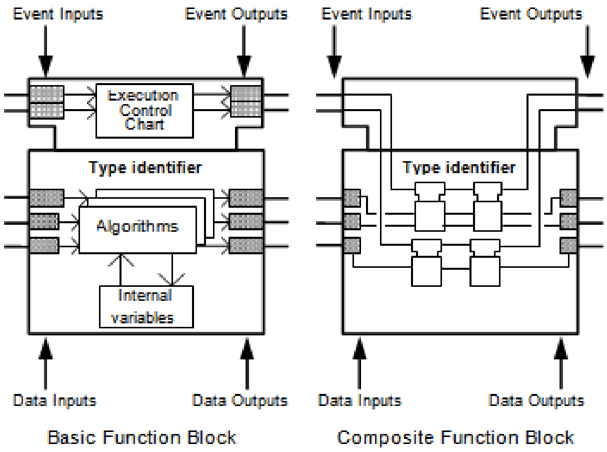


Figure 22. Internal Structures of Function Block

Three types of function blocks are designed for the collaborative process planning:

- Machining feature function block,
- Event switch function block, and
- Service interface function block.

These are the basic function block types for adaptive process plans creation and their execution control. The events among function blocks are also used for machining process monitoring.

3.1.2.2 *UI Design*

User Interface design is important for several reasons. First of all the more intuitive the user interface the easier it is to use. The better the user interface, the easier it is to train people to use it, which reduces the training costs. The better user interfaces the less help people to use it, which reduces the support costs also. The better user experience also leads to more interests from the users, increasing the user's satisfaction with the work [9].

Principles:

- Structure: The User Interface is needed to be organized purposefully, in meaningful and useful ways based on clear, consistent models that are apparent and recognizable to users, putting related things together and separating unrelated things, differentiating dissimilar things and making similar things resemble one another. The structure principle is concerned with your overall user interface architecture.
- Simplicity: The design should make simple, common tasks simple to do, communicating clearly and simply in the user's own language, and providing good shortcuts that are meaningfully related to longer procedures.
- Visibility: The design should keep all needed options and materials for a given task visible without distracting the user with extraneous or redundant information. Good designs don't overwhelm users with too many alternatives or confuse them with unneeded information.
- Feedback: The design should keep users informed of actions or interpretations, changes of state or condition, and errors or exceptions that are relevant and of interest to the user through clear, concise, and unambiguous language familiar to users.
- Tolerance: The design should be flexible and tolerant, reducing the cost of mistakes and misuse by allowing undoing and redoing, while also preventing errors wherever possible by tolerating varied inputs and sequences and by interpreting all reasonable actions reasonable.
- Reuse: The design should reuse internal and external components and behaviours, maintaining consistency with purpose rather than merely arbitrary consistency, thus reducing the need for users to rethink and remember.

The New Graphical User Interfaces (Figures 21, 22, 23)

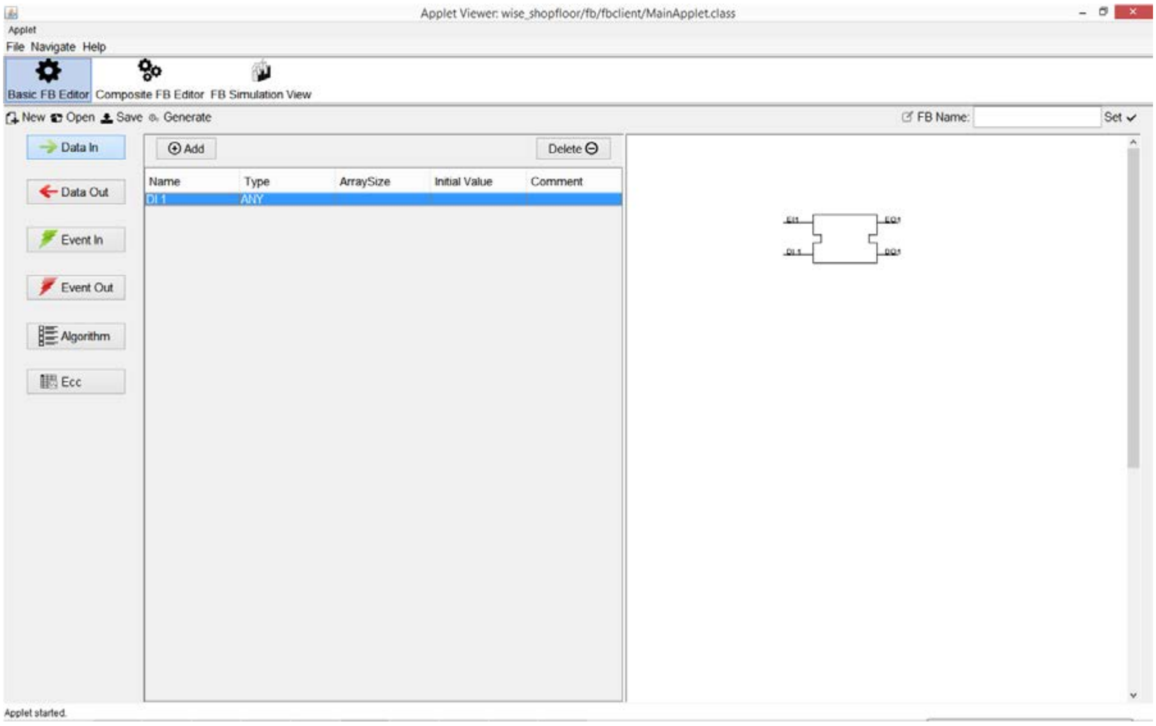


Figure 23. Basic Function Block Editor

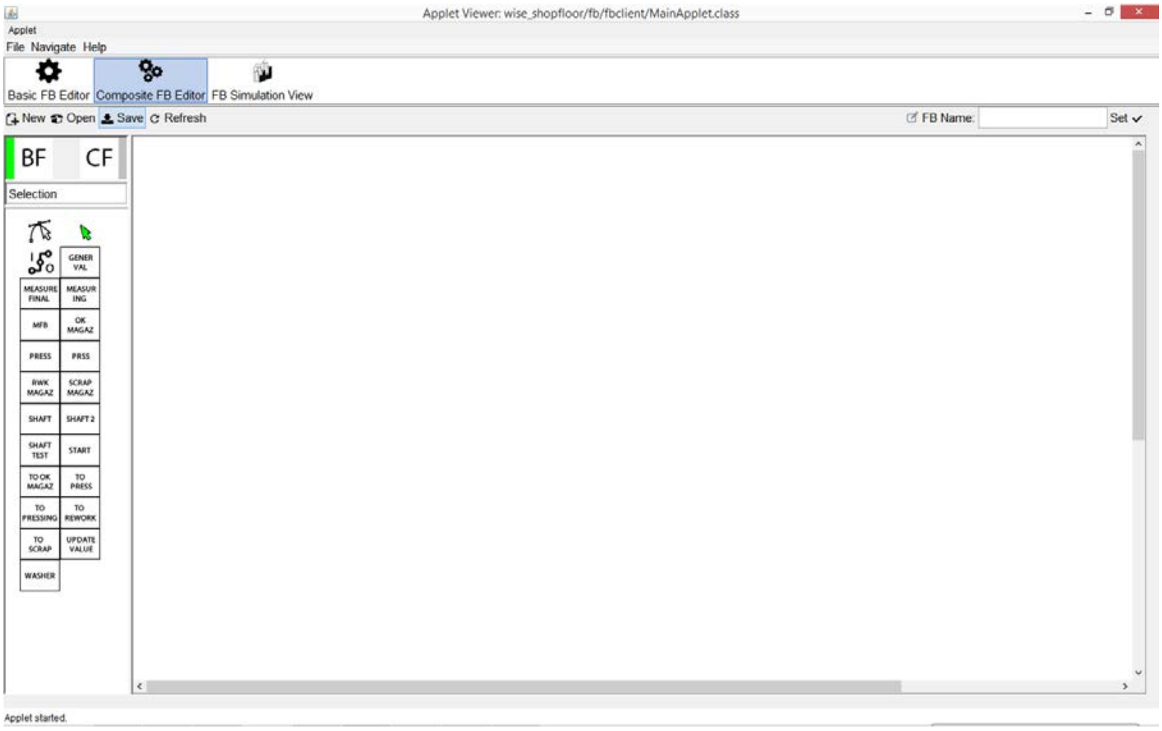


Figure 24. Composite Function Block Editor

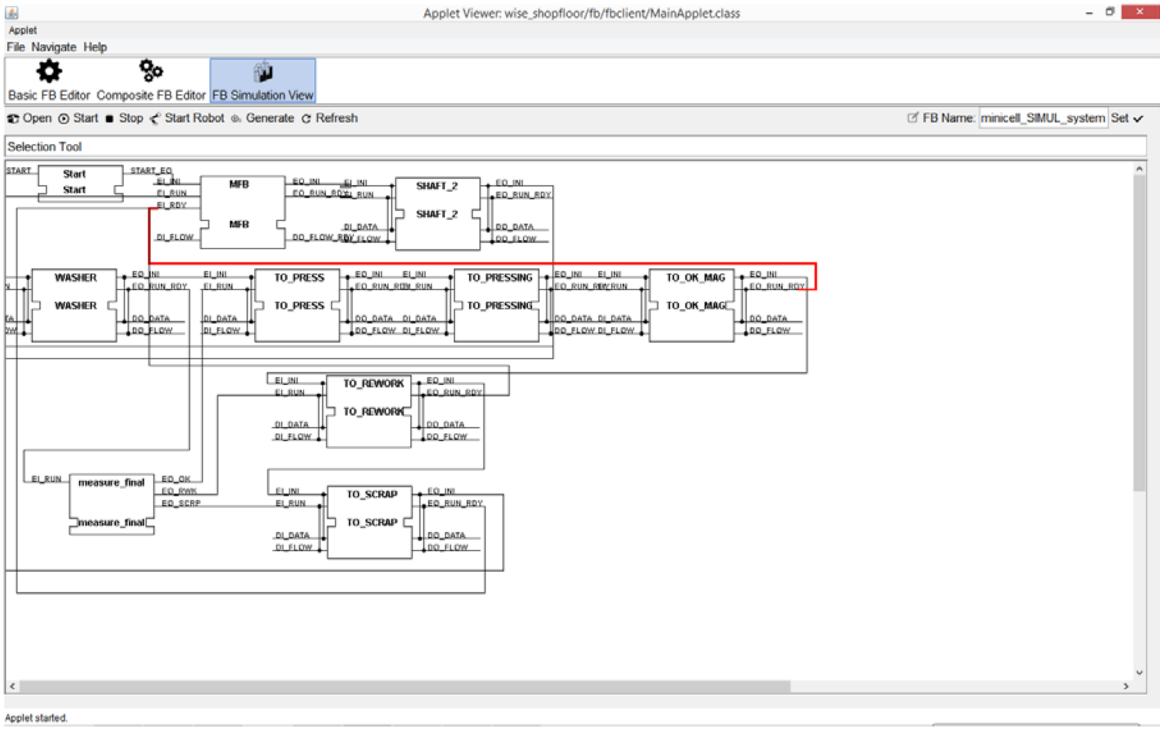


Figure 25. Function Block Simulation View

3.1.3 Operation planning (Task 3.4, 3.5)

Design and implementation

An in-house developed function block-based java runtime environment is used in conjunction with machine controllers via Ethernet. The runtime system and the conventional CNC controller together represent a function block-enabled machine controller. A simple user interface is designed and installed in a front-end controller (Figure 24). It shows a process plan (in form of a function block network) corresponding to a specific setup. It is possible to start the process for each setup and see which function block is running at the moment.

Machining feature function blocks are independent in the way they plan and perform the related material removal and they might have heterogeneous implementations with different techniques. However, the machining feature function blocks rely on a knowledge-based operation planning method. Some necessary algorithms for operation planning were implemented for function blocks. Figure 25 illustrates how the operation planning algorithms are associated with a production rules engine, machining knowledge base, and resource database to perform operation planning. Drools, an open source Java-based production rules system, is used for prototype implementation. Its object-oriented rule-based inferring engine with a Rete algorithm is used for operation planning.

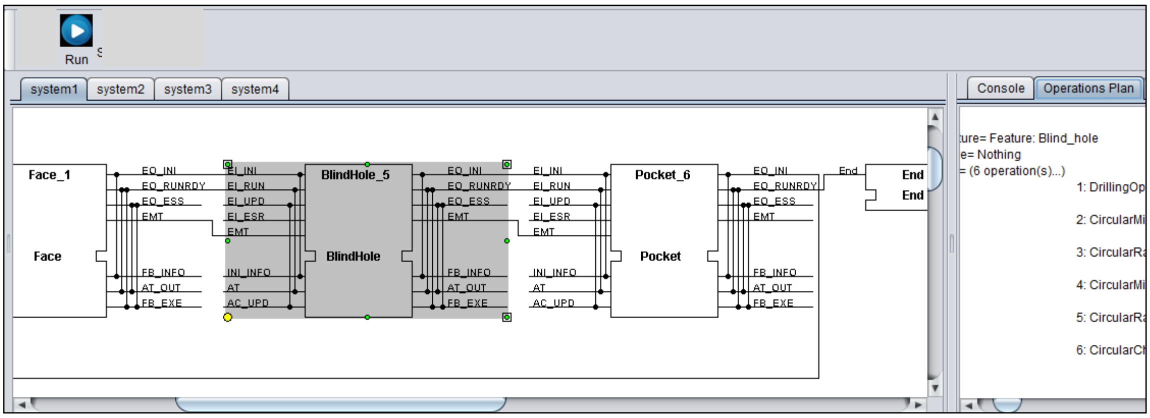


Figure 26: Function block-enabled front-end controller user interface

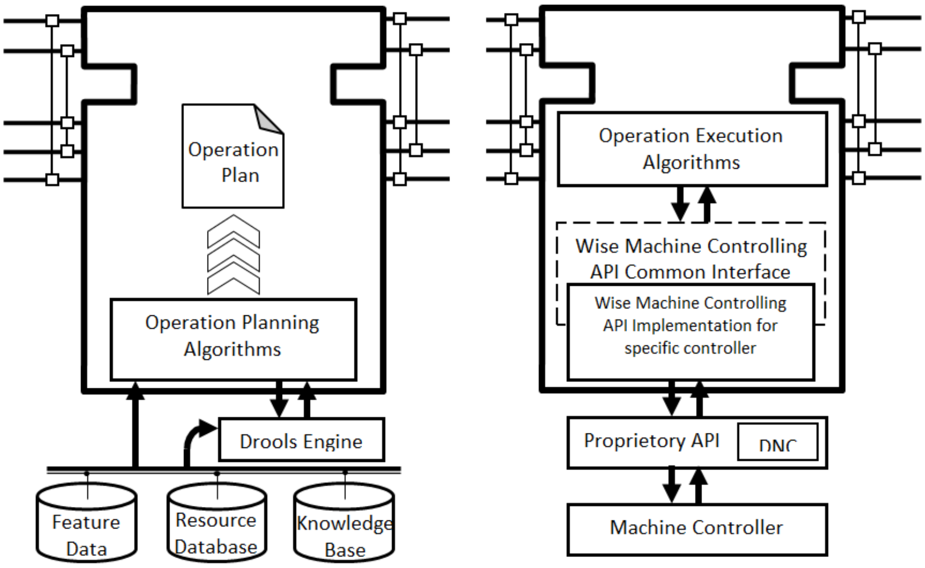


Figure 27. Machining feature function blocks (left) Providing production rules engine for operation planning algorithms, (right) Interaction of operation execution algorithms with machine controller

3.1.4 Services available through web portal

3.1.4.1 *Generic setup planner and feature sequencer*

Machining sequence generation includes machining feature grouping and setup planning, multiple setup sequencing, and feature sequencing in each setup. The output of this module is a revised machining feature list, in which the features are divided into a group of setups; both the setups and the features in each setup are sequenced. During machining sequence generation, manufacturing constraints, datum dependency precedence, topological accessibility, and regular available resources are taken into account.

The prototype for sequence generation is shown in Figure 26. When a new part is chosen, the feature list is shown in the top-left tree view in addition to the table at the bottom. The part is visualised in the middle. After generic setup planning and feature sequencing, the results are shown in a tree view on the bottom-left as well as in the graph viewer in the middle. The features are grouped (in the grey areas) representing different 3-axis based setups. These setups are connected to each other if a precedence relation exists between them. In each setup, features that have no precedence with each other are grouped together. The connectors among features, and groups of features, represent the precedence relations.

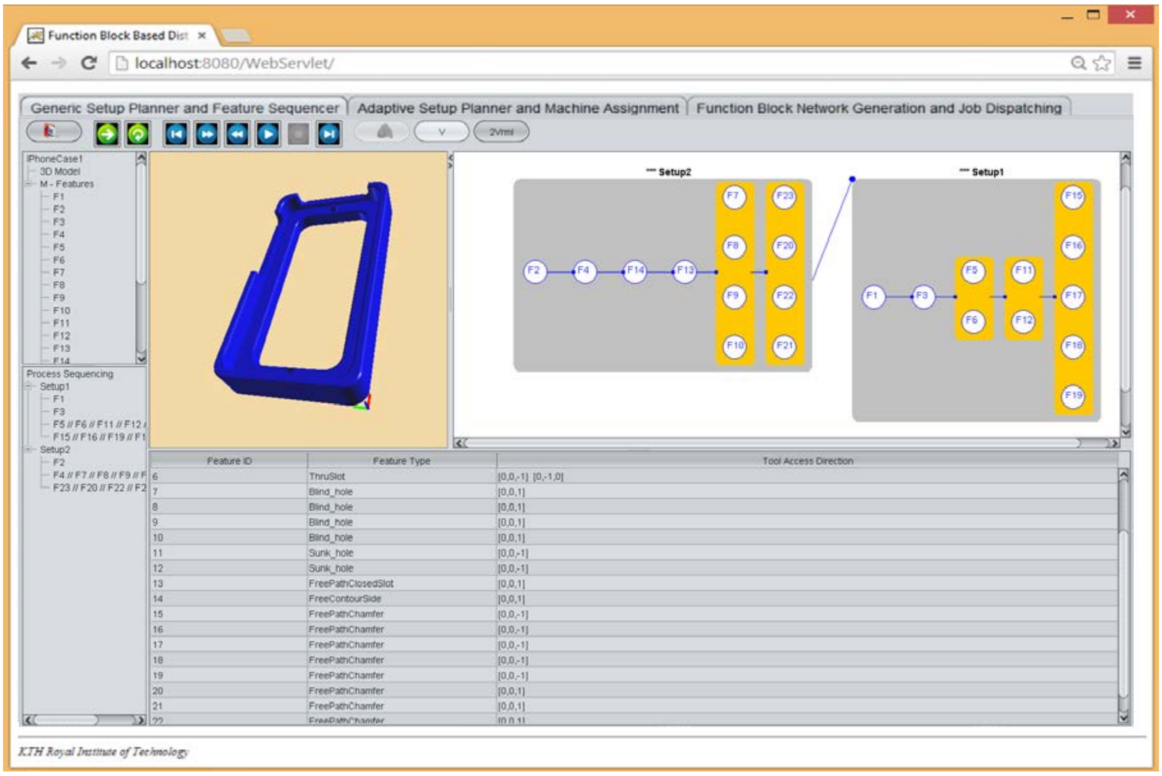


Figure 28. Generic setup planner and feature sequencer

3.1.4.2 *Adaptive setup planner and machine assignment*

Adaptive Setup Planner and Machine Assignment service takes a sequenced set of generic 3-axis based setups and tries to assign it to one or several available machines in an optimal way. Machine availability, capability, and kinematics are taken into consideration. When possible and appropriate to use machines with more than three axes, multiple 3-axis based setups may be merged together to reduce the number of setups if machine kinematics and geometry of the setups allow. This service is depicted in Figure 27 with more details reported as part of WP4.

3.1.4.3 *Function block network generator*

This service automatically generates function block networks corresponding to planned setups that are assigned to machines. The input to this service is the output of an adaptive setup planner service. The relevant function blocks then are added to a function block network including machining feature function blocks and other necessary function blocks such as the ones controlling the setups and the transition between them. The generated function block network can be dispatched directly to the machines or can go under editing process. An automatically generated function block network for a setup plan is shown in Figure 28.

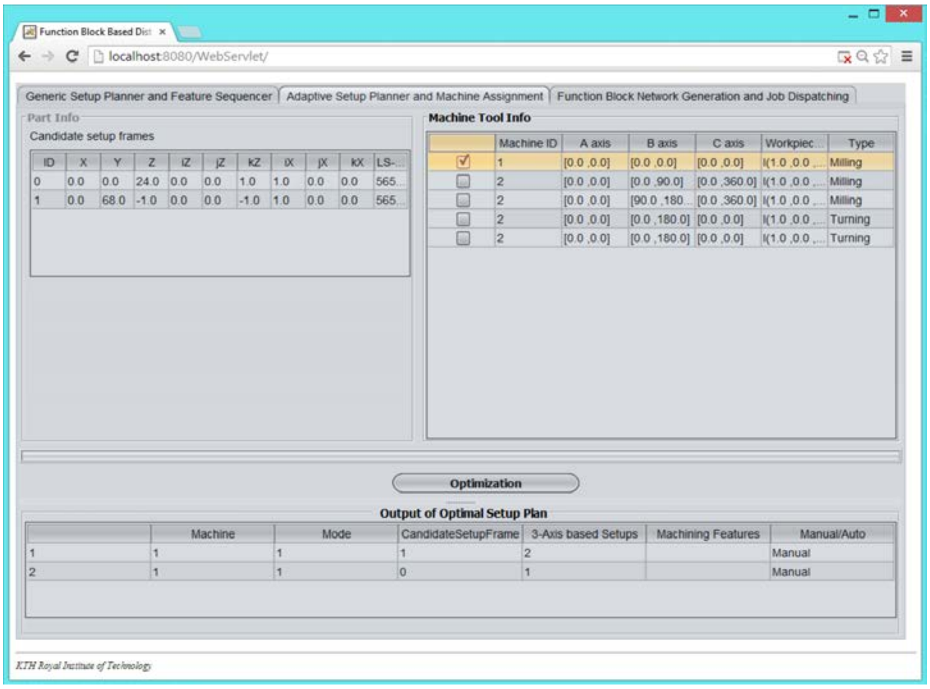


Figure 29. Adaptive setup planner and machine assignment service

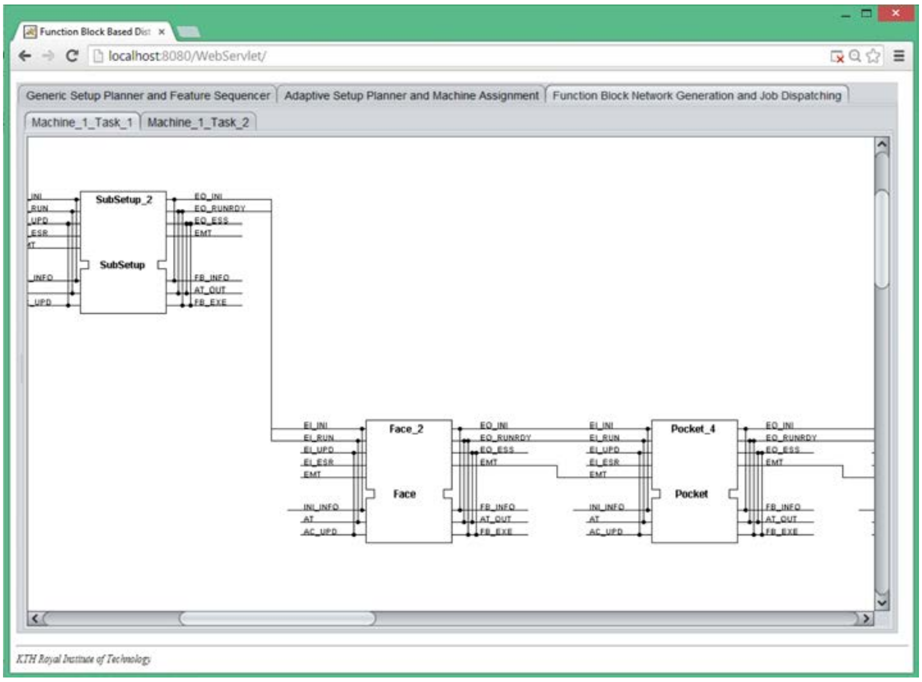


Figure 30. Function block network generator service

3.1.5 Summary

In WP3, a web portal was implemented for collaborative process planning. The services include generic setup planning and feature sequencing, adaptive setup planning and machine assignment, and function block network generation. Modules related to resource-specific, knowledge-based operation planning and execution for machining feature function blocks were also introduced.

3.2 WP4 — Adaptive setup planning

4 Work Package Number		*4*		Start date		*M7*
Work Package Title	Adaptive setup planning					
Activity Type	*RTD*					
Participant Name	**KTH**	**COV**	**LMS**	**CU**	**SAN**	**PROD**
Person-months	4.01/17.42/10	2.58/0.42/8	0.67/6/7	2/4/5	3.34/0.88/17	0/0/0
	ICT	**FT**	**AF**	**CAM**	**PKT**	
	2.5/1.5/4	3.31//4	0/0/0	0.2/2.1/2	0/0/0	

Objective:

To generate setups adaptively based on the available machines, their configurations and capabilities, by sharing real-time in-process monitoring information of WP-2.

Description of work:

This WP integrates process planning of WP3 and process simulation of WP5 to prepare and generate the optimal setup plans that fit the best to the capabilities of those available machines identified by the real-time monitoring of WP2.

T4.1: Generic setup planning (SAN) - *Completed*

In order to maintain the generality of a non-linear process plan, all the machining operations involved will be grouped using a single tool access direction (TAD) or for 3-axis machines. The resultant setup plan becomes generic and portable to other machines. This task is responsible to develop a method that analyses the TAD of each operation and group it into an appropriate setup with no violation of machinability.

T4.2: Single-machine setup merging (SAN) - *Completed*

According to the machine availability of WP2, a high-end machine with more than 3 motion axes may be selected for the part machining. This task will look into the capability and configuration of the machine, particularly its tool orientation space (TOS), and merge setups as much as possible to reduce the total number of final setups. Vector analysis is used to examine the mergability.

T4.3: Cross-machine setup merging (KTH) - *Completed*

This task interfaces with the process simulation module of WP5 to iteratively determine the most suitable machines that can meet a set of multi-objective requirements (e.g. machining cost, make span, and machine utilisation, etc.). Genetic algorithms are pre-selected for solving the optimisation problem. In order not to miss the availability window of current machines, timeliness of simulation and optimisation must be guaranteed by the processing algorithms – a major challenge of the task.

T4.4: Smart algorithms development for on-board decision making (CU) - *Completed*

Smart algorithms are needed for function blocks to determine an optimal set of cutting parameters after dispatched to and on-board in a machine. This task is responsible for developing the algorithms and embedding them in function blocks (final setups), runnable in a NC controller.

4.1.1 Adaptive setup planning and merging (Task 4.1, 4.2)

The purpose of setting up a part is to ensure its stability during machining, and more importantly, to guarantee the precision of the machining process. The task of setup planning is to determine the number and sequence of setups, the machining features in each setup, and the part locating orientation of each setup. This section focuses on tool accessibility analysis of setup planning with an assumption that one part will be machined on one machine [10].

Setup merging on one machine

In this project, tool orientations of machine tools, TADs of 3-axis based setups, and surface normal of workpiece are all represented by unit vectors. Therefore, the problem of setup merging on a 5-axis machine can be dealt with by rotating a set of unit vectors u_i (TADs of 3-axis based setups) around *Z*-axis and looking for an orientation in which maximum number of unit vectors can be embraced by the unit spherical surface patch, which represents the TOS of the 5-axis machine tool as illustrated as EFGH in Figure 29.

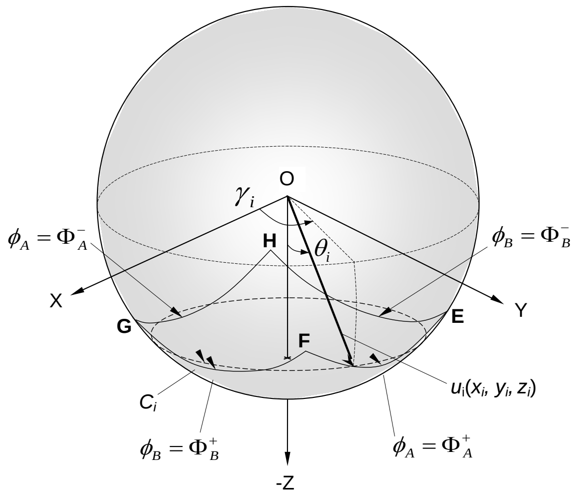
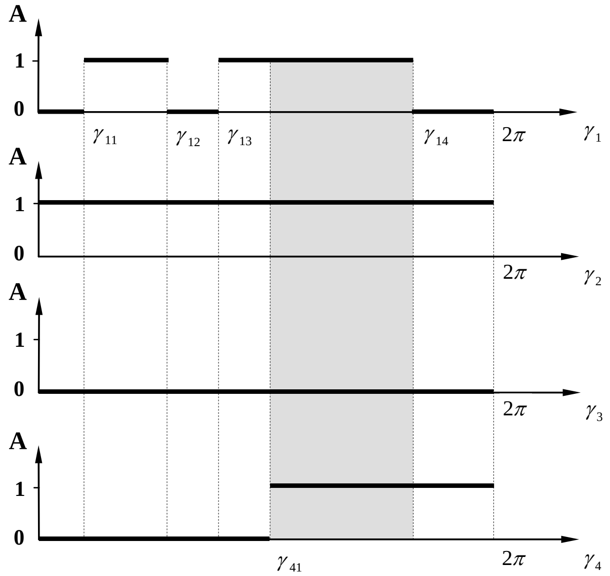


Figure 31. Search of TOS by rotating TAD around Z-axis

From the relationship of TOS and the circle C_i in space, maximum 3-axis based setups that can be merged into one 5-axis based setup can be derived together with the optimal workpiece orientation. Because the surface patch of TOS is continuous and θ_i remains constant, accessible range of u_i over TOS of the machine tool can be further embodied by the range of variable $\gamma_i \in [0, 2\pi]$. The intersecting points of the edge of the TOS and the circle C_i are the critical points where tool accessibility changes.

For a given part, all the γ angles can be obtained for each of the 3-axis setups. We sequence them from least to most, in value, over $[0, 2\pi]$. The number of 3-axis based setups that are accessible in each interval $[\gamma_m, \quad \gamma_{m+1})$ can then be calculated. The interval in which maximum number of 3-axis based setups can be accessed determines the optimal workpiece orientation, and all the 3-axis based setups falling into this interval can be merged into one setup for this 5-axis machine. This search algorithm is also demonstrated in Figure 30, in a special case where the total number of 3-axis based setups is 4.

If not all the 3-axis based setups can be merged into one setup, relocate the workpiece to the second primary locating direction and repeat the search algorithms described above until all the 3-axis based setups can be combined into one of the 5-axis based setups. For machine tools that have a rotational movement around *Z*-axis (*AC/BC* type), similar algorithms have been derived.



A: Accessibility; I=4.

Figure 32. Range of optimal workpiece orientation

4.1.2 Cross-machine ASP using GA (Task 4.3)

The purpose of the cross-machine adaptive setup planning (ASP) is to generate an optimal (or near-optimal) setup plan for a part based on the capability and configuration of each available machine, machine combinations. The basic idea is illustrated in Figure 31 where the inputs to the ASP are 3-axis based setups and the TOS of the available machines. The output of the ASP is the optimal setup plan corresponding to a chosen objective for optimisation.

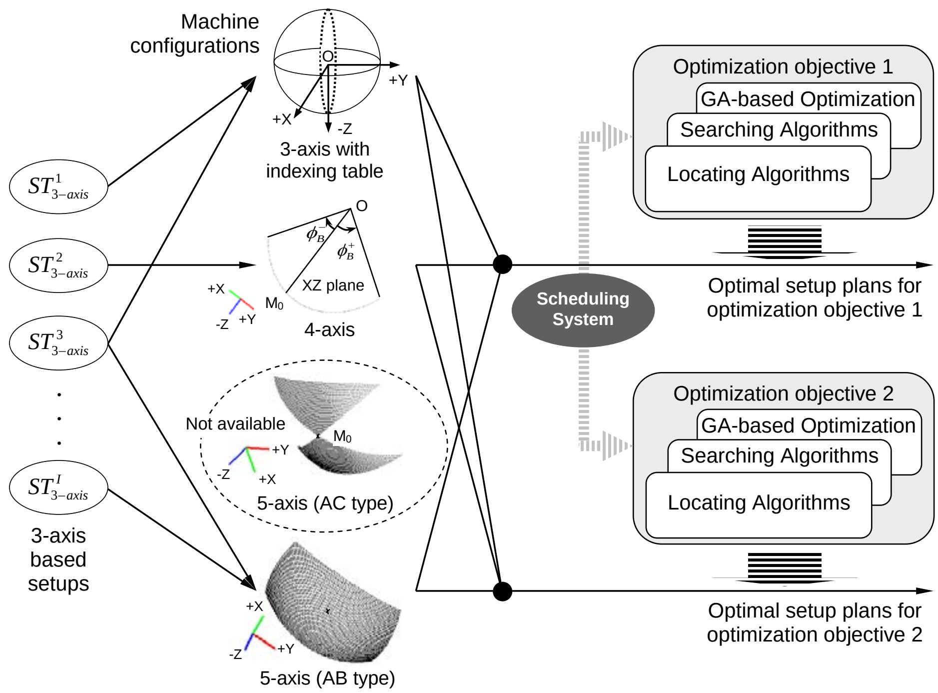
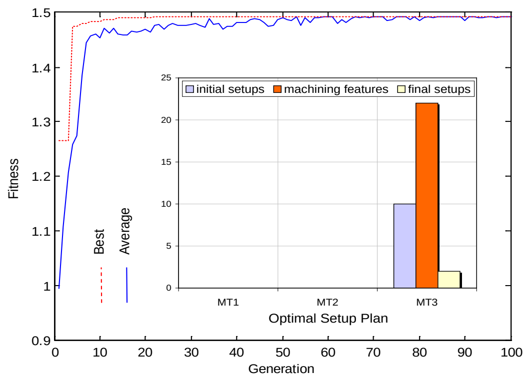
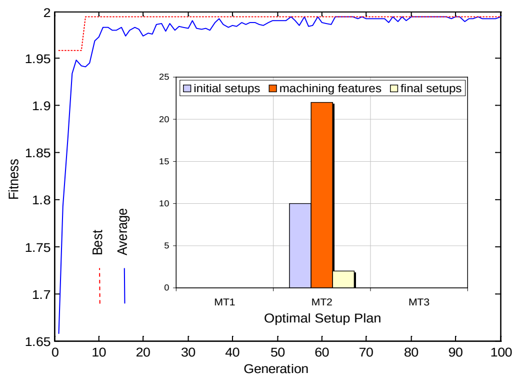


Figure 33. GA-based cross-machine adaptive setup planning

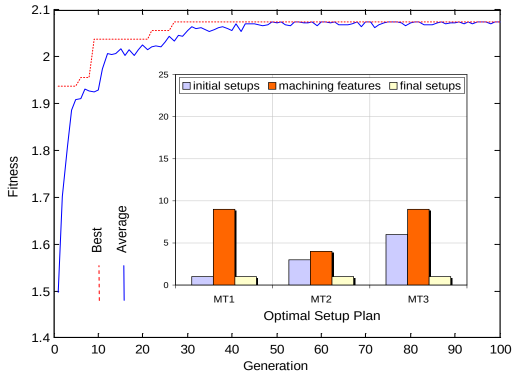
As the results of cross-machine ASP, four typical cases are revealed in Figure 32.



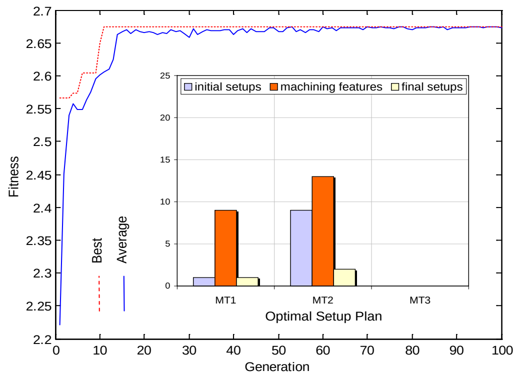
(a) $W_L=1$, $W_G=1$, $W_C=0$, $W_M=0$, $W_U=0$



(b) $W_L=1$, $W_G=1$, $W_C=1$, $W_M=0$, $W_U=0$



(c) $W_L=1$, $W_G=1$, $W_C=0$, $W_M=1$, $W_U=0$



(d) $W_L=1$, $W_G=1$, $W_C=2$, $W_M=0$, $W_U=0$

Figure 34. Optimisation results and best setup plans of a test part

In case (a) when no constraints are given to the cost, makespan and machine utilisation, all final setups go to MT_3 (the 5-axis machine). If cost reduction is required as shown in case (b), all final setups go to MT_2 (the 4-axis machine). In case (c) when a minimum makespan (or a quick production) is required, the final setups are distributed among all three machines. In this case, machining time is the major concern. In other words, although different numbers of setups and machining features are assigned to each machine, all machining jobs should be completed at roughly the same time, thus the minimum makespan. Finally, when the weight of cost factor is doubled, all machining jobs of MT_3 are forced to be moved to MT_2, as shown in case (d). The reason of not further moving to MT_1 is due to the effect of grouping factor (W_G=1) that strives to reach a minimum number of final setups.

4.1.3 A toolbox of smart optimisation algorithms (T4.4, 4.5)

The development of a real-time optimisation system is discussed in this section, and system architecture, cutting force model, chip thickness, and initial and final models will be introduced in detail.

The following system architecture will introduce the concept of a cloud system based on FBs, and data acquisition, data analysis and optimisation algorithms will be discussed. The cutting force model and chip thickness are the core of the real-time optimisation system; therefore, detailed objective functions and the unformed chip thickness will be introduced. The initial model will discuss the single pace HC method and the final model will discuss the adaptive hill climbing (AHC) method.

The FBs based system is being developed in a Cloud environment. Tapoglou et al. (2014) proposed a FBs and Cloud based on-line tool path optimisation system, as Figure 33 shows. Four sections, including Data acquisition, Data analysis, Optimisation and Visualisation interface are introduced into the system.

In this subsection, the proposed system is similar to that introduced earlier. The difference is that the system in this research has no independent data analysis section, therefore the signals are analysed within the parameter optimisation section. Separately, the structure of the system is exactly like the system in Figure 34, which might currently be the typical structure of FBs and Cloud based on-line optimisation systems.

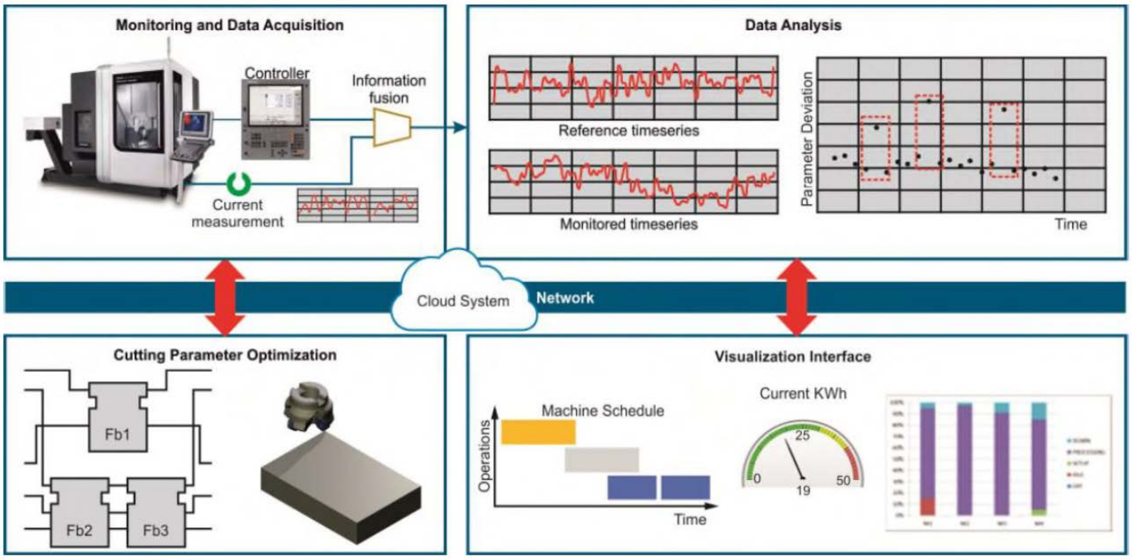


Figure 35. FBs and Cloud based solution

Tapoglou et al. [11] proposed the structure of the layer as one of the most typical FBs and Cloud based optimisation structures. This paper will also adopt this structure of layers. Tool data will be received from the CNC machine such as cutting force, feed rate and cutting speed. Featured data, such as the geometry of the workpiece, depth of cut and width of cut are transferred to the FBs through the Cloud network. All of the necessary data will be combined and put into the optimisation FBs. The optimisation algorithm inside the optimisation FBs will run based on the input data and output the optimised value of parameters. The output value will be translated into machine specific G-code because there is currently almost no protocol for running FBs on a CNC machine.

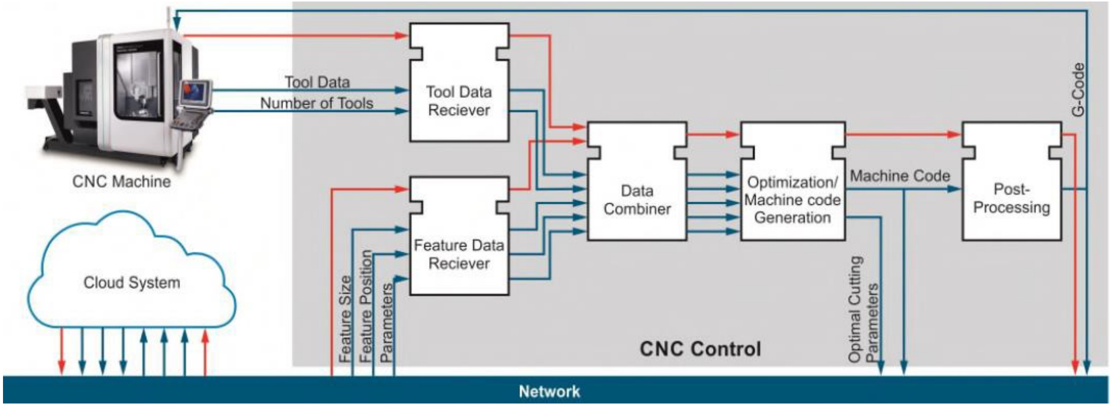


Figure 36. Structure of the optimisation software

The case study is based on a real case, and the cutting force and set of parameters are based on Adolfsson et al, (1995). The geometry of the raw material is shown in Figure 35. The material of the workpiece is SS2172, a steel combined with 0.20% C, 0.30% Si, 1.3% Mn, 0.05% P, 0.05% S, 0.3% Cr, 0.4% Cu, and 0.01% N (Adolfsson et al,. 1995). The geometry of the raw material is used to machine an iPphone case. It is small and light, which in this study is the reason that the acceleration and deceleration time of the feed rate is ideally regarded as zero. A 18KW milling centre produced by SAJO is chosen as the most appropriate machine to carry out the experiments. The maximum spindle speed of the machine is 7500 rpm.

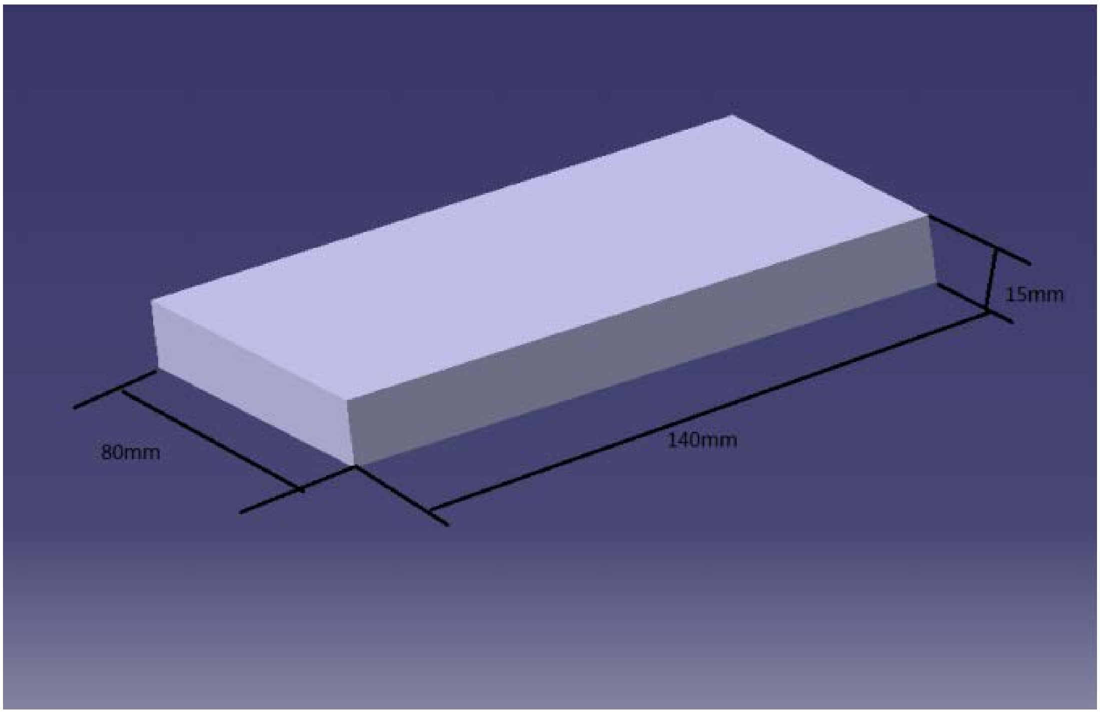


Figure 37. The geometry of the raw material

In this part a Function Block based real-time optimisation model was presented. The cutting force model is used to carry out the optimisation. Based on the cutting force function of a single cutting edge, the research developed a series of objective functions to calculate the total cutting force according to a different number of cutting edges and cutting situations. The objective function presented is less accurate than the calculation of a complex model, but it is faster with acceptable errors. Another benefit of the simplified objective function is that by using these functions, the running time of the programme is very shorter.

The model presented is proven to be capable of stabilising the cutting force with the calculation time within 10 ms if using an advanced CPU. The feed rate is decreased compared to the initial rate, however the cutting process is more stable. Furthermore, the model provides the possibility to carry out automated control and optimisation. When something unexpected happens such as an extremely high cutting force, the model can deal with the situation within 120 ms without a human operator.

However, unexpected cutting force overload is one of the most common uncertainties in the milling process. Future work will focus on combining other uncertainties in the model such as tool vibration, tool heat, workpiece vibration, workpiece heat, load on the axes, sound and power consumption. By simplifying the objective functions similar to this paper, the mode might have the ability to deal with multiple uncertainties with fast reactions.

4.1.4 Summary

This WP concerns cross-machine adaptive setup planning that contributes to process planning (WP3) and process simulation (WP5). The optimisation during setup planning considers machine capability and configurations, as well as requirements on cost, makespan and machine utilisation. The GA-based software tool can provide adaptive solutions to the changing shop floor conditions, where the availability of machines and the requirements on cost and makespan change over time. Being able to generate (near) optimal setup plans upon request quickly makes the ASP a unique exploitable.

4.2 WP5 — Integrated process simulation

5 Work Package Number		*5*	**Start date**		*M7*	
Work Package Title	Integrated process simulation					
Activity Type	*RTD*					
Participant Name	**KTH**	**COV**	**LMS**	**CU**	**SAN**	**PROD**
Person-months	0/0/6	5.59/10.82/11	1.39/2.24/4	5/17/17	1.07/0.26/5	1.08/2.29/3
	ICT	**FT**	**AF**	**CAM**	**PKT**	
	3.25/0.5/4	3//5	0/1.25/2	0.2/1.2/2	0/0/2	

Objective:

The objective of WP5 is to provide an integrated process/setup simulation environment to optimise parameters for reduced cycle time and resource consumption and increased quality and productivity. The four tasks and achievements are explained in the following subsections.

5.1.1 Efficient scheduling and simulation service (Task 5.1, Task 5.3)

Based on the generated process/setup plans, the scheduling task is to assign the setups to specific machines to be executed in different time slots, targeting a good shop floor performance such as the shortest makespan, the most balanced machine utilisation, the least total tardiness, etc. as shown in Figure 36. The X axis of the Gantt chart represents time. Each row in the Y axis represents a machine and the specific arrangement of operations on the machine. A machine is comprised of a number of time slots, which can be further classified into idle, preparation, and machining time slots.

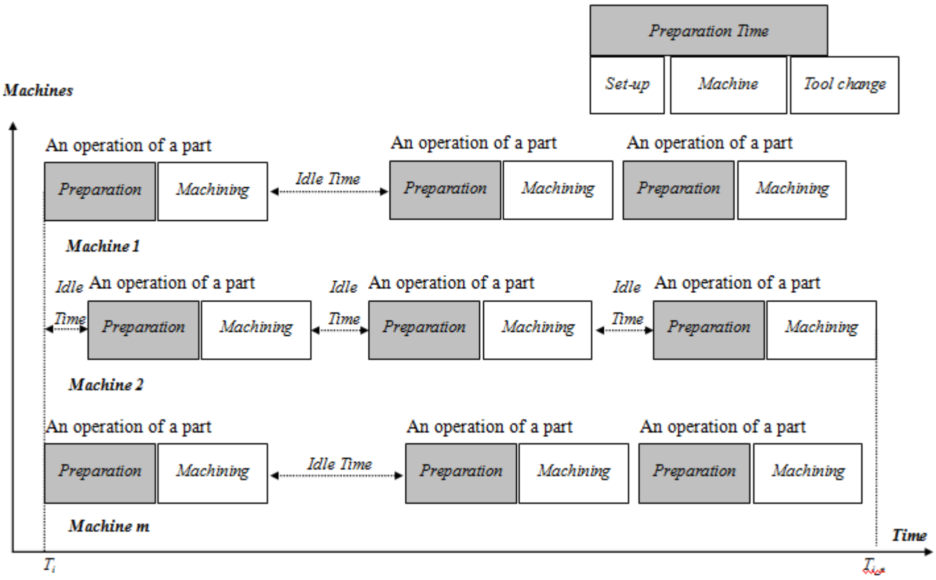


Figure 38. A Gantt chart for scheduling parts and machining operations

5.1.2 Energy consumption modelling (Task 5.1, Task 5.2)

The power profile of a machine consists of start-up, idle, preparatory, working and shutdown phases. Hence, its energy consumption can be separated into five corresponding segments.

$$E(M_i) = E(M_i).startup + E(M_i).idle + E(M_i).preparation + E(M_i).working + E(M_i).shutdown \quad (1)$$

where

$$E(M_i).startup = \int_{T_t}^{T_{t\_1}} P_{startup}(M_i)dt \quad (2)$$

$$E(M_i).idle = P_{idle}(M_i) \times T_{idle}(M_i) \quad (3)$$

$$E(M_i).prepartion = \sum_{j=1}^{n} \int_{T_{t\_2}}^{T_{t\_3}} P_{preparation}(M_i)dt \quad (4)$$

$$E(M_i).working = \sum_{j=1}^{n} E_j(M_i).working \quad (5)$$

$$E(M_i).shutdown = \int_{T_{i\_4}}^{T_{i\_5}} P_{showdown}(M_i)dt \quad (6)$$

$E(M_i).x$ represents the energy consumed during the *x* phase of machine *i*, *$P(M_i)$* represents the power demand of the *i*th machine, T_i and T_j stand for the start and end time of each phase. *$T_{idle}(M_i)$* stands for the total idle time of the *i*th machine, *n* the number of the operations to be executed on the *i*th machine.

If there are *m* machines to be used in the process planning and scheduling, the overall energy consumed by all the machines to produce the parts is

$$E_{Group} = \sum_{i=1}^{m} E(M_i) \tag{7}$$

5.1.3 Light-weight simulation visualisation for the Cloud platform (Task 5.4)

Thanks to the highly developed computer graphics technology, there are hundreds of approaches to develop visualisation software and numerous mature tools developed. However, according to the literature and the research introduced previously, there is no mature visualisation tool which is able to provide all the functions we need for tool path visualisation of a function block system. The aim of this research is to find a suitable visualisation solution especially for function blocks, so explicit and elaborate selection of visualisation methods which serve the need of function blocks visualisation precisely are the most important process in the development. A number of aspects are focused on to build this tool, such as the layout strategy of GUI, the algorithm for plotting and software structure, the API and software operating convenience.

G-code Translator Interface

For analysing the process planning generated by the function block system, manual programmed tool paths written in G-code could be a good comparison for evaluating the outcome of the function blocks. In the meantime, G-code path is also a practical validation tool for the visualizer itself. It can test whether the visualizer is well functioned, even before it visualises the tool path generated by function blocks.

A G-code translator is designed for the translation of G-code into the function block format. It is integrated into the visualizer as a dialog window shown in Figure 37. It can be accessed through menu items in the application. A file chooser is provided at the left side of the dialog. TXT files storing the G-codes are supported by the translator. Two text areas are placed in the dialog too, for displaying and comparing the two formats. After the confirmation by the user, the input information in function block format is sent to the visualizer by clicking the "Send Commands" button. By this translator, tool path written in G-code is translated into the recognisable format (function block format) and directly fed into the visualizer as an input. The visualizer interprets the information in the function block format, and generates respective tool paths for displaying.

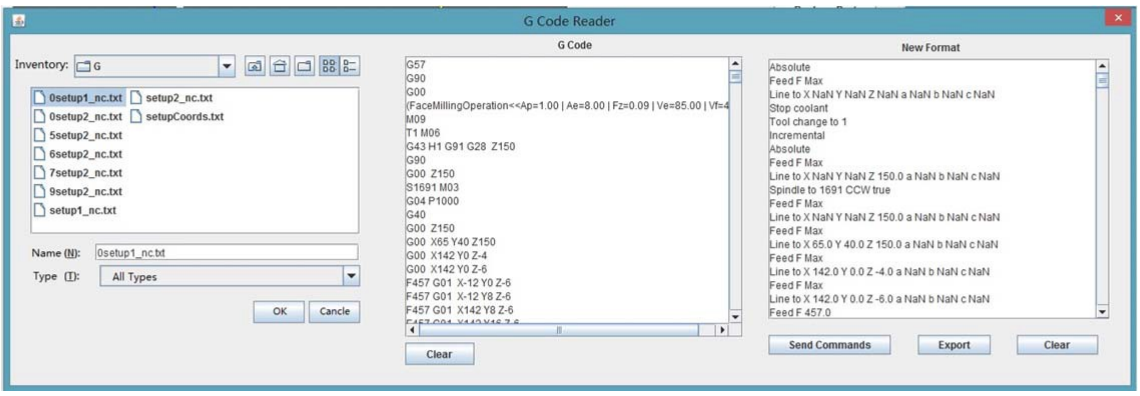


Figure 39. G-code reader dialog

Application Structure and Data Flow

The main structure of the application comprises three parts, GUI, API and graphics rendering. As shown in the data flow diagram for the application (Figure 38), each part consists of several modules which process the same function together.

The blue items represent the modules for processing the graphics rendering of the 3D virtual universe, which contains and displays everything to be visualized. The "Virtual Universe" module defined the structure of the entire 3D scene. The other six modules control the changes made to the 3D scene. The "Model Importer" controls the importation of the 3D models of the parts and the cutting tools. In the industrial requirement assessment, it was shown that the format STEP is very popular because it is generic and versatile. However, an importer for decoding STEP files is too time consuming to implement and beside the point of the fundamental demonstration of the functionality of an online FB visualizer. Hence for the current visualizer, a native Object loader was substituted as the replacement of a STEP loader. Object files, with the extension of .obj, is a kind of format which restores information of 3D models. The Object loader is provided by the native Java library. The "Command Reader" reads the commands written in function block format, translates them into internal commands, and calls those corresponding methods in the "Command API". "Data Generator" receives commands and generates data for every point in the tool path. It calculates all the information required for tool path rendering and the animation of cutting process, and stores it within itself. "Path Generator" renders the tool path, with different colours representing different feed rates. "Animation Controller" is a multi-thread module which controls the schedule of every frame for the manufacturing process animation. "Updater" draws data from "Data Generator" and updates a single frame when called by the "Animation Controller".

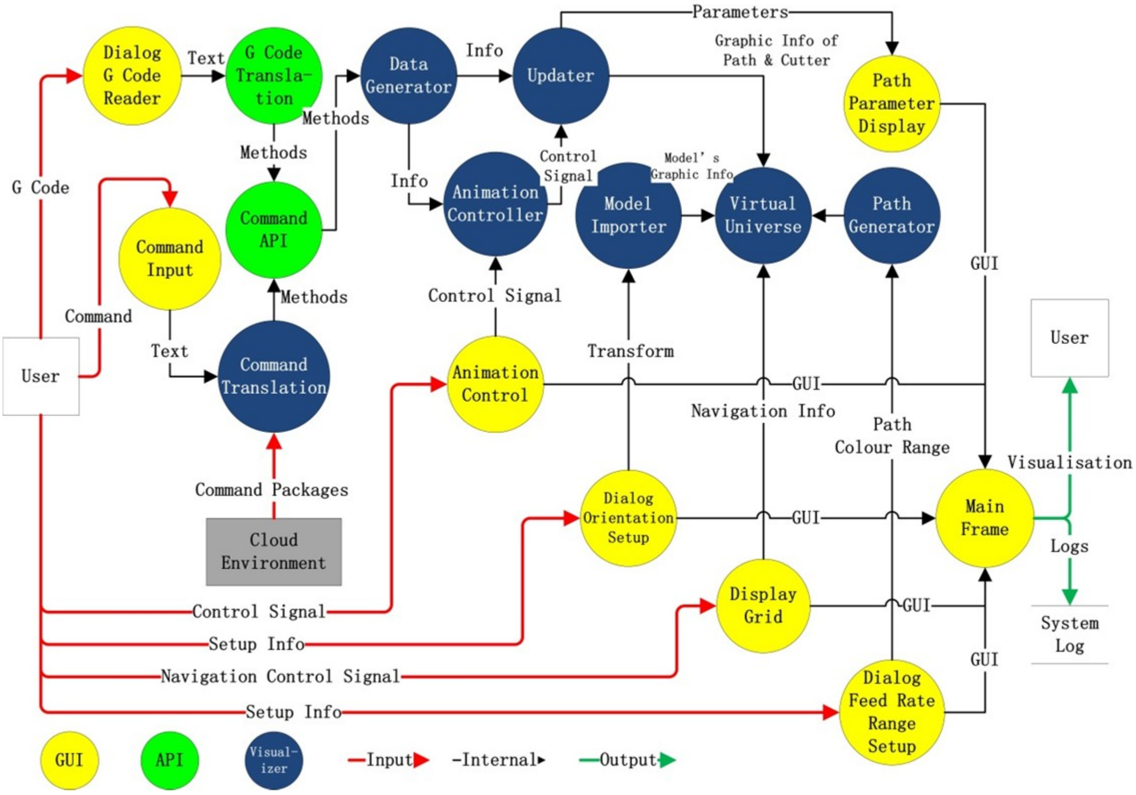


Figure 40. Data flow Diagram of the visualizer

Yellow items represent the displaying components of the “Main Frame”, the GUI of the visualizer. Eight independent modules comprise the GUI, connected with corresponding rendering components or API components. As shown in Figure 39, “Display Grid” contains 4 canvases displaying the front, top, side and isometric view of the 3D scene rendered by the “Virtual Universe” module. The navigation function is also encapsulated in this module too. “Command Input” contains a text area which allows the user to type their commands directly in for visualisation. It is designed with work mode switches too, between Function Block and G-code, Static and Dynamic respectively. These two switches control the data processing paths inside the application structure, and the differences between them will be explained later. Component “Animation Control” provides basic control functions for the animation of the manufacturing process, such as start, pause, continue and stop. Five options of animation speeds are also available for user to control, 1x, 2x, 4x, 8x, 16x. “Path Parameters Display” monitors the parameters of the cutting process on run time, such as the coordinates where the cutting tool currently is, the feed rate and the spindle speed of the machine, when the animation is active. The “System Log” reports the status of the application when operations are made or errors occur.

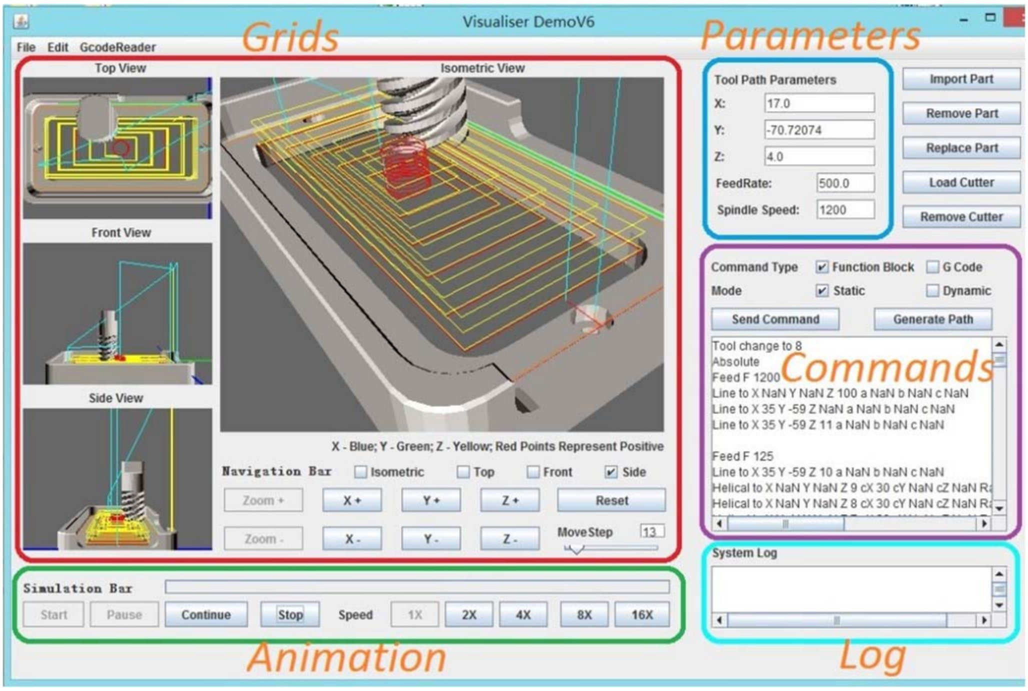


Figure 41. Components of the GUI

Besides the main window, there are three dialogs attached in the application, which are “G-code Reader”, “Feed Rate Range Setup” and “Orientation Setup”. The integrated G-code reader has already been introduced previously, as shown in Figure 40. The other two dialogs are designed for basic setups before the visualisation. “Feed Rate Range Setup” allows the user to set the range of the feed rate which defines how feed rate is represented by different colours in the “Path Generator” module. “Orientation Setup” is designed for placing the part to the right location as the tool path is planned. Offsets in three directions and rotations around the three axes can be defined here by changing the combination of the values.

The green items in Figure 40 represent the modules handling the exterior communication of the visualizer. The “Command API” translates the commands in function block format into the calling operations for corresponding methods in the visualizer. The “G-code Translation” module translates G-code into function block format. Two input formats for the visualizer are supported by these two modules.

5.1.4 3D Scene tructure

In the "Virtual Universe" module, every element in the 3D scene is structured, calculated and rendered. The "world structure" comprises three independent branches, "View Platform", "Imported Parts" and "Static Parts". In Static Parts branch, the background and the three axes of the absolute coordinates system of the universe are presented. Besides, illumination sources, including a directional light and an ambient light, are added in this branch too.

The View Platform branch contains all the structures and information of four separate view points for rendering. The structure of each view point is attached to an independent Transform Group respectively, which contains the information of location and direction of the view. "Imported Parts" branch contains the main body for visualisation, which are the part model, the cutter model and the tool path. Similarly, each of them is attached to a Transform Group too. The three orange cards, "Navigation", "Orientation Setup" and "Animation Update" represent control commands for those functions. The control commands are applied on the corresponding components, and eventually applied on these Transform Groups to become effective. Further information can be found in "Introduction for Computer Graphics" by Klawonn, K. (2008), for further details into the structure of Java3D.

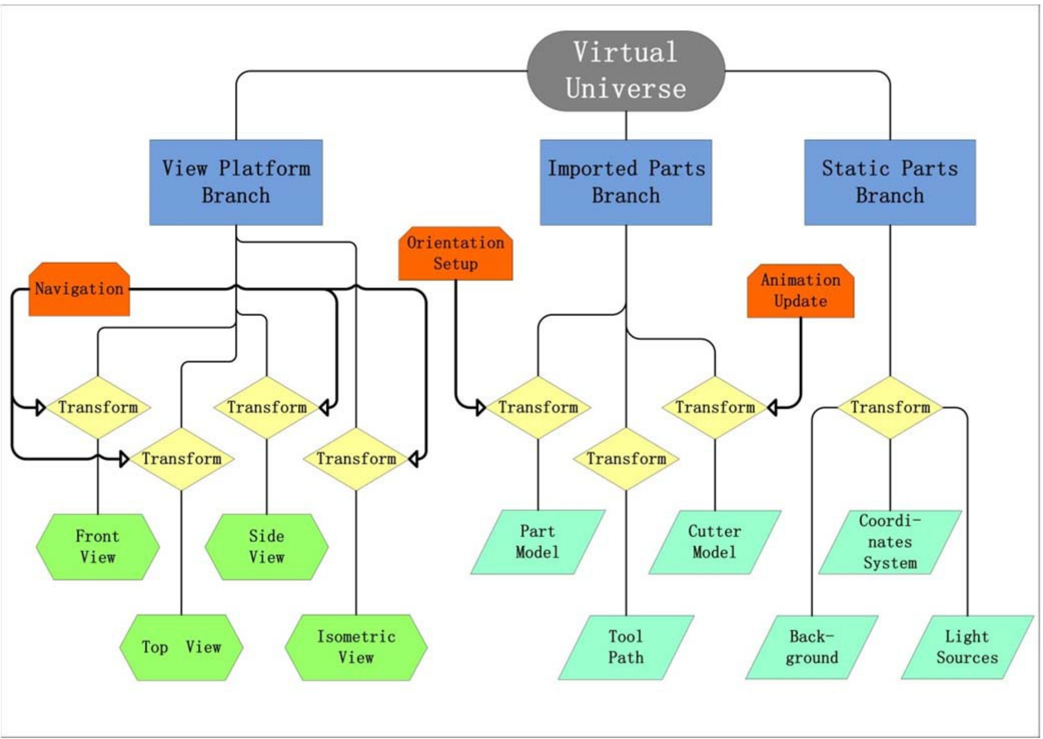


Figure 42. Structure of the 3D scene

The optimisation is to define ArrayLists in the data storage in the initialising stage of the visualizer. After the exact information of the graphics received, the data will be transported into an array with the right size, and the ArrayLists will be emptied. Afterwards, the array will be sent into, stored and referred by the virtual universe. In the aspect of memory consumption, this optimisation keeps the light-weight style of the visualizer.

5.1.5 Summary

The integrated simulation service is critical to reduce energy consumption and achieve sustainable manufacturing. In WP5, sustainable process planning and scheduling simulation and optimisation to support CAPP-4-SMEs were explored and presented in a hybrid HBMO-SA service. The experimental results have demonstrated that the service is promising and outperform the single GA, HBMO and SA for the same problem.

5.2 WP6 — Job-shop machining demonstrator

6 Work Package Number	6	Start date	M27			
Work Package Title	Job-shop machining demonstrator					
Activity Type	*DEM*					
Participant Name	KTH	COV	LMS	CU	SAN	PROD
Person-months	0/8.96/7	0/17.54/7	0/7.45/7	0/9/8	3.67/12.89/18	0/7.97/8
	ICT	FT	AF	CAM	PKT	
	0/3.3/5	0//6	0/6/8	0.6/2.5/6	1.5/0/8	

6.1.1 Test bed preparation for demonstrations (Task 6.1)

Selection of test bed environment

The initial plan presented in DoW was that Sandvik will host and maintain the test bed. However during the end of the first year in the CAPP-4-SMEs project an alternative solution based on EGI [12] was identified. EGI is based upon a European research project and could be more appropriate as a public host for software modules from a diversity of partners due to issues related to company firewalls, security and IP. After discussions with representatives at EGI it was found that a feasible way forward would be to continue the discussions with KTH PDC [13] which is connected to EGI as well. PDC were positive to collaboration and to support CAPP-4-SMEs. This in combination to the near location to three of the consortium partners it was decided to use PDC for hosting and maintaining the cloud platform.

Scope definition – cloud integration - phase 1

As mentioned in previous chapter the aim of the cloud platform is to enable collaborative process planning where different partners will integrate their functionality needed to generate the process plan. The functionality will be available through services from software components stored in the public cloud as well as from software components and databases on premise. Proper integration methods and mechanisms are thus crucial. The integration work has to be done in several phases, where the functionality as well as number of nodes and partners increases stepwise.

SCOPE: The scope for phase 1 includes defining an overall environment and architecture as well as developing, implementing and verifying the needed integration mechanisms between the components and databases for a selected test scenario (exchange of cutting tool data) involving a limited number of partners, stage 1: KTH@cloud directly integrated with SAN-on premise, stage 2: LMS@cloud directly integrated with SAN on premise.

GOAL: The goal is to implement and verify integration of P2PIE functionality in order to enable communication and exchange of primarily cutting tool data between applications in the cloud and applications and databases available on premise at supplier SAN.

After verification of the integration functionality in phase 1 it is thus expected to expand and integrate more partners, e.g. SMEs in the PDC cloud by using the P2PIE methodology, in subsequent phases.

Overall cloud environment and integration architecture

The architecture contains in summary the following parts:

- A community cloud hosted by PDC at KTH: PDC Cloud (more information about PDC will follow in the next paragraph)
- PDC responsible for operation, maintenance of infrastructure including e.g. firewalls for PDC Cloud
- A number of virtual machines, i.e. servers, are installed at PDC Cloud. Each virtual machine corresponds to one partner e.g. KTH**,** LMS, SAN, and SMEs etc.
- The partner’s virtual machines are remotely accessible by end user. Each partner is responsible for uploading their software modules.
- *Integration engines* according to the P2PIE concept to be installed at each virtual machine.
- A “SAN on premise” in Microsoft Azure™ environment is opened up;
  - o Including databases with cutting tool related data and information,
  - o Enabling provision of *digital services* in terms of cutting tool data to an application in the cloud.
  - o Enabling *integration management and monitoring* based on P2PIE concept.
- Selected functionalities from Sandvik Coromant’s Adveon™ [14] have been installed on SAN virtual machine at PDC cloud in order to support creation of cutting tool assemblies. Data is stored on SAN on-premise (more information about Adveon™ will follow in the next paragraph).
- Information about cutting tools, i.e. cutting tool data, is based upon the international standard ISO 13399 [15].

Architecture and interaction process for test scenario – stage 1 of phase 1

The architecture and interaction process of the first stage of the proof-of-concept is described in Figure 41.

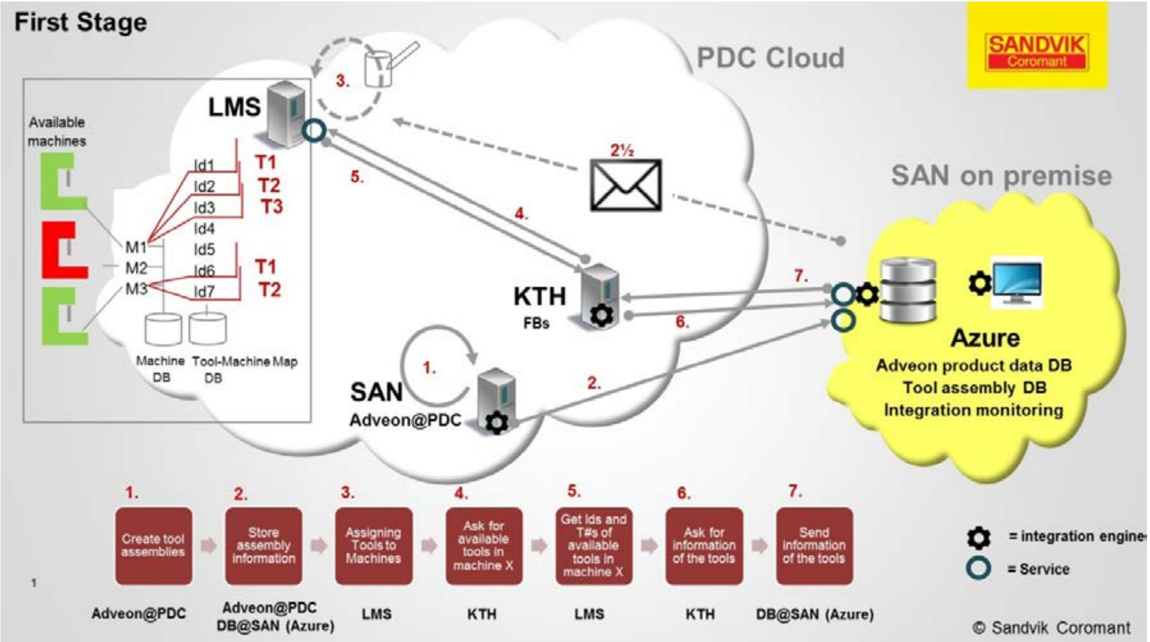


Figure 43. Architecture for Proof-of-concept stage 1

1. Cutting tool assemblies are created in Adveon™ @ PDC.
2. All data and information about the created cutting tool assemblies is stored in database at SAN on premise (MS Azure ™). No direct integration between LMS and SAN on premise is established in stage 1, information sent by e-mail (process step: **2½**)
3. LMS handles availability information about machine tools. LMS also assign and store information about the cutting tools available at each machine, i.e. the cutting tool assembly id's and corresponding T-values (T1……T*n*).
4. KTH is responsible for creation of the function block based operation plan and need information about available cutting tools. KTH asks thus LMS for available cutting tools in the available machine *X*.
5. LMS sends information about tool id's and T-numbers regarding the available tools to KTH.
6. KTH asks SAN for the detailed data about the cutting tools
7. Cutting tool data from SAN on premise is provided as a service to KTH.

Architecture and interaction process for test scenario – stage 2 of phase 1

The architecture and interaction process of the second stage of the proof-of-concept is described in Figure 42.

1. Cutting tool assemblies are created in Adveon™ client @ PDC.
2. All data and information about the created cutting tool assemblies is stored in database at SAN on premise (MS Azure ™ environment).
3. LMS asks SAN for detailed data about the cutting tools.
4. Cutting tool data from SAN on premise is provided as a service to LMS.

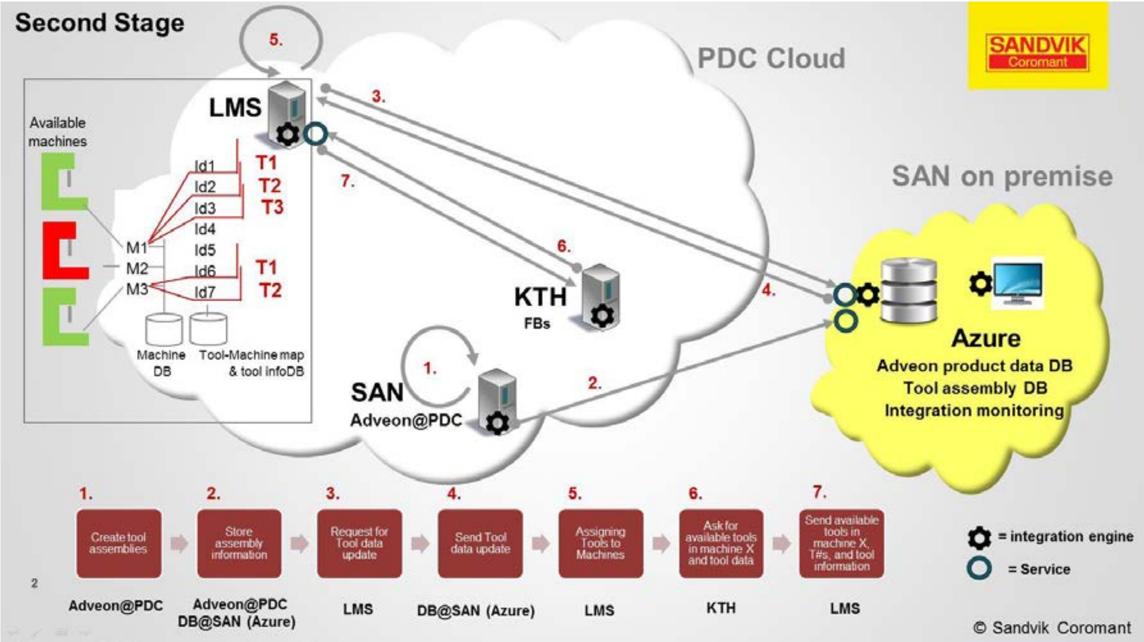


Figure 44. Architecture for Proof-of-concept stage 2.

5. LMS assigns and stores information about the cutting tools available at each machine, i.e. the cutting tool assembly id's and corresponding T-values (T1……T*n*). LMS handles availability information about machine tools.
6. KTH is responsible for creation of the function block based operation plan and need information about available cutting tools. KTH asks thus LMS for available cutting tools in the available machine *X*.
7. LMS sends information about tool id's, T-numbers and detailed cutting tool data regarding the available tools to KTH.

Proposed next steps after Proof of Concept Phase 1

The proposed next steps, after proof-of-concept of the integration mechanisms in the above mentioned test scenarios, are to stepwise extend the integration scope to include more CAPP-4-SMEs partners into the test bed, both end users (SMEs) and providers of *software functionalities/services* in the CAPP-4-SMEs consortium representing different *work packages* in CAPP-4-SMEs exchanging data in a workflow.

Such an extended test bed is conceptually illustrated in Figure 43 and may e.g. include:

1. Monitoring of machine availability and utilization (WP 2) *[ref. D2.1 report, WP2]*
2. Function block based operation planning (WP3) *[ref. D3.1 report, WP3]*
3. Set up planning (WP4) *[ref. D4.1 report, WP4]*
4. Cutting tool assembly functionality, Adveon™, supporting WP 6
5. Energy consumption simulation and optimization (WP5) *[ref. D5.1 report, WP5]*
6. Simulation functionality, NC Speed (WP5) *[ref. D5.2 report, WP5]*

6.1.1.1 *Summaries*

In this subsection the *context* of collaborative manufacturing cloud environment have been described. Based on that context *scenarios* for collaborative process planning based on cloud manufacturing have been identified and discussed. Further on, aspects that need to be considered when setting up a *multi-partner collaborative cloud environment* have been analysed.

A four-layer model has been proposed in order to capture and illustrate the relations between front- end-service layer, back-end-service layer, application layer, information and workflow to facilitate definition of multi partner architecture.

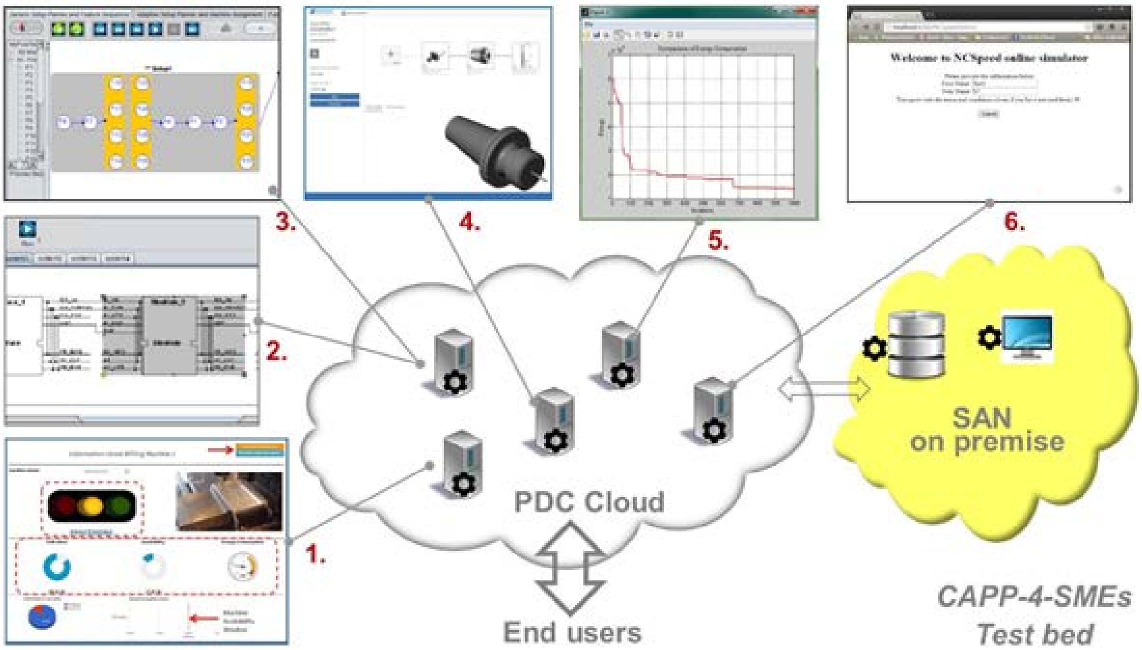


Figure 45. Conceptually illustrated extension of test bed after proof-of-concept

The P2PIE (Point-to-Point Integration Engine) method has been proposed as enabler when setting up the test bed for CAPP-4-SMEs. This proposal is based upon the successful global implementations that have been done at Sandvik internally. The essential parts of P2PIE include; *integration engines*, a central management console and a central database.

The overall cloud environment and integration architecture for the CAPP-4-SMEs *test bed* have been proposed to be based on a community cloud hosted by PDC at KTH including virtual machines for each partner, the P2PIE integration method and connections to Sandvik Coromant on-premise MS Azure™ environment.

In order to verify the integration method in the context of *multi-partner collaborative cloud manufacturing* a proof-of concept has been proposed to be carried out in two stages, each one corresponding to a defined integration scenario. This is considered as the first phase of the entire integration work in the project.

In accordance with the proposal, PDC at KTH, including virtual machines, has been established as cloud provider for the CAPP-4-SMEs test bed.

Work is currently in progress regarding realization of the stage 1 integration scenario regarding exchange of cutting tool data, including usage of Adveon™.

After proof-of-concept of the integration mechanisms in the above mentioned test scenarios, it is for the subsequent phases proposed to stepwise extend the integration to embrace more functionality (e.g. cutting data calculation, simulation, optimization etc.) and more CAPP-4-SMEs partners, both end users (SMEs) and providers of software functionalities in the CAPP-4-SMEs consortium.

6.1.2 Three Demonstrators (Task 6.2, 6.3, 6.4)

The three demonstrators were carried out at the three SMEs partners within the CAPP-4-SMEs consortium. They are Asturfeito in Spain, Cameco in Sweden and Powerkut in UK.

An overall plan for the different demonstrators was created at an early stage, see Table 2.

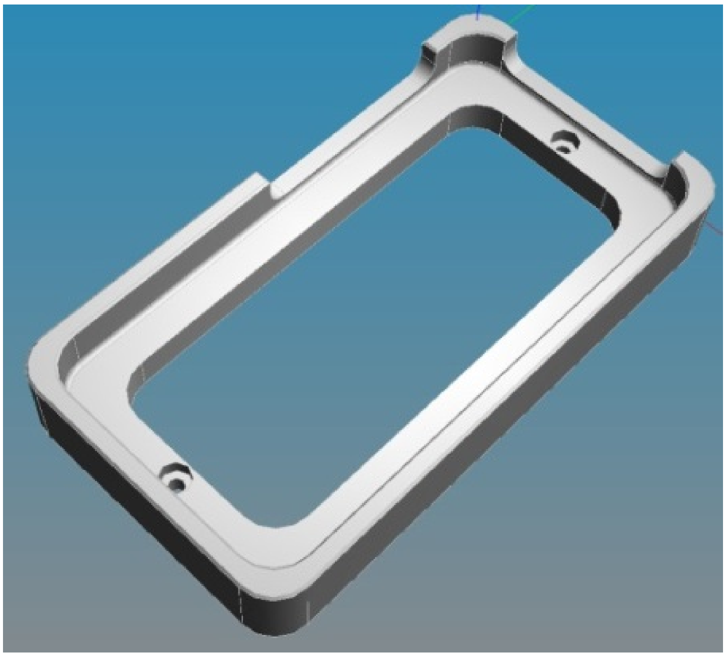
Table 2. Overall plan of functionality to show

	Demo 1	Demo 2	Demo 3
Objectives	Adaptability in operation planning • Different tools available • Different materials	Flexibility in setup merging • Different types of machines available Monitoring Different lot sizes, short due date -pcs 1-10 in machine #1 -pcs 11-50 in machine #2	The whole project according to the DoW!
Platform	Run from a laptop	Not necessary in the cloud	In the cloud
Machine tool(s)	One 3-axis machine	Three machines, 3-4-5-axis	Several machines, at least one 5-axis
Work Packages	WP1-3	WP3-5	WP1-5

6.1.2.1 *First demonstrator at Asturfeito in Spain*

"This task will test the basic functions and performance of the integrated CAPP-4-SMEs services through a simple case study. The machining experiments will be limited to one machine at a time and the machining features of the test part will only require three-axis machining."

Demonstrator part



Designed by Prodintec

Material: AL-7075 T-6

(Aluminium)

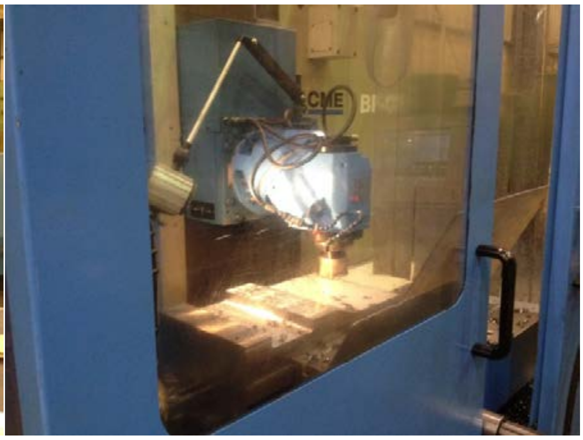
Tools by Sandvik Coromant

Dimensions: 126x68x18 mm

Figure 46. Demonstrator part 1, CAD-model

Machine tool

For the 1st demonstrator a CME BF-01 was selected. It is a 5-axis machine tool but since we only needed 3-axis it was considered being a 3-axis machine in the system.



CME BF-01

Controller: Heidenhain TNC 426

Spindle speed: 3000 rpm

Spindle interface: ISO-50 taper

Manual tool change

Figure 47. CME BF-01 at Asturfeito

Results

The demo was run at two different times. The first was March 13 to 17 and the second April 12-13. The second period was directly followed by a workshop at Prodintec where the recorded results and a live session, through a web-cam, were shown. The part was cut in two different setups. By changing the tools available in the machine we did not only get different operation plans but also different operation types. For example, if a drill with needed diameter was missing an endmill was selected and the hole could be produced by a circular interpolation operation.

By making different tool sets active we could get a new operation plan and a new NC-program in less than one minute.

During the demonstrator we also changed the workpiece material from aluminium to steel. We could then immediately generate a new program with cutting data adjusted to cut in steel.

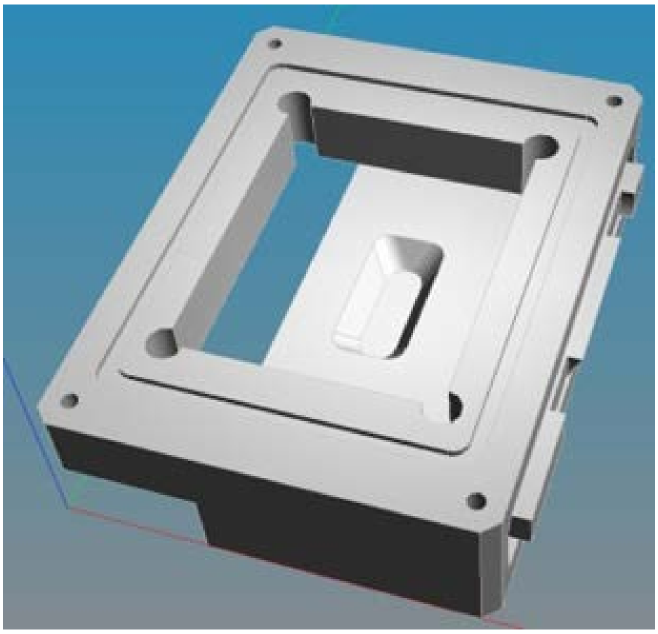
The work packages involved in this demonstration were mainly WP2-Machine Availability Monitoring and WP3-Collaborative Process Planning.

Figure 48. Demonstrator part 1

6.1.2.2 *Second demonstrator at Cameco in Sweden*

"The second demonstration will further test the services through a regular (or common) case study. The test part will require five-axis machining and need to be fabricated on more than one machine."

Demonstrator part



Designed by Prodintec

Material: EN AW2030 T4 (Aluminium)

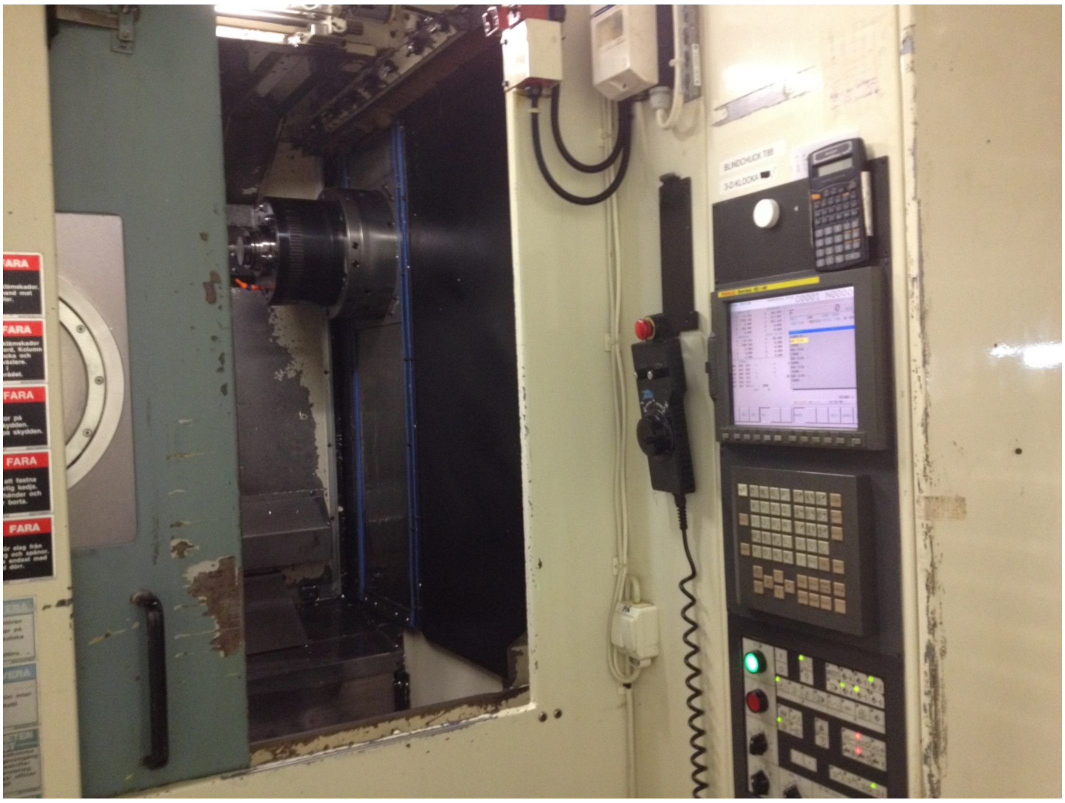
Tools by Sandvik Coromant

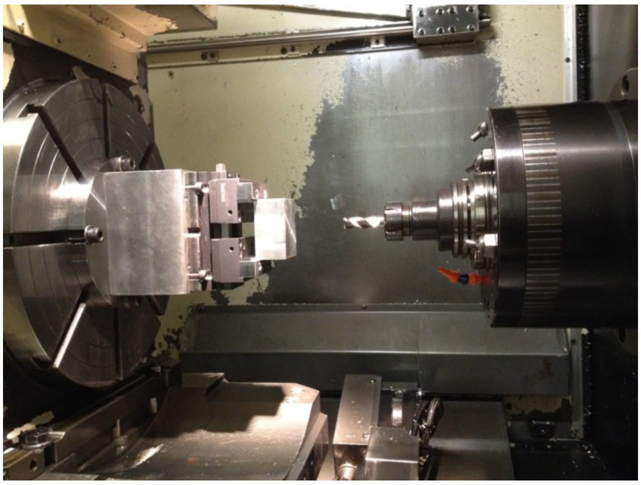
Dimensions: 75x60x20 mm

Figure 49. Demonstrator part 2, CAD-model

Machine tool

For the 2nd demonstrator a Niigata SPN50-H.O. was selected as the machine tool where we actually were cutting the demonstrator part, it is a horizontal 5-axis machining center.





Niigata SPN50

Controller: Fanuc 16i

Spindle speed: 15 000 rpm

Spindle interface: ISO-50 taper

Tool storage: 90 tools

Figure 50. Niigata SPN50-H.O. at Cameco

We also had two other machines available in the system, a machine at the Sandvik Coromant facility in Sandviken and one at Asturfeito that was used during the previous demonstrator. These machines were only used to show some functionality in the programs, not to actual cut parts.

Results

We ran the demo at Cameco during June 4 to 12. This time the following workshop was held in Germany and we recorded the live demo for presentation on June 16 in Dusseldorf.

The different scenarios were run successfully in the machine tool. We used the two different tool sets to show the flexibility in the operation planning and three different machine tools to show the setup merging. Finally we changed the dimension of a slot and two of the holes, we also moved the position of these holes. The part was then cut according to the new design.

The work packages involved in this demonstration were mainly WP3-Collaborative Process Planning and WP4-Adaptive Setup Planning. But during the following workshop in Dusseldorf we had WP2- Machine Availability Monitoring on-board to provide information about available machines and tools. That information was used by the process and setup planning software. The actual machine at Cameco was not monitored but instead three machines in Greece were monitored and their availability was shown during the workshop. These machines were located at two different facilities to emulate the monitoring of distributed manufacturing environments.

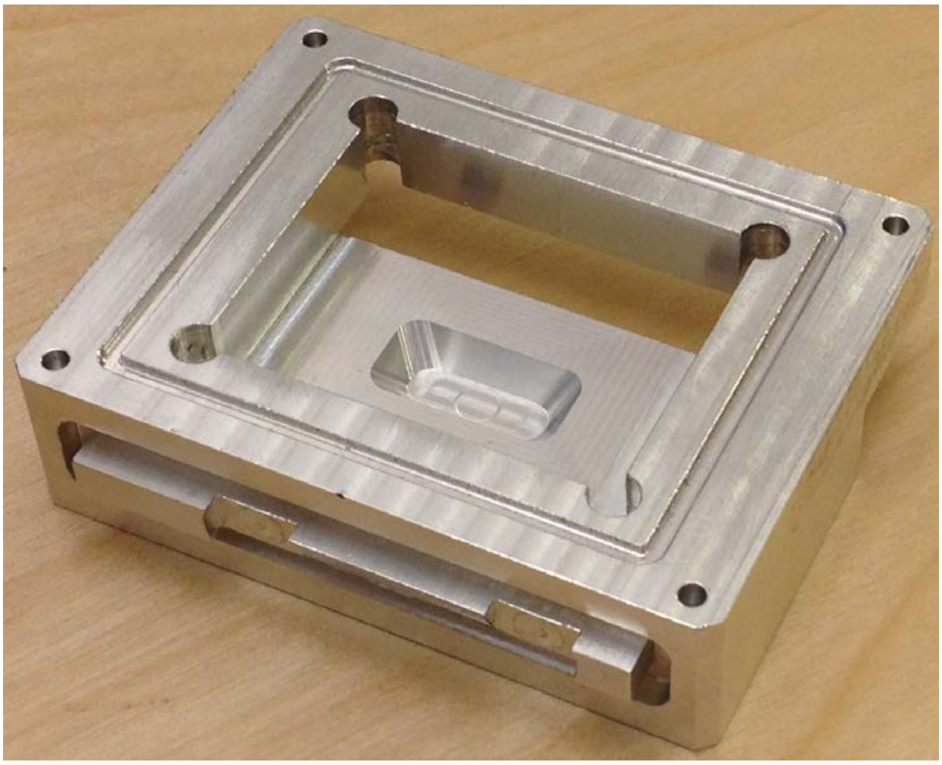


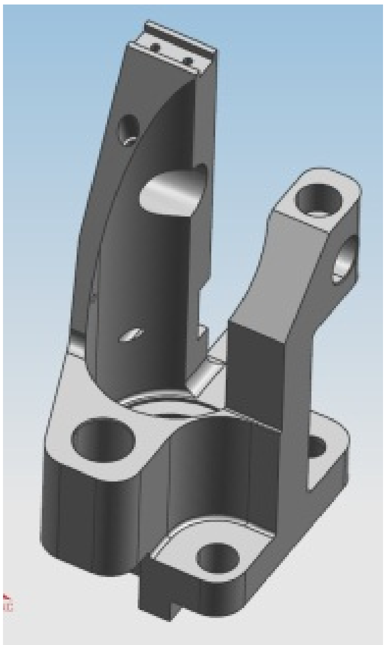
Figure 51. Demonstrator part 2

6.1.2.3 *Third demonstrator at Powerkut in UK*

Task according to DoW

"The purpose of this demo will be to validate the long-distance performance of the Cloud-based services when the test part used is complex. The test part will have much more machining features compared with the previous ones, being complex in shape and location/orientation, and requiring multiple setups on different machines. Job routing, line balancing and cost optimisation will be validated together with the performance testing of real-time machine availability monitoring."

Demonstrator part



Designed by Powerkut

Material: Nylon 88

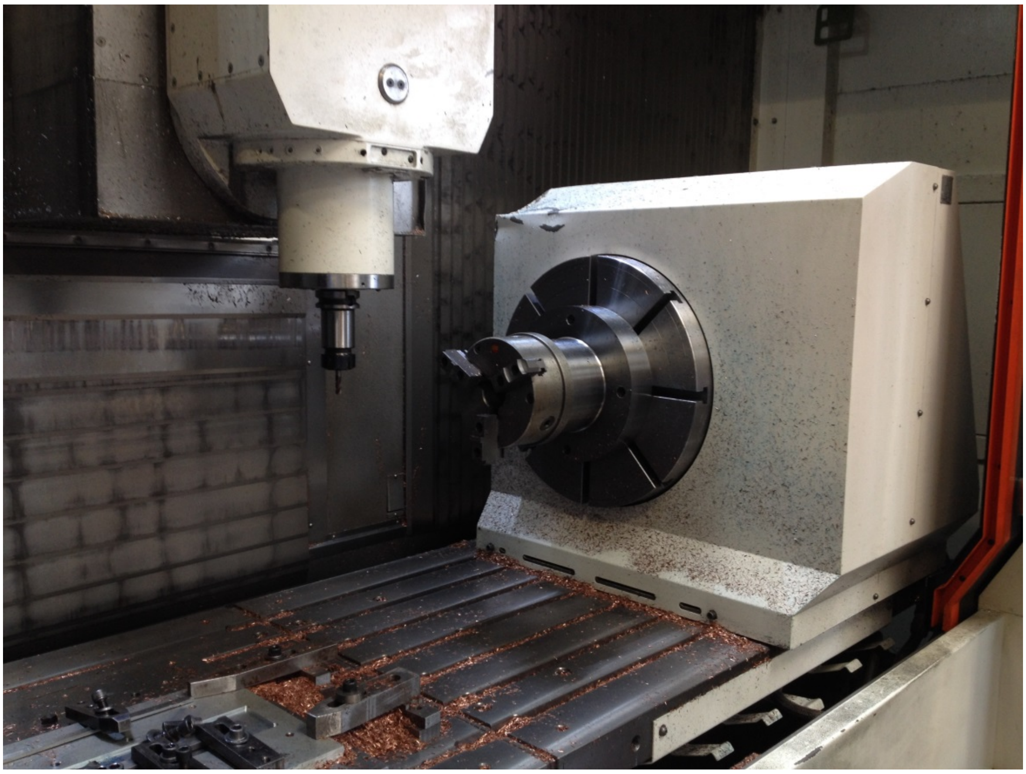
Tools by Sandvik Coromant

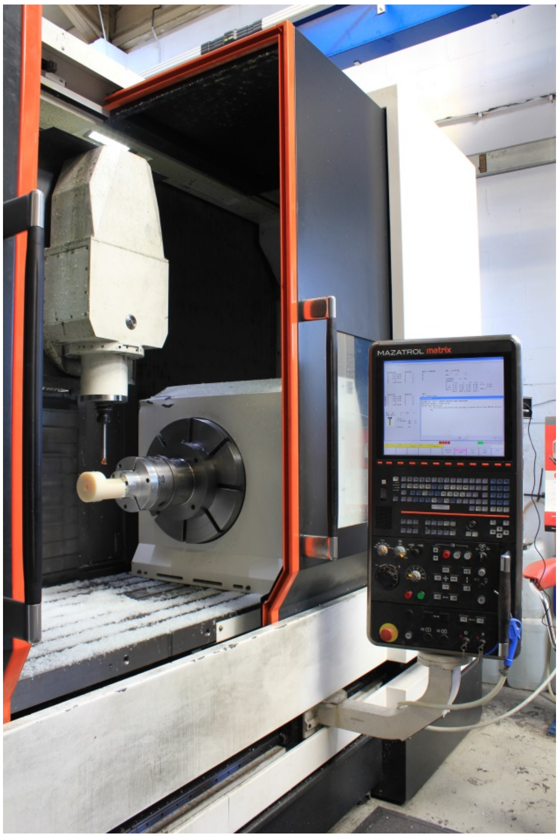
Dimensions: “111x85x55 mm”

Figure 52. Demonstrator part 3, CAD-model

Machine tool

For the 3rd demonstrator a Mazak 5-axis vertical milling center was used.





Mazak VTC800/20SR

Controller: Mazatrol matrix

Spindle speed: 18 000 rpm

Spindle interface: MAS BT-40 taper

Tool storage: 30 tools

Figure 53. Mazak VTC800/20SR at PowerKut

Objective and Scenarios

Demonstrator part 3 was much more complicated than the previous test parts when it came to the number of features, location of features and interacting features. Therefore the main focus for this demonstration was to show the operation planning of this part.

Results

The third and final demonstration was carried out at PowerKut in Coventry, UK, on and off during a period of two months, from the end of August until the end of October. This time the following workshop was actually held in the same area where the results from the demonstrator could be shown both as recorded movies and as a live demo at PowerKut´s facility.

The complexity of the part enforced several enhancements of the algorithms behind the operation planning. These were successfully implemented throughout the demonstration period.

In this machine the part could be produced in two setups. The original plan was to machine in Aluminium alloy, EN-AW 6082, but because of the complexity of the part we decided to use Nylon 88 to start with. This was done just to make sure that all operations worked and to minimize the risk for breaking any tools. When everything worked fine when cutting the part in Nylon, we decided to stick with that for the following workshop. That was mainly due to the fact that this time, changing the material, would not add anything when it came to demonstrate the functionality of the projects different work packages.

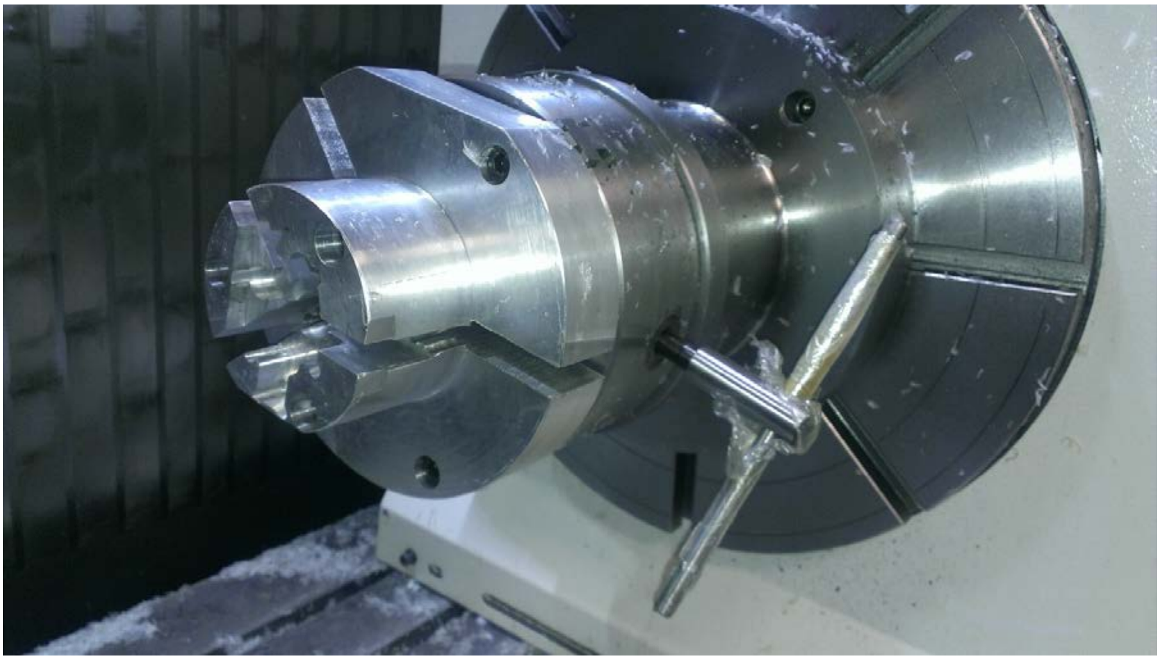


Figure 54. Fixturing for 2nd setup at PowerKut

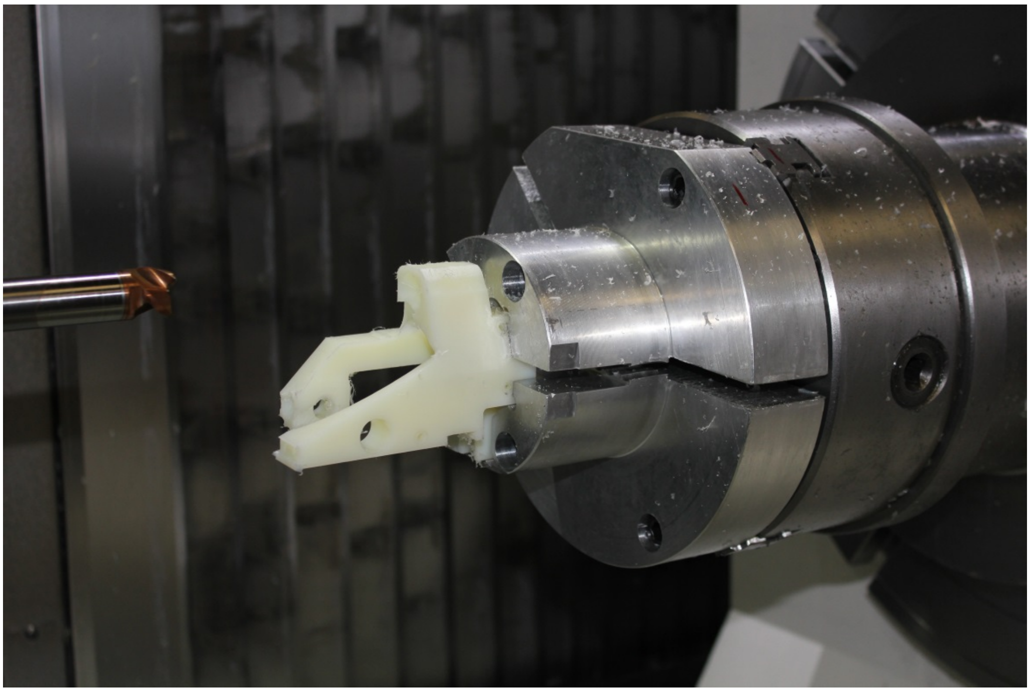


Figure 55. Machining 2nd setup at PowerKut

Again the information about available machines and tools was sent by WP2 to other work packages. But this time the geometrical information about the tool assemblies were handled in a slightly different way. All the needed tool assemblies for this demonstration, about 20 pcs, were created in Adveon™ installed at the PDC cloud. Adveon™ is a software application using the international standard ISO 13399 for representation of information about cutting tools. After the tool assemblies had been created they were stored at Sandvik Coromant's on-premise database (MS Azure™). LMS, WP2, could then retrieve the accurate geometrical data for all the assemblies and pass the information to other work packages.

At the end of the 3rd demonstration period, several of the integrated services were presented at the workshop held jointly by Coventry University and PowerKut.

Figure 56. Demonstrator part 3

In summary, the actual deliverable D6.2 is the three demonstrators conducted at three SME partners' facilities. This subsection is to recap the technical details and the findings of the three real-world demonstrators for the ease of understanding.

6.1.3 Comparative Analysis and Benchmarking (Task 6.5)

6.1.3.1 *CAPP-4-SMEs characteristics and innovations*

CAPP-4-SMEs is a key enabler to minimise cost, improve adaptability, responsiveness, robustness, and sustainability of manufacturing processes, in order to enhance the competitiveness of European companies, particularly SMEs, in sustainable manufacturing environment. The following functional modules are developed via the CAPP-4-SMEs project:

- A series of innovative and adaptive process planning services to support SMEs to simulate, evaluate, plan and optimise their dynamic and complex manufacturing processes and execution systems in collaborative value chains, in a bid to achieve efficiency, cost-effectiveness, robustness, sustainability, smartness and user intervene-friendliness during process planning,
- A knowledge-based and efficient simulation service to support multi-criteria manufacturability evaluation from the beginning of product lifecycle so as for SMEs to achieve first-time-right in terms of accuracy and reliability for customised product processes as well as improved overall energy profiles to comply the tougher eco-regulations,
- The event-driven function block technology for on-board adaptive process control functions at machine level through process plan embedding, smart algorithm invocation and bi-directional communication for SMEs to achieve real-time responsiveness, adaptability and overall resource effectiveness,
- A monitoring service for up-to-date machine availability and utilisation to ensure that decision making for planning and optimisation become resource-aware and well informed,
- Cloud and service-oriented computing approaches, which are the new-generation supplement, consumption, and delivery model for the over-the-Internet provision of dynamically scalable resources and utility computing, as a service platform to support SMEs to move away from developing and maintaining resource-intensive and standalone CAPP systems and migrate to portable CAPP services accessible and configurable over the Internet.

6.1.3.2 *Industrial demonstrators and industrial cases*

As mentioned in the tasks from the Description of the Work in the project, three industrial demonstrators in Spain (AF), Sweden (CAM) and UK (PKT) respectively have been set-up. The details are below:

Small-scale demonstration of a simplified case study (AF, Spain)

This task tested the basic functions and performance of the integrated CAPP-4-SMEs services through a simple case study (Figure 55(a)). The machining experiments are limited to one machine at a time and the machining features of the test part will only require three-axis machining. Since the demo facility and the application server are relatively collocated, network performance can be eliminated. It allows the project consortium to focus on the core functionality of the services in terms of efficiency, responsiveness, CNC controller connectivity and robustness. Adaptability and first-time-right against changes are validated.

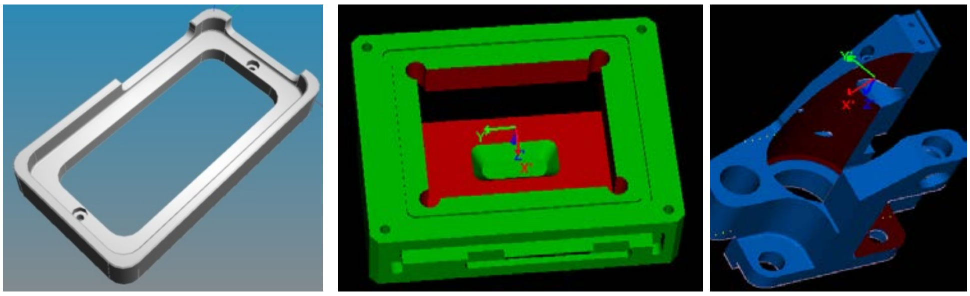


Figure 57. (a) Test Part One (14 machining features); (b) Test Part Two (25 machining features); (c) Test Part Three (52 machining features)

Mid-scale demonstration of a regular case study (CAM, Sweden)

The second demonstration further tested the services through a regular (or common) case study (Figure 55(b)). The test part requires five-axis machining and need to be fabricated on more than one machine. Such an arrangement is suitable for testing a common application scenario of Cloud manufacturing where end users will conduct their everyday machining jobs via the Internet in the future. With the application server in Sweden, the Spain based demonstration tested both the network performance of the services as well as the remote machine monitoring and optimal machine assignment.

Large-scale demonstration of a complex case study (PKT, UK)

The third demonstration was located in UK at PKT's facility. The part is shown in Figure 55(c). The purpose of this demo was to validate the long-distance performance of the Cloud-based services when the test part used is complex. The test part has much more machining features compared with the previous ones, being complex in shape and location/orientation, and requiring multiple setups on different machines. Job routing, line balancing and cost optimisation was validated together with the performance testing of real-time machine availability monitoring.

Comparative analysis and benchmarking

The detailed analysis on the individual services has been provided in the aforementioned sub-sections. The technical and scientific innovations of CAPP-4-SMEs system are summarised below:

- The capability of recognising generic machining features, on the basis of a novel way of representing features, provides a robust and flexible means not only for single but also for complex interacting machining feature recognition to support process planning,
- The definition of rules for an automatic generation of machine-independent process plans,

- A decision support tool for the choice of the machine on the basis of machine capability and machine availability,
- The use for re-configurability and adaption of locally executable Functional Blocks that are currently executed in an intermediary local hardware due to the inaccessibility of commercial NC, but in future could be executed within the machine NC itself,
- A visualization software interacting with the Functional Blocks that allows to visualize the tool paths, and provides virtual dry-run simulation capability to detect problems before the actual machining process,
- The development of wireless, low cost non-intrusive sensors to provide the basic infrastructure of machine monitoring.

In conclusions,

- The demonstrations showed that the CAPP-4-SMEs concept is an innovative solution applicable in real-world industrial workshops, with improved user-friendliness, flexibility, accuracy, quality, robustness, reliability, adaptability, efficiency, overall productivity, and user satisfaction,
- Distinguished advantages of the CAPP-4-SMEs over existing practices in industries, and the improvement of the services through different industrial workshops and feedbacks by end users have been stated in the aforementioned sub-sections from WP1 to WP6,
- Meanwhile, the functional modules and services developed can have a value as stand-alone exploitable results making a stepwise approach virtually possible,
- The general business model requires the rapid set-up of a community of SMEs ready to adopt this new paradigm and needs to overcome the threshold that disruptive innovation destroys the value of the accumulated investment, before delivering, in the mid-to-long term its very valuable advantages.

6.1.4 Service Improvements (Task 6.6)

A Cloud-based architecture, which supports SMEs to move from developing and maintaining resource-intensive and standalone process planning systems to flexible and cost-effective services accessible and configurable over the Internet, has been designed as the backbone of the CAPP-4-SMEs project. The scalability and reliability of the designed architecture have been validated through real-world practical cases with large quantity and variety of data. The services developed in WP-1 to WP-6 have been integrated into the Cloud-based architecture for global deployment.

Meanwhile, WP-1 also provide a machining feature recognition service to establish seamless linkage between input design models and the following process planning services.

The framework of the Cloud architecture and the feature recognition function provided by WP-1 are illustrated in Figure 56 and Figure 57.

Feedback on the services

- Portability and Cloud Environment Deployment: in an industrial environment, different operational systems and programming environments for various services have been used. The feedback from industrial workshop is that a Cloud environment, which is accessible globally, should integrate and execute the services into a single Cloud platform. Service deployment into a standardised Cloud infrastructure should be considered;
- Interface: CAPP-4-SMEs consists of various services from machining feature recognition, facility monitoring, set-up planning, process planning, and simulation/optimisation. End users expect a unified interface could be provided to facilitate their process planning process based on the services of CAPP-4-SMEs;

- Feature recognition: CAPP-4-SMEs provides a robust and effective machining feature recognition service to automate the process planning from design model input. In order to address end users' requirement, a feedback from end users is that customised feature types should be included for the end users to define their own features.

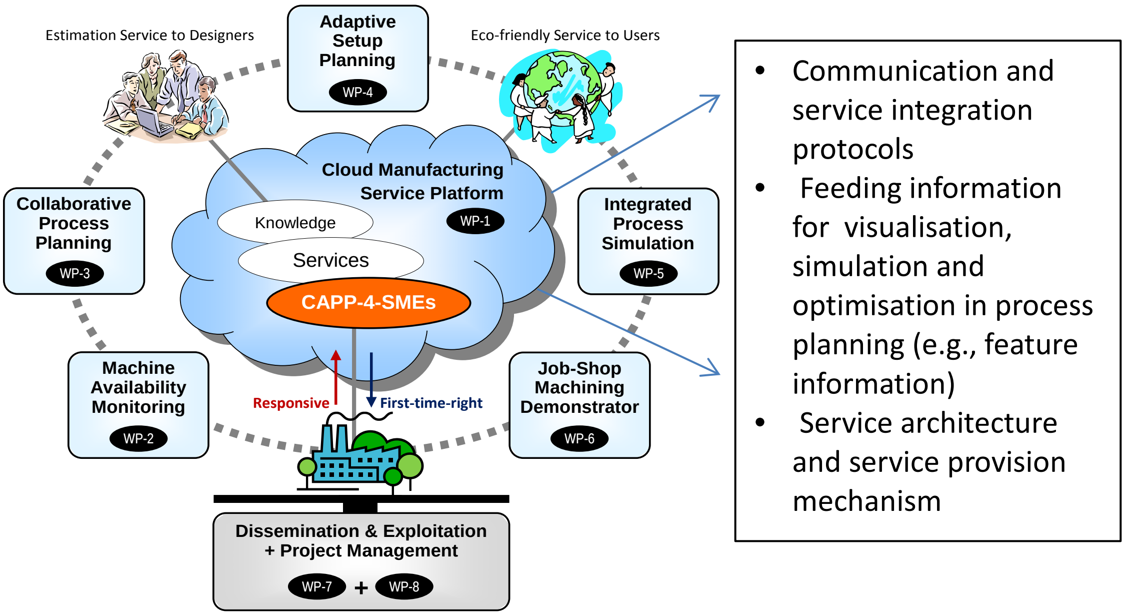


Figure 58. Cloud architecture and feature recognition by WP-1

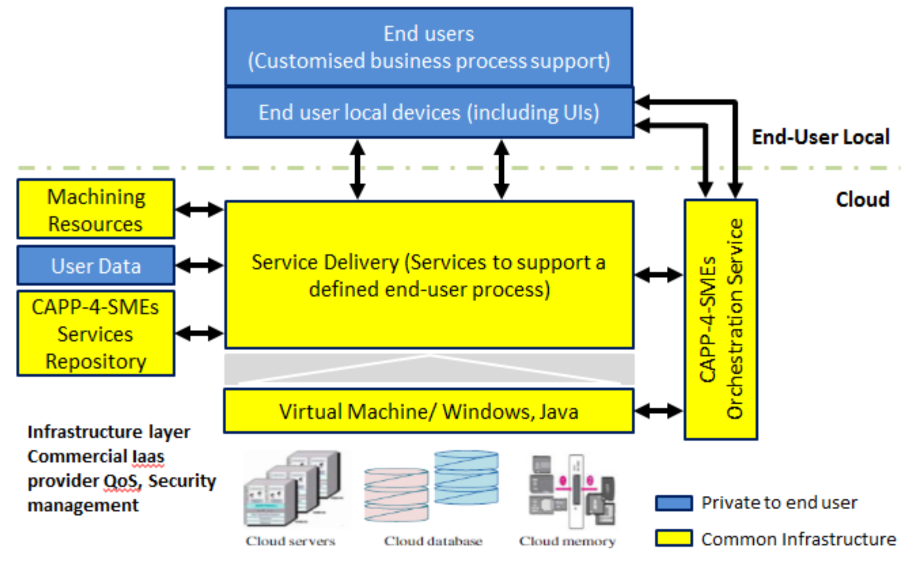


Figure 59. Framework of the CAPP-4-SMEs architecture

Service Improvements

- Portability and Cloud Environment Deployment: an European Federated Cloud environment, i.e., EGI (www.egi.eu), has been adopted to be the Cloud infrastructure for the CAPP-4-SMEs service deployment. With this standardised infrastructure, the portability, global accessibility, robustness of the Cloud infrastructure, etc. for the CAPP-4-SMEs services can be maintained effectively. The CAPP-4-SMEs services are now deployed and executed in the EGI Cloud infrastructure environment;

- Interface: Vaadin has been used to create a single user interface for the CAPP-4-SMEs services. Vaadin uses Java as the programming language for creating web content. It is a cross-platform solution integrating the services programmed in different languages and executed in different operational systems. The Vaadin-based unified interface for the CAPP-4-SMEs services is illustrated in Figure 58;
- Feature recognition: the robustness and effectiveness of the machining feature recognition service has been further validated using complex real-world industrial parts, and demonstrated in the industrial workshops. For instance, Figure 59 illustrates the screenshot of feature recognition for a complex industrial part used in the aerospace industry. The openness of the features for user-defined types needs to be further enhanced in future.

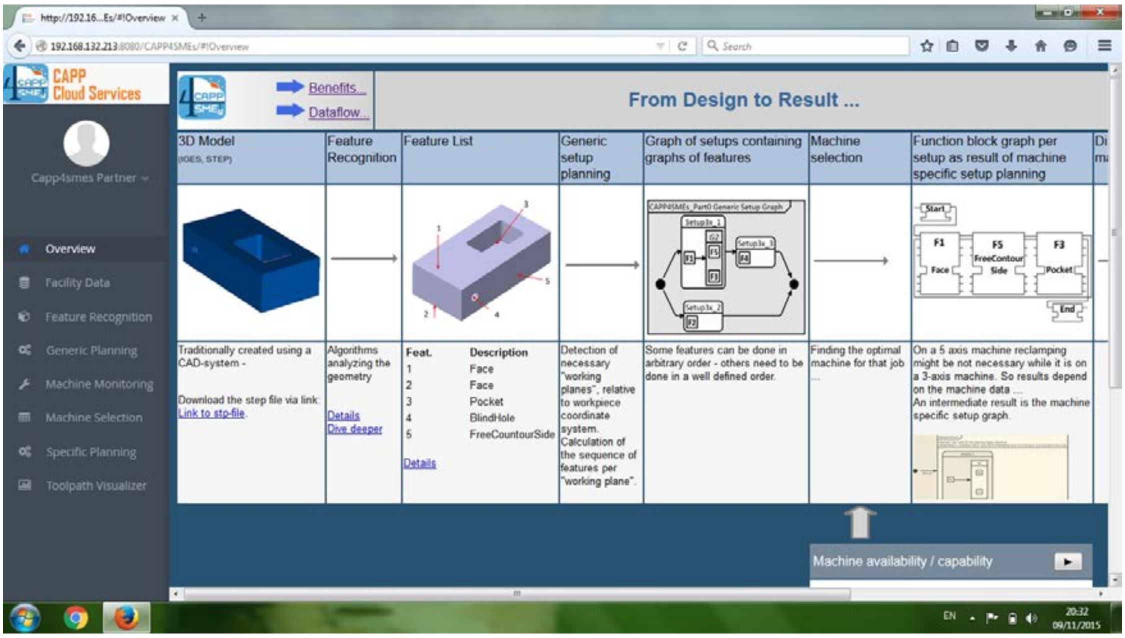


Figure 60. Vaadin-based unified user interface for the CAPP-4-SMEs services

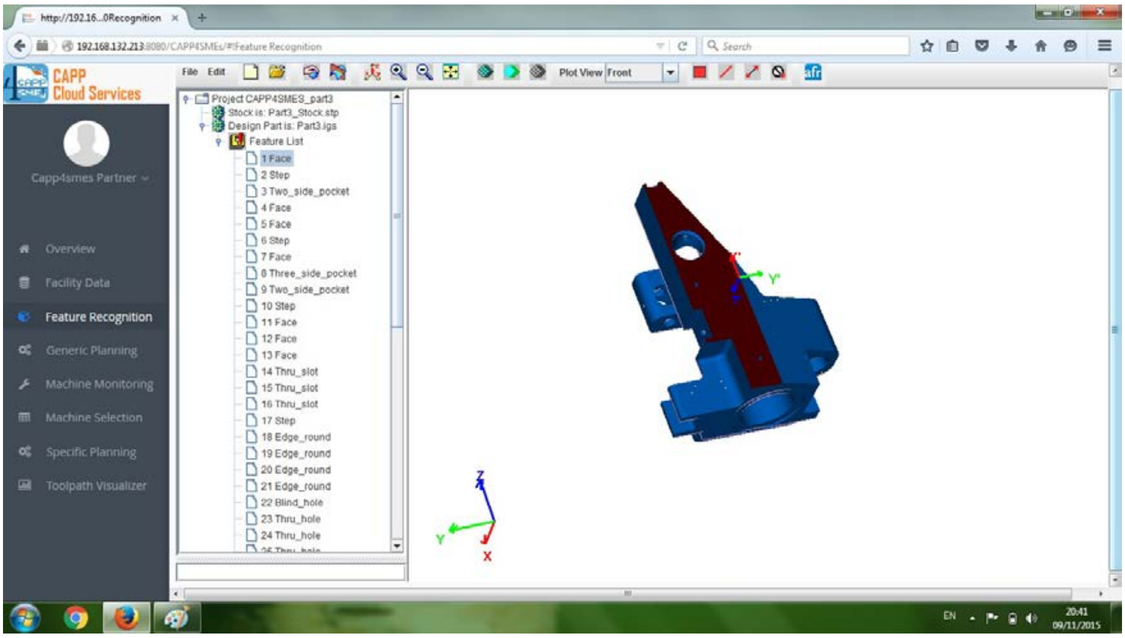


Figure 61. Machining feature recognition for complex real-time parts

6.1.4.1 *WP2*

Service improvements

The feedback from inside the consortium and the industrial audience was evaluated based on the scope and requirements of the project to enhance the capabilities of MAV. Based on the aforementioned points, revisions and enhancements have been performed in software and hardware.

The availability of the machine tools is provided in time frames that correspond to the planning time horizon of the enterprise. The time horizon of the availability windows depends on the data provided by the scheduling tool as it holds the knowledge of the production planning. A screenshot of the availability functionality in MAV is provided in Figure 60.

Duration (minutes)	Starts	Ends	Previous Task	Next Task
240	2015-09-15 21:00:00 +0200	2015-09-16 01:00:00 +0200	MILL5	MILL2
300	2015-09-16 05:00:00 +0200	2015-09-16 10:00:00 +0200	MILL2	MILL3
1260	2015-09-16 13:00:00 +0200	2015-09-17 10:00:00 +0200	MILL3	MILL4

Figure 62: The calculation of the machine tool availability windows based on the integration with the planning system

Other than the real time current measurement visualisation, the GUI for the human operator has been enhanced to provide holistic information about the operation of machine tools through the monitoring of the actual machining time and tool usage. Based on these measurements, the utilisation of the machine tool can be accurately determined and the remaining operating time of cutting tools can be estimated based on the total tool life. Thus potential failures can be identified prior to occurrence. Towards this end, the maintenance department is also kept in the loop by a communication interface and monitoring information. The operator can inform the maintenance department about unexpected machine tool failures that intercept the production. This is developed in software as a text box paired with the “DOWN” status button. By replying in real-time, the maintenance department can assist the operator to solving negligible failures and therefore save production time.

Furthermore, due to the fact that the availability of the machine tool is not the only precondition to perform a machining task, a checklist has been included in the operator’s GUI to provide information about the availability of the raw material, tools, fixtures and remarks of the operator as indicators of the preparation level. This functionality is developed as a standalone feature in this phase of the project, but it can be integrated to inventory management IT tools to capture more parameters that affect the schedule adherence on the shop floor. The aforementioned developments are presented in Figure 61.

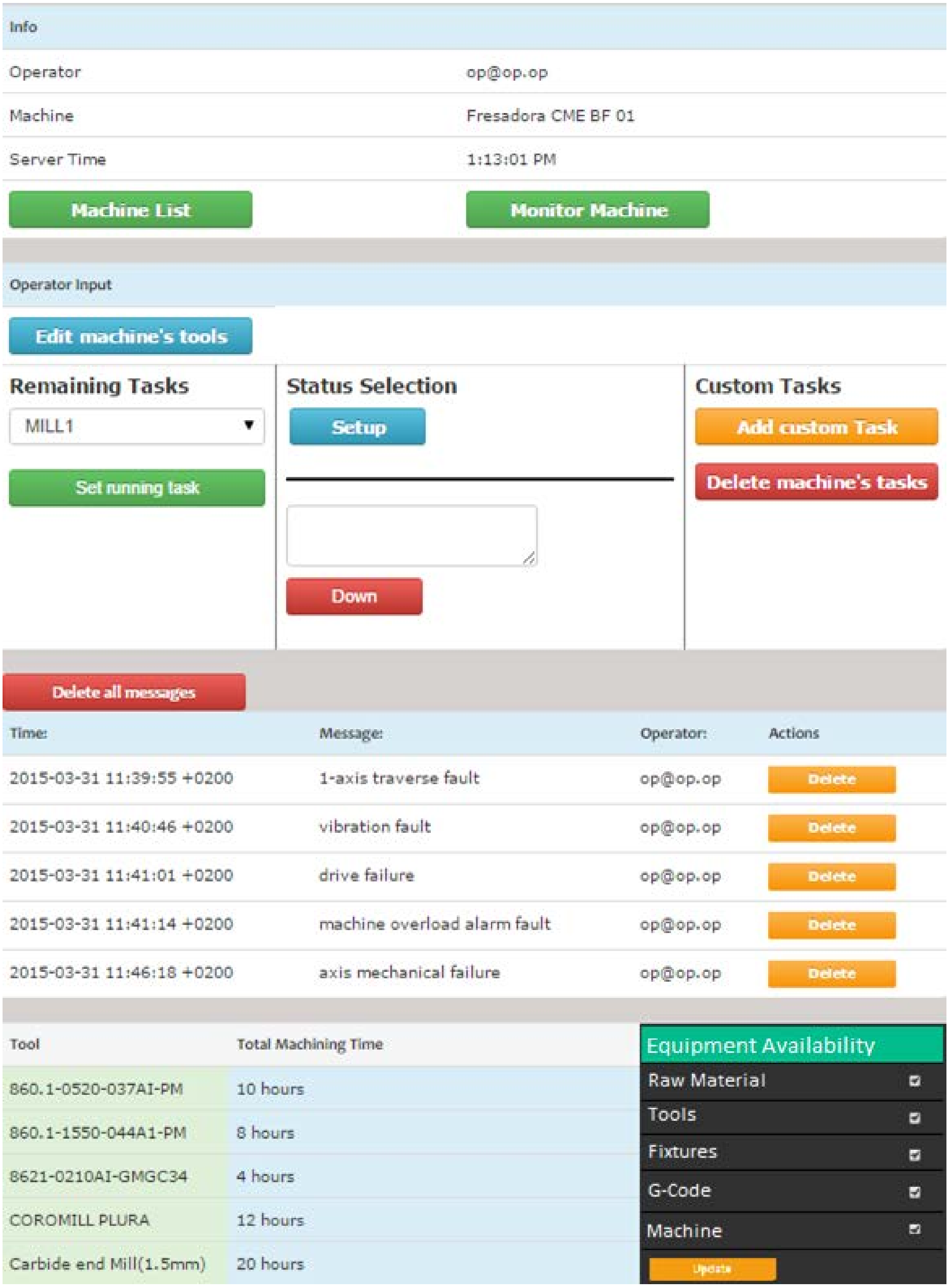


Figure 63. The GUI for the human operator

To facilitate the communication with the shop floor, a GUI is implemented for the maintenance department. This GUI visualises all the necessary information, i.e. messages from operators, the remaining operating time until failure of the machine tools, the current status of machine tools, the availability windows, and real time measurements. By using a text box, the maintenance experts can respond to the failure reports from the operators and therefore provide solutions. The remaining operating time of machine tools is calculated based on the actual machining time, determined from real time measurements, and the mean time between failures (MTBF) that is provided by the machine tool manufacturer. This information, supported with real time measurements can assist the maintenance department to schedule the maintenance tasks according to the condition of the machine tools and therefore result to condition based preventive maintenance. A screenshot of the GUI for the maintenance department is shown in Figure 62.

Figure 64. The GUI for the maintenance department

The developments on the communication between the maintenance department and the human operator enhance the inter-company collaboration using the potentials of new technologies. The issue of collaboration among employees via IT tools is crucial to the improvement of the knowledge sharing that can lead to increased productivity.

Regarding the issue of integration with other IT tools, integration has been performed with the tool library Adveon, which is developed by Sandvik Coromant. The user of Adveon creates the tool assemblies that will be used in their production and a SOAP service performs the data upload to the Cloud. As long as the tool assemblies are in the Cloud, MAV identifies and downloads the tool assemblies that correspond to a specific enterprise based on the Adveon user identification. This integration simplifies the tool management and automates the procedure to store the tool assembly attributes in MAV.

The DAQ that was designed for CAPP-4-SMEs is revised to support more current sensor connections with the purpose to measure the power consumption of machine tools. Furthermore, its compact design facilitates the installation inside the electrical cabinet of the machine tools, without interfering with its normal operation and without obstructing the ventilation system of the cabinet. The core architecture has not changed, as it meets the project requirements for machine availability monitoring with the data rate of 2 measurements per second to Cloud.

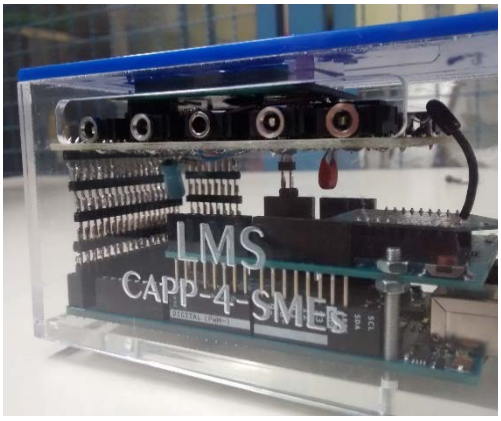


Figure 65. The compact DAQ developed as required by the industry participants of the workshops

Figure 66. The first version of the DAQ (left) and the improved compact version (right) in the electrical cabinet

The compact DAQ enables the use of three current sensors dedicated to the monitoring of the energy consumption. The procedure for calculating the real time power consumption of the machine tool and therefore its operating cost is presented as follows.

In the general occasion, the apparent power of a three-phase load is:

$$S = \sqrt{3} \cdot V_l \cdot I_{average} \tag{8}$$

where S is the apparent power in VA, $I_{average}$ is the average line current of the three phases in A, and V_l is the line voltage of the grid in V,

Despite the fact that modern machine tools are balanced three-phase loads, this fact does not apply in older machines. Therefore, with the purpose to approximate the load as a balanced load, $I_{average}$ is calculated by averaging the current measurements of the line currents via the energy consumption sensors.

When the power consumption is estimated, the next step of the procedure is the energy consumption estimation. The energy consumption is estimated by assuming an average power factor of 0.4 in all three phases, using the Eq. 9. The value of 0.4 is determined by measurements performed by using a high precision power measurement instrument.

$$W = S \cdot cos\varphi \cdot t \tag{9}$$

where W is the energy consumption in kWh, S is the three-phase apparent power in VA, cosϕ is the power factor of the load, and t is the actual machining time in h.

Using the energy consumption of a task, the energy cost of the task can be calculated as:

$$Cost = W\ [kWh] \cdot EnergyCost[\frac{€}{kWh}] \tag{10}$$

The parameters needed to calculate the energy consumption of the machine are:

- The nominal RMS value of the line voltage of the grid (V_l). This parameter is not fixed and varies in different countries. Thus, a data entry field in MAV in added for this purpose.
- The actual machining time is the value already calculated in MAV based on real-time machine availability monitoring.
- The energy cost per kWh depends on the cost rate set by the energy provider. This value is a data entry field in MAV.

MAV acts as an IT solution for centralised control that enables real-time awareness, especially in distributed manufacturing environments. It employs the State of the Art technologies of Wireless Sensor Networks and Cloud Manufacturing to enable flexibility, scalability, and ubiquitous access to information. It can be offered as Software-as-a-Service (SaaS) which makes it suitable for SMEs that require cost efficient and scalable tools. The development as a web service provides access to the shop-floor data via personal computers or mobile devices. Furthermore, the open architecture of MAV offers integration capabilities with existing IT solutions to improve the information flow and enhance the software functionalities.

Figure 67. The MAV login screen

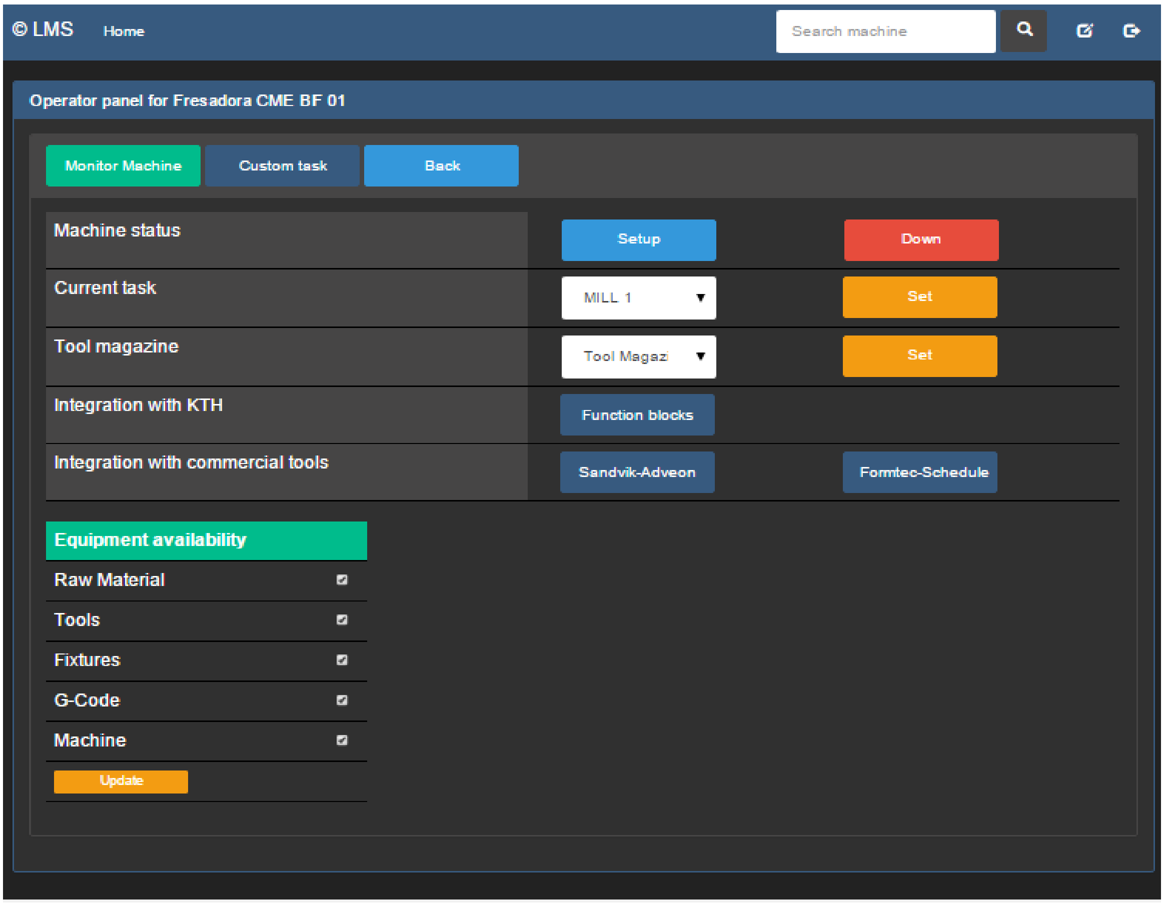


Figure 68. Updated Human Operator GUI

Based on the feedback retrieved during the three workshops, the human operator GUI of the MAV has been updated as shown in Figure 66.

MAV is suitable for all kind of manufacturing enterprises as it can tackle disturbances that are generated from the unawareness on the machine tool availability as a consequence of schedule deviations or unexpected failures. The production planning can benefit from MAV by leveraging the feedback on the monitored sequence of tasks, and the machines that are not available when generating the schedules. Furthermore, the real-time power consumption measurements can indicate whether the machine tools operate inside the preferred ranges. The database of MAV acts as a container for the specifications of the shop floor equipment which can be recovered easily when required.

Additionally, MES providers can benefit from MAV by integrating it in their software solutions. This integration can bridge the gap between the resources and the management software by enabling real-time coordination and precise execution of production operation and meet the increasing customer demands in terms of lead times and customisation.

In future work, Big Data Analytics are considered to manipulate the huge amount of sensorial data that are produced on the shop floor. With Big Data Analytics, insights on the performance of machine tools based on sensorial measurements will be gained. Moreover, further integration aspects will be considered to include also other types of IT tools, such as inventory management tools.

6.1.4.2 *WP3 and WP4*

1. Portability: To enhance the portability of CAPP-4-SMEs services, the WP3 and WP4 modules are improved and amended during the demonstrator implementation. The java codes are deployed from the client side to the server side, which means the major computing and 3D displaying functions are performed remoted on the CAPP-4-SMEs Cloud. In this way, the end users are supported by more light-weighted modules, which can be accessed by more kinds of terminals.

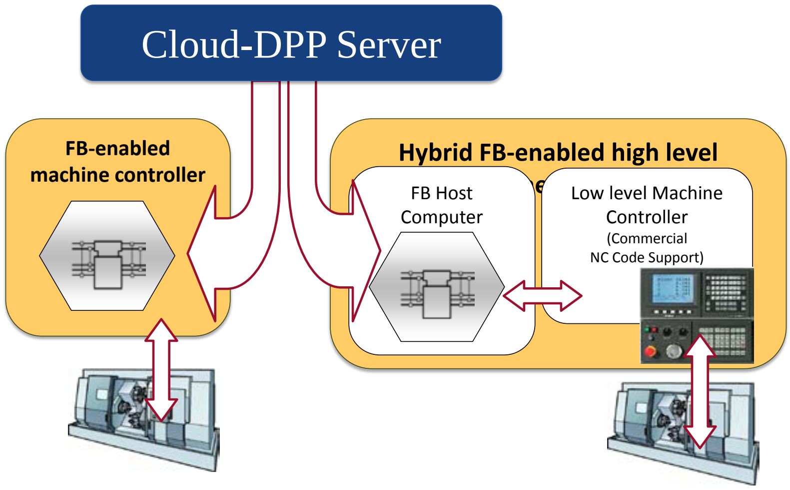


Figure 69. Improved Function Blocks Execution model on Machine Tools

2. Interfacing: it is challenging that the NC controllers are utilized and configures diversely among different machines. That is partially why there are thousands of post-processers available on the NC market. In the CAPP-4-SMEs project, native configuration mechanism can be embedded within the Function Block algorithms, which means machine-specific knowledge can be encapsulated within the modules and deploy on the shopfloor.

Figure 70. Machining execution

3. Knowledge transfer: the knowledge modelling and automation is one of the bottle necks of automated process planning. During the implementation of CAPP-4-SMEs project, the WP3 and WP4 modules are modified to introduce human-machine interactions also. To some degree the human operators are able to modify the conditions and input the machining

knowledge into Function Blocks by updating and improving internal algorithms and variables. In this way the machine intelligence and human experience are merged in the CAPP-4-SMEs solution.

4. Disruptive Innovation: during the deployment of new knowledge, it is common that the current stake holders react in a protective or cautious manner. Not to mention that big amount of investment has been put to the current solutions already. In the future, it is decided that more quantifiable factors can be presented in the public events. For example, it can be identified that how much time and cost the CAPP-4-SMEs solution saves for the industry, compared with conventional approaches. In this way it encourages direct and effective impact to the future partners and users.

5. Improved Generic Setup Process

- Grouping features with same tool access directions.
- Generic setups can be used in 3 / 4 / 5 axes machines.
- Initial sequencing based on datum references.
- Setups and features sequencing based on sequencing rules:
    - Machinability rule
    - Surface feature splitting prevention
    - Hole aperture preservation
    - Volume sorting
    - Feature type grouping

The result is graph of the generic setups and features within them.

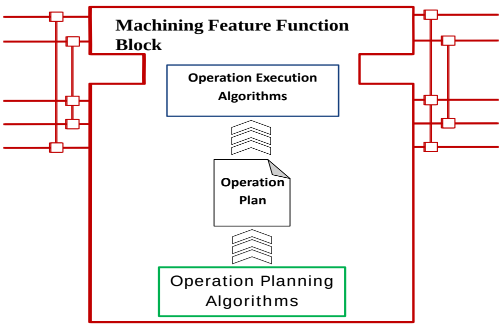


Figure 71. Function Block for manufacturing a machining feature

6. Improved Collaborative and Adaptive Process Planning Service

- Setup Merging and Machine Assignment
- Operation Planning and Execution
    - Setup Merging and Machine Assignment
    - Looking for an optimal solution for grouping generic setups and assigning them to the machines
    - Minimizing the number of setups.
    - Corresponding function block networks generated for each group of merged setup are to be sent to

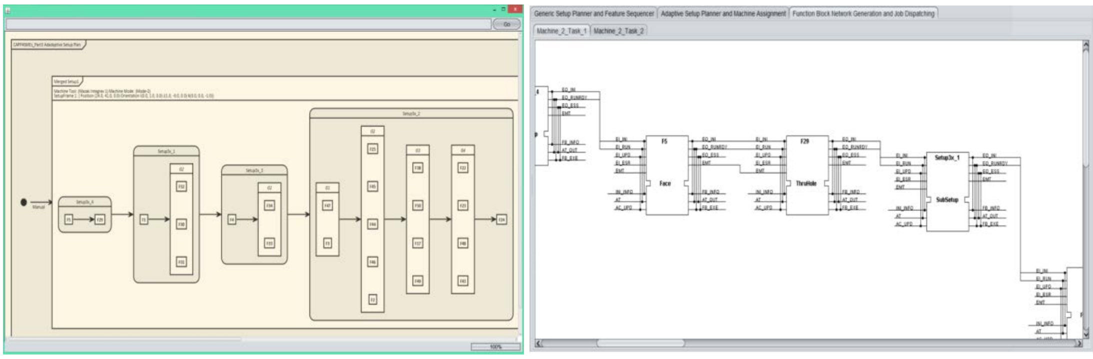


Figure 72. Generic process plan (left) and machine specific setup plan (right)

6.1.4.3 *WP5*

Job Dispatching service

Using the feedback provided, the job dispatching service underwent a series of improvements enhancing both the functionality and the accessibility of the service.

Dynamic data such as the available tools and their dimensions, the availability window as well as the characteristics of the geometry that needs to be machined were included in the decision making algorithm in order to take a well informed decision. In order to get the required information an additional interface was created. This interface describes the feature characteristics and is retrieved using an XML protocol. The data included in this interface are presented in the following table.

Table 3. Feature Data used by the job dispatching service

Part Data	
Part Name	Part Dimensions
Material	Number of features
Feature Data	
Feature ID	Feature Position
Feature Type	Feature Dimensions

The decision making algorithm was also altered to cope with the additional information gathered by the service and the criteria were tuned accordingly. The criteria used in the revised algorithm are presented in the following table.

Table 4. List of selection criteria with the correlated data

Criterion	Correlated data
Machining Space	Part dimensions, machine axis travels
Productivity	Spindle power, Rapid traverse speed
Eco Efficiency	Power consumption
Adaptability	Number of axis
Economy	Running cost
Availability	Availability window
Tool Suitability	Available tool dimensions, Part characteristics

A web based environment was developed to interact with the service, view the available machines and their characteristics, alter the sources through which the data are retrieved and tune the decision making algorithm to the individual end user needs. Furthermore the service was uploaded and runs on PDC cloud, making it accessible to any user having the appropriate credentials. PDC is part of KTH, which runs the Cloud service for the CAPP-4-SMEs project. The user interface itself has been developed using elements that adapt to the screen resolution thus ensuring better user experience. This environment is presented in the following figure.

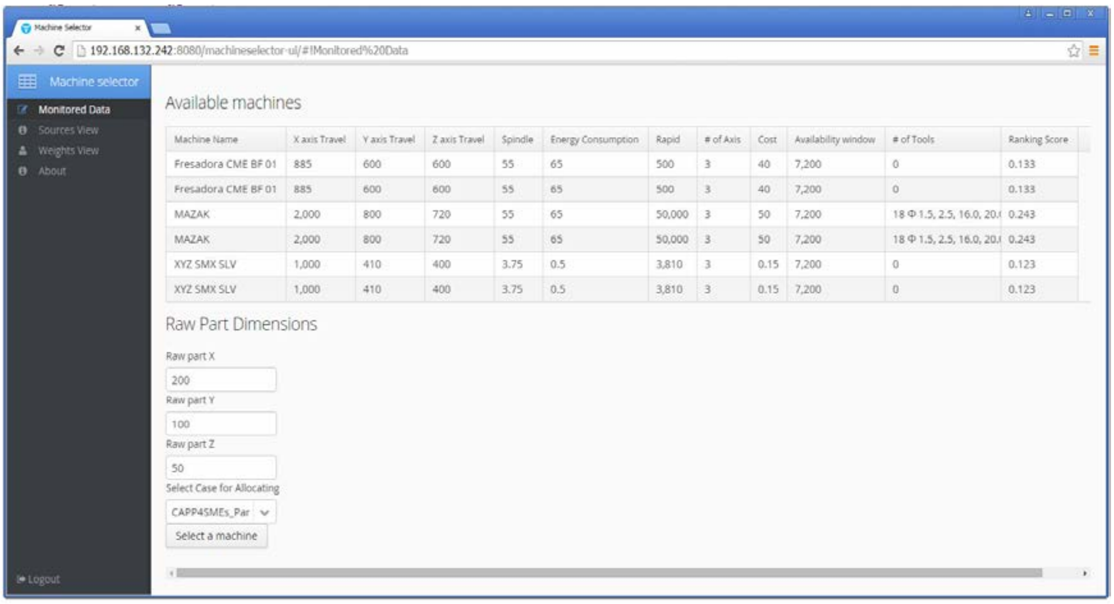


Figure 73. The GUI of the Job dispatching service

6.1.4.4 *Visualisation Service*

The improvement for each feedback has been considered and attempted. The improvements are described as follows:

1. Owing to the effort of configuring Java Runtime Environment (supporting Java application) and Java3D interface (supporting Java3D application) to run the initial implementation of the visualizer, the next implementation was expected to be easy to access without tedious installing procedures. Therefore, following the same core lightweight visualization algorithms, the new visualizer was reprogrammed by JavaScript language instead of Java and the enabling 3D graphics technology was modern WebGL instead of Java3D. This version can run in a web browser without any extra installation. The following figure shows the comparison of the previous visualizer running as a desktop application with the improve one which runs in a web browser (Google Chrome in this case).
2. The feature of the web-based visualizer also enables the visualization service to be accessed across different hardware platforms. Running the visualizer in a web browser of PC, tablet or mobile phone brings much more flexibility for users to verify toolpath. Hence, the issue of the working platform has been resolved. Besides, the newly developed application adopted responsive web design. This approach ensures the layout of the visualizer can be adjusted according to different screen sizes which provide optimal user experience.
3. To fulfil the requirement of “Interactive manipulation of Function Blocks”, the strategy of toolpath visualisation has been altered from plotting a monolithic path to drawing a series of toolpath feature by feature. Each feature-based toolpath carries its own information. According to Figure 72 (bottom), the user can view the feature list on the left side in a tree structure and toggle toolpath depending on the need.

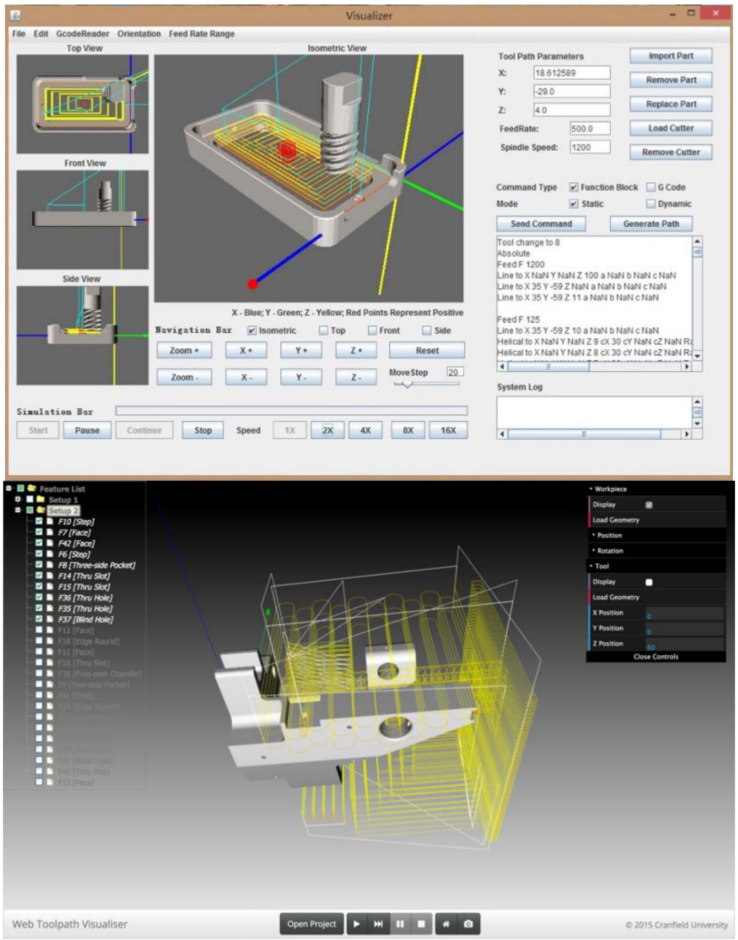


Figure 74. Screenshots of the previous visualizer (top) and the improve one (bottom)

4. In the new visualizer, the following functional requirements according to the feedback are satisfied. All the improvements enhance the usability of the lightweight visualizer.

- The background of the software is set to a clear scene where used to be a black canvas.
- Mouse wheel is used to control the zoom operations and also the 3D object can be panned by dragging with the right mouse.
- In the cutting process simulation mode, the step which is current running is indicated in red lines.
- G-Code can be interpreted into toolpath by dragging and dropping G-Code files into the visualizer.

5. Cloud integration is achieved. The input of the visualizer is the output from the machine specific setup planning module, so an interface between these two ends was defined. The data containing the Function Block based toolpath information generated by the setup planning system can be automatically fed into the visualizer through internet communication.

The lightweight visualizer can help users verify the machining code generated by Function Blocks by providing the functions of tool path plotting and cutting process simulation. This service runs in a Cloud environment and can be accessed by using a WebGL-enabled web browser on a PC, tablet or mobile phone. The input of the visualizer is from the machine specific setup planning module and is to be translated into feature-based toolpath. In short, the lightweight visualization service provides an efficient and effective way of interacting with the toolpath as well as manipulating Function Blocks. The improvements are summarized in the following table.

Table 5. Improvements of the lightweight visualizer

	Initial version	Current version
Programming Language	Java (require configuration)	**HTML/JavaScript (no need to install)**
3D Rendering Technology	Java 3D (outdated)	**WebGL (currently widely used)**
Working Platform	PC	**PC, tablet, mobile phone**
Function Blocks Manipulation	No	**Yes**
Cloud Integration	No	**Yes**
User Experience	Qualified	**Enhanced**

Two functions suggested by the experts – more 3D model formats support and tool hold for crash detection - have not been realised because of limited research time. They are considered as the work for future research. Moreover, future work involves the dynamic input-visualise mode designed to meet the requirement of real-time for the visualizer. This work mode will be able to visualise the changes of toolpath shortly after they are made by Function Block system.

6.2 WP7 — Dissemination and exploitation

Work Package Number	*7*	**Start date**			*M1*
Work Package Title	Dissemination and exploitation					
Activity Type	*OTHER (*Dissemination and exploitation*)*					
Participant Name	**KTH**	**COV**	**LMS**	**CU**	**SAN**	**PROD**
Person-months	0.5/0/2	1.17/3.62/2	0.81/1.71/2	0/1.5/2	1.41/0/3	1.05/2.13/3
	ICT	**FT**	**AF**	**CAM**	**PKT**	
	0/3.3/5	0//6	0/6/8	0.6/2.5/6	1.5/0/8	

This WP concerns dissemination and exploitation activities. One vital goal of the dissemination plan (D7.1, accepted by EC) of this project is to synchronise the activities of the project partners and keep them in touch with the project progress. This will streamline the contribution activities.

Externally, CAPP-4-SMEs targets three different major groups:

- the scientific & academic communities,
- the industrial manufacturing services sector, and
- providers and developers of manufacturing machines and tools.

Given the differences among these groups of stakeholders, in terms of needs, foreseen benefits, cultural traits and expected impacts, dissemination of CAPP-4-SMEs foreground has been structured into sections according to the target groups. This will ensure payoff of the dissemination and exploitation activities and increase industrial outreach and take-up of results. Since representatives of all three major groups are among the project partners, the development of the dissemination plan is strongly based on partners' contributions.

The D7.1 dissemination plan is designed as a live document, which will be updated, enriched and extended along the project lifecycle. Later on, the dissemination plan will be extended by an exploitation plan. In other words, the initial operational conception and programming of activities is periodically enhanced and refined according to the progress and the results of the project and the evolution of the prototypes. The idea of bringing RTD results to sizeable impacts in industry is shown in Figure 73, where dissemination and exploitation play an essential role.

The dissemination and exploitation activities are performed in accordance to two specific, industry-oriented and tightly interconnected plans:

- a *Dissemination Plan*, focused on conveying information to audiences beyond the consortium boundaries, related to the design, performance and, specially, outputs of the project, and
- a *Exploitation Plan*, by forming networks of parties interested in taking advantage of project´s outputs, aiming at shaping the exploitable results of the project and configuring the conditions for the future commercial usage of knowledge created by this project.

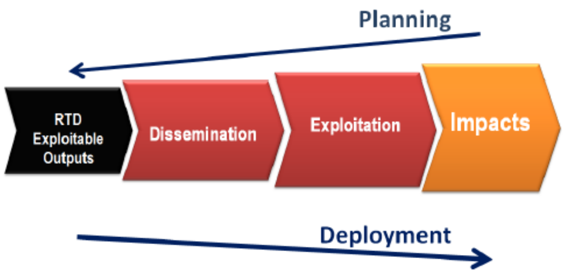


Figure 75. Dissemination and exploitation process

As shown in Figure 74, these two plans work closely together to adjust their activities, respectively. The dissemination plan acts as the base on which the exploitation activities can build upon.

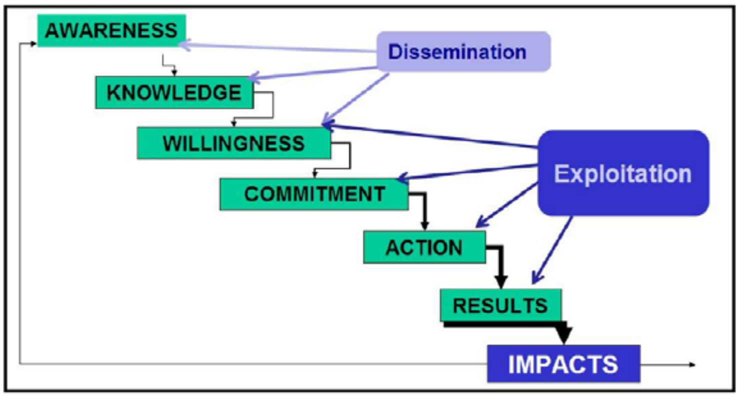


Figure 76. Relationship between dissemination and exploitation

6.2.1 Objectives

The CAPP-4-SMEs project undergoes an *exploitation driven dissemination* strategy as depicted in Figure 75, activities of which aim at reaching the following objectives, beyond contributing to the attainment of FP7 objectives:

- raising awareness and disseminated information about the project and promoting uptake of CAPP-4-SMEs cloud architecture, methods, tools and services among the early adopters,
- paving the way for deploying advanced but mature and usable CAPP-4-SMEs technologies solutions, to be validated under controlled exploitation scenarios, with the view of fostering future wide take-up by the industry,
- building-up a sustainable community, facilitating dialogue and further collaboration between research and industrial players,
- producing a market and technology watch, in order to secure alignment and relevance of CAPP-4-SMEs outputs with respect to customer needs and expectations, while taking into account trends/threats arising from the potential competitors,
- understanding and best possible identification of medium- and long-term challenges across industries and market players,
- defining future commercal/industrial usage of project's exploitable outputs, facilitating the formulation of individual partners, and
- producing multiplied outreach effects on industry and society, aimed at fostering take-up of the outcomes of the project.

The formulation of the successive versions of the Dissemination and Exploitation Plan requires progressive definition of the future exploitation of CAPP-4-SMEs outputs and cloud services with continuous interaction with dissemination activities, for shaping dissemination target groups, messages and actual knowledge sharing activities, thus **fostering the consortium to increasingly follow an exploitation driven dissemination strategy**.

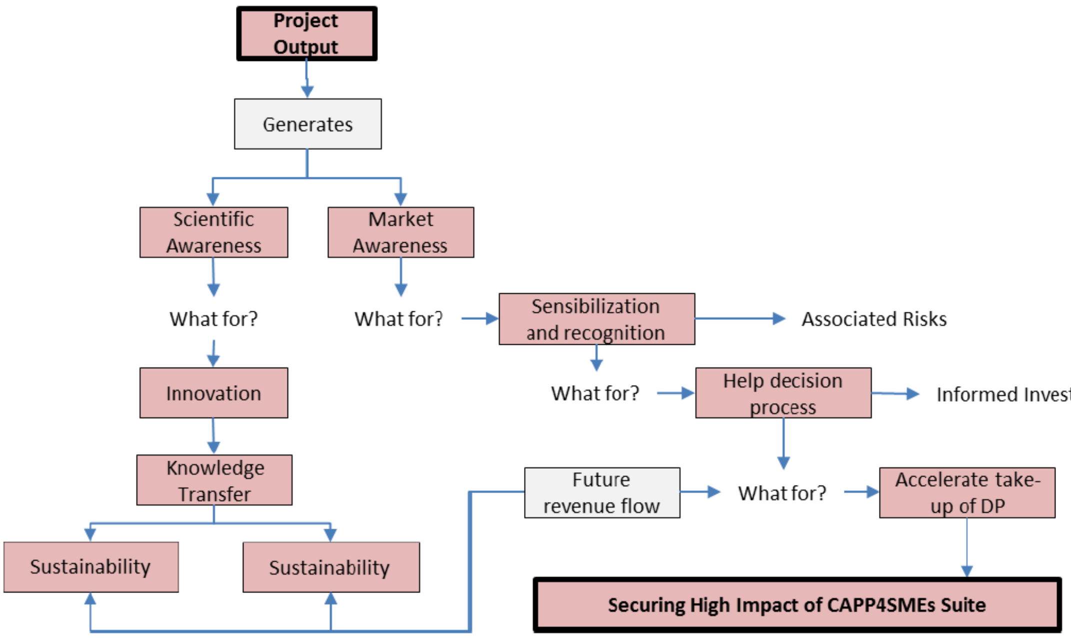


Figure 77. Formulation of successful research output

Target groups

Although target audience is deemed as quite wide, industry oriented dissemination and exploitation efforts are mainly focused towards the following target groups:

- Market–potential: Small and medium manufacturing companies, specially companies acting as manufacturing service provider for larger OEMs and suppliers in the machinery, automotive, aerospace, medical device, shipbuilding and consumer electronic industries with functional engineering activities in the discrete manufacturing sector. This target group is the main beneficiary of CAPP-4- SMEs since the full scope of the solution is aimed at the typical business processes of such organisations. According to this, this group is the 'end-user'. Furthermore, the project's design principles (mainly the cloud based, service oriented approach) consider the main demands of this group: fast and flexible deployment, low IT-hardware requirements, low start-up investments, benefits even at lot size 1, fast reaction on radically modified boundary conditions.
- CAD Software vendors, integrators and consultants: CAPP-4-SMEs target companies specialised in CAD model generation. There is a potential for embedding a feature based technology already in the design of the mechanical parts. Working with software developers, integrators and consultants as partners, provides the agility to expand market reach and take advantage of opportunities more quickly. This group is the key for successful distribution of CAPP-4-SME's technology. It is a vital requirement to convince this target group of the benefits.
- Providers and developers of manufacturing machines and tools: Since vital parts of CAPP-4-SMEs are potentially located inside a machine controller, this group should be convinced to adopt the new approach. Furthermore, main parts of optimisation base data are influenced by tool capabilities. Therefore, seamless integration of tool data and tool services are a potential business model for companies engaged in this business. Typical audience at this target group is the research and development department.

6.2.2 Dissemination plan (Task 7.1)

The CAPP-4-SMEs dissemination plan is focused in conveying information to audiences beyond the consortium boundaries, related to the design, performance, usability business models and specially, outputs of the Project. Thus communication and dissemination of project results align and coordinate the CAPP-4-SMEs communication strategy with message, channel, frequency and timing of the actions.

Based upon experience in previous RTD Projects and marketing activities performed by CAPP-4-SMEs partners, the initial CAPP-4-SMEs *industry-oriented dissemination strategy* is configured under two main action lines:

- Action Line 1: Building-up visibility by creating an adequate level of awareness among target groups
- Action Line 2: Building-up a portfolio of potential exploitation stakeholders, by establishing networks of parties interested in taking advantage of project´s outputs, looking for the creation of future business opportunities in manufacturing services and outsourcing.

In this regard, the industry-oriented exploitation-driven dissemination activities comprise the chain of steps shown in Figure 76. Recent and planned dissemination activities are listed in Table 6.

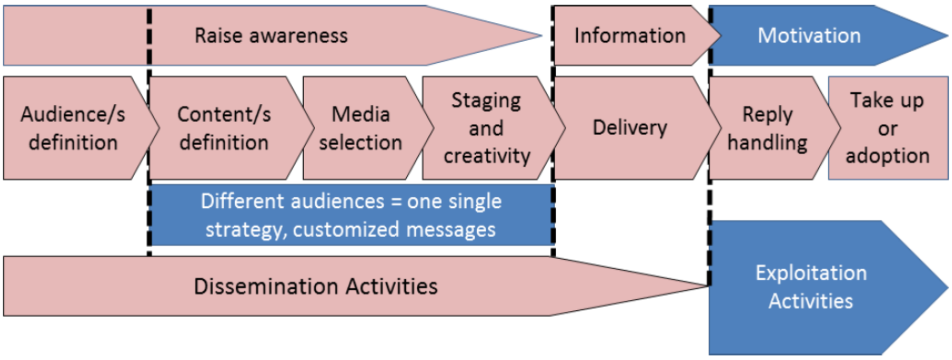


Figure 78. Dissemination activity chain

The CAPP-4-SMEs Consortium has proposed to gain visibility through building tactical alliances with affinity groups and other relevant EU FP7 projects. This is appropriate for projects that are engaged in the development of intelligent information management in the industrial mechanical engineering and manufacturing environment. The activities are:

- jointly promoting and strengthening the projects impact at European industry level
- extending project outputs exploitation opportunities in the industrial SME segment
- sharing dissemination forums and events
- providing and sharing good lessons, best practices and guidelines
- promoting cross-fertilisation

Table 6. Selected dissemination activities

Date	Type	Audience	Title	Author	Partner	Location/Link
2013						
2013	**Conference**		Knowledge-Based Operation Planning and	M. Givehchi, B.	KTH	Advances in Sustainable and Competitive
Spring 13	**Presentation**	Big Chinese			FORMTEC	Germany, PR of China, Taiwan
13-Jun	**Publication**		A hybrid honey-bee mating optimization and	X.X. Li,	COVENTRY	17th IEEE International Conference
				W.D. Li,		
				X.T. Cai,		
				F.Z. He		
13-Jun	**Publication**		Multi-granularity partial encryption method of CAD model	X.T. Cai, F.Z. He,W.D. Li,X.X. Li,	COVENTRY	17th IEEE International Conference Computer Supported Cooperative Work in
13-Jun	**Conference,**				ICT	Imagine FOF 2020 Conference
13-Aug	**Presentation**				CRANFIELD	CIRP Conference, Denmark
13-Sep	**Presentation**	Delegates of			COVENTRY	Coventry
13-Oct	**Presentation**	Delegates from			COVENTRY	Coventry
13-Oct	**Conference**				ICT	Manufuture Conference
2014						
14-Mar	**Conference**		Inclusion in presentation in on current CU research		COVENTRY	Interoperability for Enterprise Systems
14-Mar	**Conference**	Researchers/	Machine availability monitoring for adaptive	Mourtzis D. Doukas	LMS	http://www.det-2014.de/en/home.html/
14-Apr	**Exhibition**	Public/	MACH 2014		CRANFIELD	http://www.machexhibition.com/
						(UK)
14-Apr	**Conference**					International Conference on Sustainable
14-May	**Publication**	Public	Presentation in local newspaper		PROD	
14-May	**Tutorial**	Industry	The Principles of Sustainable Manufacturing	Tapoglou N.	CRANFIELD	Tenth Symposium on Tools and Methods
14-May	**Talk**		CAPP through Cloud manufacturing for CNC	Mehnen J.	CRANFIELD	CIRP UK assembly, Cardiff UK
14-May	**Invited Speech**			W.D. Li,	COVENTRY	2014 International Forum on Green
14-Jun	**Publication**		CAPP-4-SMEs presentation in EFRA newsletter		CRANFIELD	
14-Jun	**Link**		EGI / PDC			
14-Jun	**Conference**	Researchers/	Optimal toolpath programming based on real-time	Tapoglou N.	LMS	
14-Jun	**Conference**	Researchers /	Cloud Based Feature Recognition System to	Arivazhagan A.,	COVENTRY	http://www.asmeconferences.org/msec20
14-Jun	**Conference**		Optimal Machining Parameter Selection Based On	Tapoglou, N.,	CRAN	ASME 2014 Manufacturing Science and
14-Jul	**Keynote**		Cloud-DPP: Distributed Process Planning in the	Wang, Lihui	KTH	6th International Conference on High
14-Sep	**Conference**		Uncertainties in Cloud Manufacturing	Yaser Yadekar,	CRANFIEELD	Submitted to CE 2014, The 21st ISPE
				Essam Shehab,		
				Jorn Mehnen		
14-Sep	**Conference**		A Taxonomy for Cloud Manufacturing	Yaser Yadekar,	CRANFIELD	Submitted to ICMR 2014, Proceedings
				Essam Shehab,		
				Jorn Mehnen		
2015						
15-Apr	**Workshop**	Industry			PRODINTEC	
15-Apr	**Publication**	Public			PRODINTEC	http://www.lne.es/gijon/2015/04/27/prod
15-Apr	**Publication**	Academic	Generic machining process sequencing through a	M. Givehchi, A.	KTH	Journal of Manufacturing Systems,
15-Jun	**Publication**	Industry	Cloud based platform for optimal machining	N. Tapoglou, J.	LMS	ASME -Journal of Manufacturing Science
15-Jun	**Workshop**	Industry			FORMTEC	
15-Jun	**Conference**		A New Era of web collaboration: Cloud computing	D. Mourtzis, B.	LMS	International Working Conference Total
15-Jun	**Conference**	Industry	A cloud-based approach for maintenance of	D. Mourtzis, E.	LMS	48th CIRP Conference on Manufacturing
15-Jun	**Congress Paper**		Cloud-based Adaptive Shop-floor Scheduling	D. Mourtzis, E.	LMS	Accepted for publication in the
15-Jun	**Conference**		A Framework for Cloud Manufacturing Enabled	Tapoglou, N.,	CRAN	APMS 2015 International conference
15-Jun	**Conference**		Online on-board optimization of cutting parameter	Tapoglou, N.,	CRAN	13th Global Conference on Sustainable
15-Jun	**Conference**		Cloud-Based Job Dispatching Using Multi-Criteria	Tapoglou, N.,	CRAN	48th CIRP Conference on Manufacturing
15-Jun	**Conference**		A Semantic Representation for Process-oriented	Gernhardt, B.,	KTH, ICT	ASME 2015 Manufacturing Science and
15-Jun	**Publication**	Academic	Latest Advances in Function Block Enabled	M. Givehchi, A.	KTH	Proceedings of the 4th International
15-Jun	**Publication**	Academic	Adaptive distributed process planning and	M. Givehchi, A.	KTH	Flexible Automation and Intelligent
15-Aug	**Conference**		A semantic representation for process-oriented	Gernhardt, B.,	KTH, ICT	ICAT 2015 International on Advanced
15-Jun	**Publication**		A Semantic Representation for Process-oriented	Gernhardt, B.,	KTH, ICT	International Journal of Advanced
15-Jun	**Publication**	Academic	A hybrid honey-bee mating optimization and	X.X. Li, W.D. Li, X.T.	KTH	Integrated Computer Aided Engineering
15-Jun	**Publication**	Academic	Encryption based partial sharing of CAD models	X.T. Cai, F.Z. He,	COV	Integrated Computer Aided Engineering
15-Jun	**Publication**	Academic	A systematic approach of process planning and	S. Wang, X. Lu, X.X.	COV	Journal of Cleaner Production, 2015, 87,
15-Jun	**Publication**	Academic	A customised encryption approach for	X.T. Cai, W.D. Li,	COV	ASME Transactions Journal of Mechanical

Although cooperation takes different approaches on a case-by-case project, main alliances targeting industry related stakeholders include the projects:

- SMARTPRODUCTS. Also located in the domain of design and engineering of products.
- SMARTVORTEX. A project which concentrates on computation of massive and fast sensor data stream. The CAPP-4-SMEs Partners Sandvik Coromant and InConTec are participants in this project which can be seen as a use case for milling machine monitoring.

A not-to-be-neglected target group for dissemination activities is the consortium itself. It is vital to keep all participants in touch with project progress. Every partner has to be involved into discussions decisions. Knowledge has to be synchronised among the partners and the tasks have to be shared carefully avoiding double work. For this purpose following actions have already been taken:

- Creation of an internet based project repository. It is hosted by KTH.
- Periodic online meetings (biweekly) for knowledge exchange and decision making.
- Establish a software versioning system for software-based project results, hosted by LMS.

- Founding of a ‘Walkthrough Group’ with weekly online-meetings. This group works along the workflow of reference project to discuss all occurring problems. It is a very helpful approach for the identification and tuning of interfaces between the project partners/work packages. The group formerly started as the ‘Software Group’ during a kick-off meeting in Mühlheim, Germany organised by FT. All group members are engaged in creation of software or should deliver services to be integrated.

For details of dissemination strategy and activities, please refer to D7.1 Dissemination Plan.

6.2.3 Exploitation plan (Task 7.2)

Market opportunities

Positioning CAPP-4-SMEs

CAPP-4-SMEs is a pioneer in being a fully Industry 4.0 application ranging from design to machining via milling process.

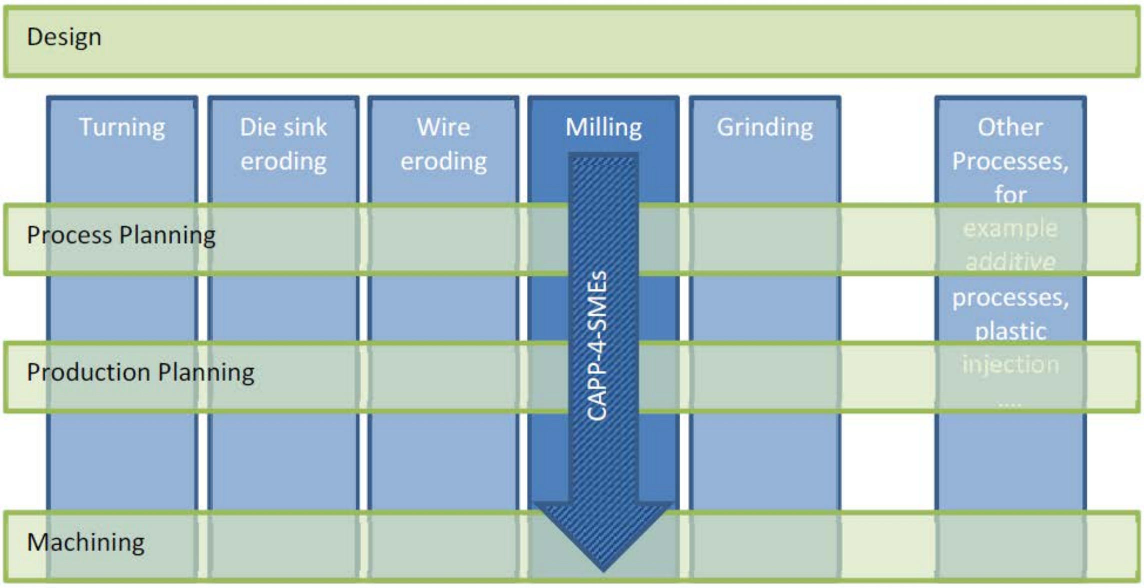


Figure 79. CAPP-4-SMEs positioning

The typical end user of CAPP-4-SMEs is a SME running milling processes. The end user convenience, economic benefit and the chance to exploit new business areas are the main criteria for market opportunities.

Analysis of current workflow and business model

In the context of early exploitation activities, POK supported by COVUNI made a workflow analysis for 3 typical SMEs to verify the convenience of the CAPP-4-SMEs' approach. These workflows include the technical and as well the administrative aspects of typical SMEs job processing. The result showed up the complexity even of small businesses and the need for integrating and optimizing and at the same time for flexible solutions. There is a potential gap for modular, service based, orchestration on demand solutions. Since low entry level and easy to run systems are important for SMEs cloud based approaches are well suited for that.

Furthermore the analysis showed that most of the time in a manufacturing project is spent in preparation activities, like quoting. This fact has to be faced by any upcoming solution. At the same time it can be a big marketing benefit to have solutions reducing that overhead.

The importance of streamlining administrative overhead might decrease with big lot sizes. But the companies being analysed have been carefully selected to have very different portfolios, so that the evidence of the statement still will be present. As conclusion the seamless integration into administrative systems or the extension by administrative modules is vital.

Interviews with several SMEs during dissemination activities showed up: There are two main things

SMEs engaged in goods creation offer to customers:

- Process knowledge
- Manufacturing capacity

European SMEs typically tend to see their market benefit in process knowledge. Manufacturing capacity is more or less a secondary aspect that can be even handled by outsourcing. Considering these preconditions any solution must be able to

- protect and preserve process knowledge,
- simplify and streamline the access to external manufacturing capacity,
- simplify external offering of manufacturing capacity while protecting process knowledge.

If designed to protect intellectual property in process design and parameters a cloud based approach with distributed planning capabilities potentially is a good choice.

Regarding company workflow CAPP-4-SMEs is a disruptive approach. That might not fit well to the slow and careful evolution of current manufacturing in SMEs. There is a tendency to stick to the well established, powerful and well known tools like CAD/CAM and devices like NC-code driven machines. One reason for that is the large amount of capital bound to these tools and devices and the resulting economic reach of decisions. They need to be done carefully to preserve the existence of the company. Tools with low financial entry level like CAPP-4-SMEs can simplify decisions and increase dynamics.

It is impossible for a new solution to offer the same functional extent as tools having been developed over 30 years (like CAM systems). CAPP-4-SMEs is a feature based approach. That means that for the next upcoming years there will always miss certain features for certain cases. Easy and structured extendibility is vital. But CAPP-4-SMEs will not be able to replace existing solutions immediately.

For existing companies a fruitful coexistence of traditional systems and CAPP-4-SMEs is a step into a more dynamic future. CAPP-4-SMEs has to face the demands resulting out of this fact.

Conclusions for Exploitation

CAPP-4-SMEs can be the seed for new business models for new and existing companies using a completely new workflow. Nevertheless it will have to fulfil several medium and long term demands.

- Market visibility must be achieved beyond project scope
- The modules need to be improved over time for sufficient power and flexibility to do the same things that can be done with current systems / workflow.
- All business processes and logic needed for the daily work must be available
- The user interface must be convenient for the typical user group and use cases
- Full service, implementation assistance, support with long term perspective must be guaranteed.

That is beyond the scope of the project. The targets for CAPP-4-SMEs approach are SMEs running milling processes. But the targets for exploitation activities are companies / organizations picking up CAPP-4-SMEs concepts, ideas, code, etc. and establishing a professional, innovative and reliable offer for SMEs.

CAPP-4-SMEs is trying to introduce a new technology into the machining industry. Typically a start-up would try to sell the new approach by promoting a new product. Nevertheless the start-up will have to do some development. If it is sufficient to

- develop an user interface and use the project outcome at the state of project end as backend or
- if a complete redesign using another development tool chain is preferred depends on the decision of the start-up. In any case the return on investment is crucial in the start-up creation.

As a foundation for further target-oriented exploitation several strategies have been developed.

Exploitation Strategies

There is no need to decide for one special strategy – a mix of all is possible for exploitation.

Strategy 1: Core of new Business Models

This strategy advertises CAPP-4-SMEs (especially the main module Cloud DPP) for direct use as a core of a completely new business model. For new manufacturing start-ups the result of CAPP-4-SME could be used as the main tool for any manufacturing activities. This approach depends on the coverage and quality of the project outcome.

Any extension in the manufacturing business depends on further development of CAPP-4-SMEs based on the existing code. A completely new combination of skills like programming and manufacturing could be a potential foundation of new companies. In this context a very tight cooperation between a software service provider and a production company can also be an opportunity.

Furthermore there is a chance for milling machine manufacturers or tool providers to offer specialized versions of CAPP-4-SMEs along with their products.

Another possible business model: Using the CAPP-4-SMEs approach it is possible to create services which are able to find most convenient companies for certain manufacturing jobs – only having some drawings and little more additional information. Providing and / or using these services could be the innovative business of a start-up.

Strategy 2: Common User Interface

One main exploitation strategy is to do a follow up development for a common user interface (CUI)

for the end user. Dependant on the final result of the project, there can be remarkable work to do.

The main development task will be to orchestrate and perhaps adapt the CAPP-4-SMEs backend web services to reflect all needed business processes and use cases.

Even if the final result of the project is convenient for daily work, it is limited to milling processes. To enlarge the scope the whole system should undergo an abstraction cycle. Afterwards the system could be able to administrate all types of manufacturing processes – even if not every process is supported by powerful algorithms and requires manual input.

Potentially the output of existing systems (for example CAM-systems) can be seamlessly integrated on demand. The result finally will be a modular system building a powerful integrating framework for cloud based production planning. Developed like this the solution will integrate smoothly into current companies and be an important cornerstone for Industry 4.0. This will increase acceptance and confidence and finally increase the market impact.

The exploitable results of CAPP-4-SMEs in this scenario are

- Well documented back end web services with well documented interfaces (API's)
- Verified functionality of the web services
- A basic user interface for these web services for demonstration, debugging and testing
- Very good system documentation as a base for reimplementation using another development tool chain.

All documents, code, algorithms etc. need to have a qualifier for

- being result of the project (so that intellectual property can be shared among project partners)
- having been created out of project scope (then the follow-up usage of that intellectual
- property needs special agreements).

Every work package leader is responsible to meet the requirements regarding documentation and code quality.

One way into that exploitation strategy could be follow-up projects in the Horizon 2020 context. It is investigated if there is an overlap with other initiatives like FLEXINET. It could also be picked up by a research organisation out of that scope. Dependant on the focus of a potential follow-up project the results will be in the range between end user qualified to pure academic relevance. One important aspect for the design of any follow up activities is to keep the knowledge of the CAPP-4-SMEs participants.

A second way into that exploitation strategy would be to find a commercial follow-up by a company with development power. There are discussions among consortium members about this. But finally the exploitation activities could go into the direction to find an external organization. The decision to find an external organization should be made near term, at least 6 month before end of project, so that necessary activities are in the scope of the CAPP-4-SMEs project.

A third way into that exploitation strategy would be to found a spin off by one or more consortium members or persons. Right now it is not expected to find potential protagonists for that.

Until the decision for a follow-up type (commercial or not) has not been made, no portions of intellectual property created in the context of the CAPP-4-SMEs should be made public available, to keep the chance for commercial usage.

Strategy 3: Integration by other Systems

Another exploitation strategy is to prepare the CAPP-4-SMEs results for usage by existing systems. This will potentially boost the excellence of existing ERP-, PLM-, MES-, PPS-, CAM-systems in milling process planning. Since the web based / cloud based approach is not very wide spread among providers of these systems the integration of CAPP-4-SMEs result could be a very smart step to distributed process planning.

At the same time this is a clear path how to spread CAPP-4-SMEs power into companies since every company already uses one or more systems like this.

The exploitable results in this scenario are the same as for strategy 1: It's all about good documentation, well designed interfaces (API), easy to understand functionality.

As prove of concept FT (WP7-leader, Dissemination and Exploitation) and LMS (WP2 leader, Monitoring System) developed an interface between the monitoring system and a legacy MES / PPS hybrid planning system (the Microsoft® Windows® native application 'PLT'-system by FT). The monitoring system is used as the shop floor based tool for job picking, job starting and job finishing. The interface is a HTTP-based web interface. The monitoring system is getting the next jobs for a machine from the planning system. Job picking and finishing is reflected to the planning system.

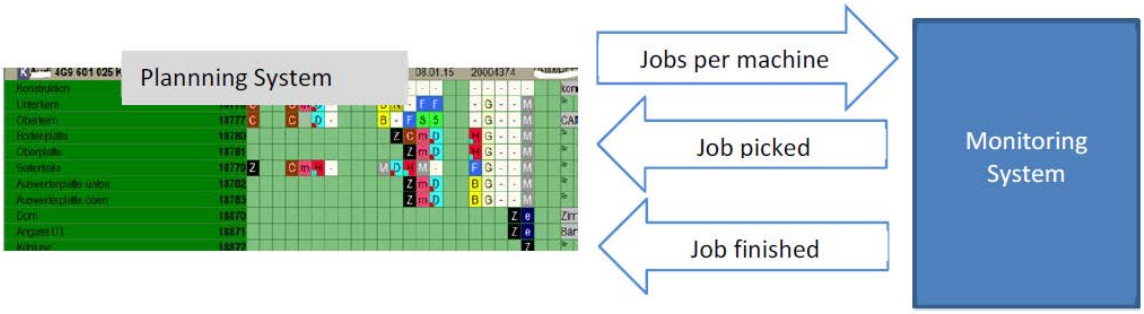


Figure 80. Interface planning system / monitoring system

This interface can be extended for additional information on demand and shows the flexibility of integration via web based API's.

As soon as interfaces are ready and stable for usage they potentially should be published for external use. For keeping future relevance of the results, advertising, user support as well as further development needs to be done by a follow-up organization or project. These are the same as for strategy 1. The decision for a follow-up method in the context of this strategy needs to be made near term, too. Dependant on the decision exploitation activities have to be scheduled.

Strategy 4: Exploiting separate Modules / Functionality

During project evolution several modules or functionalities have been determined which could attract market attention or have technological relevancy for Industry 4.0 even if not used in CAPP-4- SMEs – context.

S4.1 Feature Recognition System

Description: The module uses IGES, STEP drawings as input and creates a list of features. The format of the list is explicitly described. It is programmed in C/C++ and uses OpenCascade.

Author / Developer: COVUNI

Commercialization hints: For commercialization the licensing of OpenCascade has to be investigated.

Comments: A user interface for manual interaction or pure manual creation of feature lists is under discussion. Furthermore, a user interface would be helpful for input of data that is not part of the drawings files (like tolerances, inter feature constraints)

Potential: Feature recognition has many potential usage scenarios. A solution offering sophisticated algorithms for that is on the radar of every CAD/CAM provider. Even CNC-controller manufacturers could be interested in this.

S4.2 Cloud-DPP

Description: This module is the main module of CAPP-4-SMEs. It includes functionalities like generic setup planning, machine specific setup planning, operation planning dry runs, etc. Each function includes powerful algorithms supporting tasks that normally need to be done manually with lots of knowledge.

Author / Developer: KTH

Commercialization hints: If non-commercial use is planned commercial products nested in the solution are a problem.

Potential: Even if there is no follow-up project for continued development on this module, the research results and the resulting algorithms are very interesting for evolution of Industry 4.0. Furthermore using function block methodology as base for description of process plans in milling context is innovative. One aim of CAPP-4-SMEs is to prove the power of that approach. Function block technology is potentially relevant for CNC-control providers as a new way for controlling machines in the Industry 4.0 context. KTH is searching for a follow-up development financing.

S4.3 Machine Availability and Monitoring Module

Description: This module has as main purpose the development of a machine availability monitoring module providing the system with information regarding machine status, machine specifications, machine availability windows and energy consumption. Three main inputs are considered in this module. Sensory input through current sensors, machine schedule through planning system and input from the shop floor through the machine's operator. The data collection for a milling machine, the data acquisition, the data processing, information fusion and finally the visualization of the results are the five fields that are investigated in this module. The up-to-date information of the monitored machines will be useful for adaptive process planning and setup planning to make well- informed decisions according to the real-world situation and it also for other modules so that optimal process/setup plans can be generated for the right resources at the right time with high throughput.

The module is programmed using typical web technologies like Apache http service, Ruby on rails framework, Python, NoSQL database(Mongo), etc. All the used development tools in the Machine

Availability Monitoring module are open source, thus licensing is not a concern but might be under commercial use. The user interface is browser based (without the need for plugins).

Author / Developer: LMS

Commercialization hints:

Potential: The machine monitoring system itself can be the base for very interesting tools like predictive machine supervision, shop floor information system framework, facility data management and can even act as the base for a production planning system. The usage of sensor data can be the foundation of manufacturing observing and control systems. Using external sensors is an important approach for integrating legacy machines into Industry 4.0.

S4.4 Tool Finder / Cutting Parameter Finder

Description: Two decisions have to be made during the workflow.

1. Select the tool based on available information like work piece material, planned average cutting depth, planned average cutting width, strategy (roughing, finishing, boring, threading), feature depth, etc.
2. Select the cutting parameters (like feed, spindle speed, etc.) during operation planning.

These parameters may change frequently per machine move due to changing tool engagement.

This functionality is nested inside Cloud DPP. FT proposed to isolate that functionality and do some follow-up development and investment (~ 1 man year) on this. Since the quality of the decisions depends on the quality of the database an easy extendible and editable data backend is a vital demand. Taking into account that these parameters sometimes are part of a company's know how this functionality gets strategic importance.

Author / Developer: KTH, potential follow-up by FT

Commercialization hints:

Potential: If the project results are convenient FT plans to use the functionality commercially inside FT's NCspeed. NCspeed is a simulation and optimization software sold worldwide. Since the functionality includes a systematic input for process know how this could be a very interesting tool for milling companies as well as tool providers. FT customers are asking for functionality like this – so immediate market impact can be expected. In any case some amount of follow up investment in terms of further development is necessary.

S4.5 Light Weight Visualizer

Description: In CAPP-4-SMEs operation planning happens inside function blocks which is not very transparent for human checks .If a shop floor worker wants to inspect tool paths or events during machining a visualizer is necessary. This is the role of the light weight visualizer. But the light weight visualizer can read legacy G-code, too. So it could be useful out of CAPP-4-SMEs' scope.

Author / Developer: CU **Commercialization hints: Potential:**

S4.6 Function Block Designer / Function Block Network Designer

Description: The description of the process plan in CAPP-4-SMEs is based in function block methodology. Furthermore the algorithms for generating machine moves for milling a feature is embedded inside a function block. So this module is very useful for development, debugging, testing.

Author / Developer: KTH

Commercialization hints:

Potential: The module can be a very helpful tool for research and development of function block based projects beyond CAPP-4-SMEs.

S4.7 Postprocessor Web-Service

Description: According to the design of CAPP-4-SMEs the operation planning should happen on the machine controller. Operation planning is basically calculating the machine axis moves for milling a feature. If the machine controller is not able to do this, operation planning could run on another device and create work piece based device neutral moves. A postprocessor is needed to pick up the device neutral moves and generate legacy machine specific NC-code to drive the milling machine. This functionality could be isolated and be implemented as a web service.

Since every CAM-system needs this functionality it could be a useful tool to simplify the job of CAM- systems. This tool could be for instance offered by machine manufacturers and simplify adaption needs of CAM-systems to specific machines. This would be a remarkable selling benefit.

CAPP-4-SMEs uses this functionality for the demonstrators, so at project end there will be some generic templates as samples.

Author / Developer: Commercialization hints: Potential:

Exploitation Risks

There are many exploitation risks. The main risks for this project need special investigation.

Handling foreground intellectual property

The background of the project partners is very different and the project flow already has shown that it is a big benefit to embed different perspectives. At the same time different perspectives can lead to conflictive interpretations of handling the joint intellectual property generated as the research output of the project. This can create barriers inhibiting successful exploitation. To illustrate the potential sources of risks for successful exploitation, virtual extreme positions of the project partners are used:

The manufacturing SMEs (AF, CAM, POK) in the consortium might have interest to get an improved, more efficient system for running certain processes. This could potentially be a benefit for these companies on the market. But if every company has access to the same solution the benefit is lost. The interest of manufacturing companies could be to have exclusive rights on the new method for themselves and perhaps for clustered companies. This is an interest conflict with consortium members being a software or tool provider or a research organisation. Software providers would tend to get lots of users for increased revenue, the same for tool providers offering the system along with their tools. Research organisations would tend to make publications. This basically allows anyone to engineer a comparable system. Even offering the solution in a public available cloud service without massive user check and protection of intellectual property could be against the interests of manufacturing consortium members.

If software providers (FT, ICT) define their commercial interest not only by service oriented business (like support, implementation assistance, teaching, computing resources) they need exclusive access (for example closed source) to the solution. If at the same time a research organisation gives away the source code under open source conditions the business model of the software provider might be destroyed.

If a tool provider (SAN) offers the solution as a benefit if using their tools, this is an interest conflict with software providers. Software providers would tend to be open for any tool provider to avoid any limit regarding number of users. Also manufacturing companies might not like to be too deeply dependant on a certain tool provider.

Research organisations tend to see the project result as public property, which can be used by anyone and especially by research organisations as the foundation of continued research. Findings are widely spread by publications to underline the quality of research. This is in parts contradicting commercial usage of findings.

It is obvious that these positions can be a problem for successful exploitation.

All project partners act inside a legal framework formed by the common consortium agreement (CCA). This limits the extreme positions mentioned before and regulates handling of the joint intellectual property created during the project. Furthermore some extreme positions might not be according to common rules of European research projects.

The main objective of the project is to commercialize the project results for competitive benefits of European economy. Any problems jeopardizing this objective have to be detected as early as possible and be sorted out by interest balancing. Avoiding these problems is an important objective of exploitation activities.

Time to market

Time to market is time needing investments with a remarkable risk losing money. Bridging that time is a big challenge needing willing investors and a detailed business plan. To analyse the situation a time to market estimation for the key exploitable results has been made:

Table 7. Time to market overview

Key exploitable result	Time to market (months)	Remarks
Feature Recognition System	18	18 person months, so reduction possible
Cloud DPP (CAPP-4-SMEs' main module)	36	
Machine Availability and Monitoring Module	24	Extensions necessary
Parameter finder	-	-
Lightweight visualizer	24	
JAVA based function block and function block network IDE	1	

As a result the modules with a more commercial relevancy have a remarkable time to market. It is to be expected that following exploitation strategies 2 (common user interface) and 3 (integration by other system) need a comparable time to market. The estimated result may be characterized according to following picture.

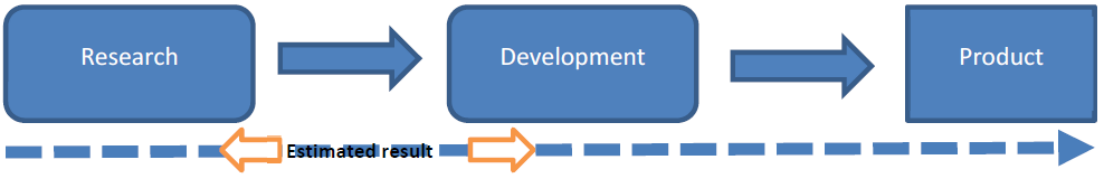


Figure 81. Estimated result range

The big benefit of CAPP-4-SMEs' project layout is, that research results will have to be verified in demonstrators. So an advanced code base will already exists at the end of project. This can be a good foundation for follow up development and further research.

Exploitation Activities

Exploitation activities of the project have been designed into the three demonstrators and four public workshops in Spain, Germany and UK. The geographical distribution of the activities is aimed to attract more small and medium-sized companies to tryout our adaptive solutions.

Exploitation Seminars

Two exploitation seminars have been organized (Athens, Greece on Dec 13, 2013 and Gijon, Spain on Dec 14, 2014). These seminars supported very well in the analysis of the exploitation situation. The results of these seminars are reflected in this document.

The results can be summarized in the figure below. The importance of early adopters needs to be underlined. Reference customers help bridging the investment gap until market readiness, especially since time to market is an issue for this project.

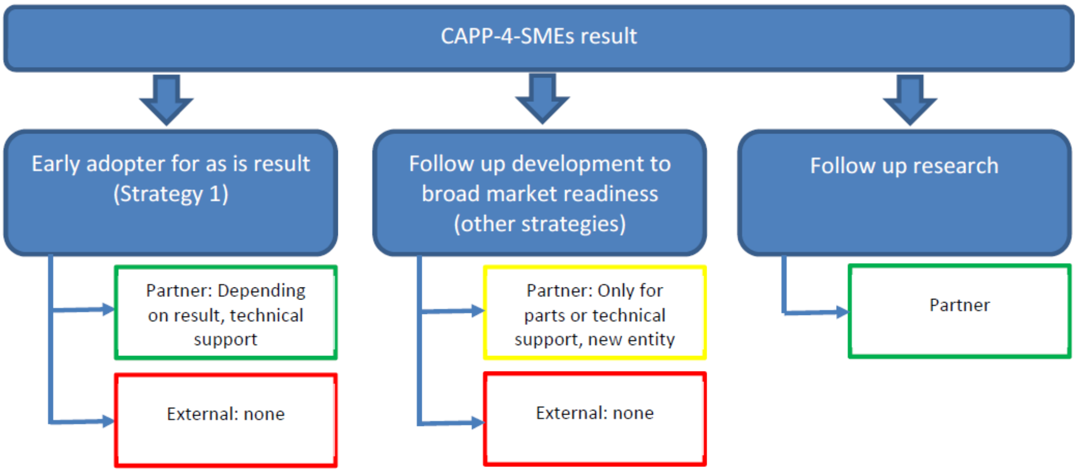


Figure 82. Exploitation situation

So there are conclusions for further exploitation activities:

(1) The needs of internal potential early adopters will be analysed very carefully. It will be investigated if the planned usage with the offered technical support can lead to a resilient business plan. Potentially the **ESIC2 Service** will be helpful for that.
(2) Find external early adopters or create one.
(3) Find external entities or create one to do follow up development. All exploitation strategies can be used.
(4) Check for follow up research opportunities.

Agreement / contract on joint intellectual property

The foreground of the project is mainly programmed code with theoretical background described in the deliverables documentation. According to current project state a split up of the code base usage at end of project is an option. There should be a commercial direction with a closed code option for further development. The other code usage direction is for research / education usage only. It will be investigated if a contract or agreement can support that split and foster future development activities.

If there is a follow up research project which uses the outcome of CAPP-4-SMEs as input the commercialisation of the follow up project can lead to concurrency situations. It needs to be investigated if there is a solution for that.

Check related research projects

Potential projects are: **ADVENTURE, APPS4AME, MSEE, CLOUDFLOW, CLOUDSME, SMARTER, EASY- IMP, E-CUSTOM, FITMAN, ADVENTURE.** The projects will be investigated for connection points. The participants of these projects can be potential early adopters of follow up developers / integrators.

Summary

It is obvious that it is necessary to start exploitation activities as early as possible. That is conflicting with the fact, that the optimized exploitable results are only available at the end of the project. Nevertheless preparation for exploitation has been concluded in the context of creating this document.

Further activities will primary concentrate on finding early adopters – inside and outside the consortium. The dependency between project output quality and success of this strategy is a key for commercial relevancy of the project. Early adopters and reference customers are a smart way to bridge the investment gap until product capabilities open a bigger customer base.

The secondary approach to find investors for follow up development is not conflicting with the primary approach. For several reasons right now there is no candidate inside the consortium for the whole project represented by the Cloud DPP module. Founding a new entity is under discussion. Creating curiosity of external investors will be an important task of the workshops. External investors are customers for the CAPP-4-SMEs' output. A legal framework to handle this relation needs to be established.

6.2.4 Three workshops (Task 7.3)

For all workshops FT developed the framework presentation and moderated the meeting.

For that purpose FT created an easy description of a typical machining job workflow using the CAPP-4-SMEs modules. In comparison to a traditional workflow the benefits of the CAPP-4-SMEs approach are very obvious. This has been helpful to get attention from industry and has been good didactic entry point for detailed presentations.

This workflow shown in Figure 81 is interactive, offers dive-deeper links and is public accessible via the CAPP-4-SMEs home page http://www.capp-4-smes.eu/ or directly http://formtec.spdns.de:8078/workflow.html. The workflow has been evolved through project progress. The workflow contains dive-deeper links to detailed documents, a full dataflow diagramm developed by ICT and several demo videos. Finally it has been integrated into the integrating user interface. One important aspect of the workflow is to be the integration kernel for the separated research results. The full power of the CAPP-4-SMEs approach is dependant on the communication between the modules. It has been a permanent exploitation activity to reinforce integration – especially as preparation for the workshops.

FT developed a second entry point into discussions. The comparison of 3D-printing and CAPP-4-SME's approach is very interesting. It can be shown that milling supported by CAPP-4-SMEs modules can have the benefits of 3D-printing but avoids some of its drawbacks. The reason is reduced complexity of process planning using CAPP-4-SMEs approach. It is possible to concentrate on the description of the results.

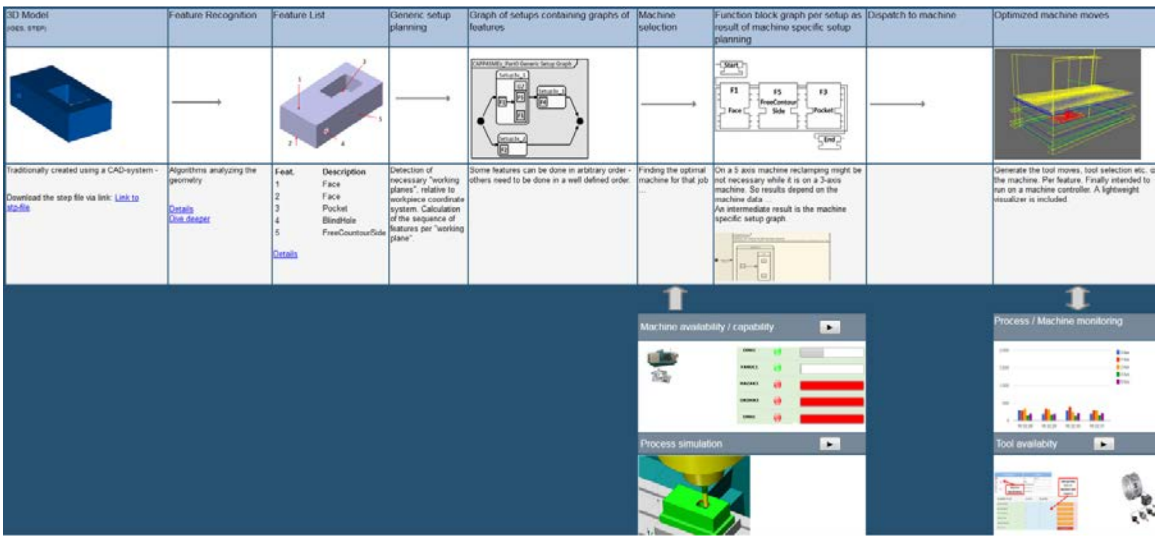


Figure 83. Workflow page

All workshops have been massively supported by the resident project partners. FT thanks them all for their support and great work.

6.2.4.1 *Coventry Workshop*

Date	Resident Organizer	Factory Tour
October 07, 2014	COV	PKT

Figure 84. Participants at Coventry workshop

6.2.4.2 *Spain Workshop (Gijon)*

Date	Resident Organizer	Factory Tour
April 23, 2015	PROD	AF (Remote)

This workshop is combined with Demonstrator 1.

Figure 85. Working session at Spain workshop

6.2.4.3 *Germany Workshop (Düsseldorf)*

Date	Resident Organizer	Factory Tour
June 15, 2015	FT / SAN	CAM (Remote)

This workshop is combined with Demonstrator 2.

During the workshops in Gijon and Düsseldorf remote machining has been demonstrated, the job has been created during the workshops, machining happened on the Asturfeito / Cameco shop-floors in Spain / Sweden. Remote machine monitoring could be demonstrated as well. This underlined the power of the distributed, cloud based approach.

Figure 86. Consortium partners at Germany workshop

6.2.4.4 *UK Workshop (Coventry)*

Date	Resident Organizer	Factory Tour
Oct 29, 2015	COV	PKT

This workshop is combined with Demonstrator 3.

Figure 87. CAPP-4-SMEs consortium at UK workshop in Coventry

6.2.4.5 *Feedback*

Along with project progress the quality and practicability of the research results and the quality of visible parts (like the user interface) increased. Especially the industry workshop participants evaluated the presentations regarding practical usability and economic benefits. Therefore, the amount of feedback during the workshops, like discussions, questions, etc. increased from workshop to workshop. Starting with workshop 2 (Gijon) a questionnaire has been run to gain additional feedback (see Appendix 1 for a sample).

The range of feedback is from "where to purchase that" to "lots of further development needed". This subsection attempts to list the main aspects of the feedback.

- Cloud based solutions are accepted as a smooth and smart entry into a new manufacturing style. The service integrating approach of well communicating modules is highly appreciated and a big benefit regarding traditional scenarios with isolated modules.
- An adaptive approach for process planning is very interesting but for end user readyness further development and research is necessary.
- Data protection, data privacy is a very important aspect for acceptance.
- Even isolated services (like machine monitoring) are interesting for special needs.
- Function blocks as a system for process description is a good and interesting approach.
- There is potential for new cooperation (research or development) on feature based machining with University of Auckland, NZ.
- Industry participants underline the benefits of the integration ("from CAM to machine in a few clicks") whereas academic participants are more interested in certain research results (like function blocks etc.). So exploitation regarding impact to industry should focus on integration and end user readyness. Academic exploitation should focus on dissemenination of partial results as input for further research.
- Tolerances are important for process parameter selection – but there is no well known standard to add tolerances to 3D Models. It is manual work to add them. There are recent developments in the STEP standard, a special extension includes tolerances.
- The presentations attracted lots of curiousity – the main objectives are fully accepted and the approach of CAPP-4-SMEs is supported by many statements of the meetings participants. Even interest for purchasing could be generated. But it needs to be checked if the reduced and in parts simplified scope of the research results is compatible to the planned use case. In this sense market impact is present. The gap between industrial practicability, direct economic benefit demanded by industry and the research result is still a challenge. Further exploitation activities are needed to find a way to preserve the knowledge.

7 Deliverables and Milestones

The project deliverables and milestones throughout the who project period are summarised in Table 8 and Table 9, respectively.

Table 8. Project deliverables throughout 36-month period

WP n°	Deliverable N°	Title	Nature	Dissemination level	Delivery date from Annex I (proj month)	Actual date	Status	Note
1	1	Technical report	Report	PP	31/07/2013 (8 months)	11/11/2013	Accepted	
1	2	Demonstration platform	Demonstrator	PU	31/07/2014 (20 months)	31/07/2014	Accepted	
2	1	Prototype for data collection and visualisation	Prototype	PP	31/05/2014 (18 months)	31/05/2014	Accepted	
2	2	Prototype for web-based real-time monitoring	Demonstrator	PU	30/11/2014 (24 months)	30/11/2014	Accepted	
3	1	Web portal for end users	Demonstrator	PU	31/05/2014 (18 months)	31/05/2014	Accepted	
3	2	Function block designer	Prototype	PP	31/01/2015 (26 months)	30/01/2015	Submitted	
4	1	Software tool for setup grouping and merging	Prototype	PP	31/05/2014 (18 months)	31/05/2014	Accepted	
4	2	A toolbox of smart optimisation algorithms	Prototype	PP	30/11/2014 (24 months)	30/11/2014	Accepted	
5	1	Simulation service for designers	Demonstrator	PU	31/05/2014 (18 months)	31/05/2014	Accepted	

5	2	Simulation service for machining and factory-level process planning	Demonstrator	PU	30/11/2014 (24 months)	30/11/2014	Accepted	
5	3	Visualisation algorithms	Other	CO	31/01/2015 (26 months)	30/01/2015	Submitted	
6	1	CAPP-4-SMEs test bed	Demonstrator	PU	31/03/2015 (28 months)	30/03/2015	Submitted	
6	2	Three demonstrators	Demonstrator	PU	30/09/2015 (34 months)	10/11/2015	Submitted	Deliverable deadline extended due to the European factory vacation season during summer time. Extension is approved by PO
6	3	Technical report	Report	PU	30/09/2015 (34 months)	10/11/2015	Submitted	Deliverable deadline extended due to the European factory vacation season during summer time. Extension is approved by PO
7	1	Dissemination plan	Report	CO	31/05/2013 (6 months)	11/11/2013	Accepted	
7	2	Exploitation plan	Report	CO	30/11/2014 (24 months)	30/01/2015	Submitted	Since Exploitation Seminar is organized at the end of 15 Dec 2014, the deadline is extended to summarize and include the latest seminar results. Extension is approved by PO
7	3	Three workshops	Other	PU	30/09/2015 (34 months)	10/11/2015	Submitted	Deliverable deadline extended due to the European factory vacation during summer time. Extension is approved by PO
8	1	Project management & mid-term report	Report	PU	31/05/2014 (18 months)	31/07/2014	Accepted	As required by PO, extension is applied to include financial data from FormCs
8	2	Project management & final report	Report	PU	30/11/2015 (36 months)	30/11/2015	Submitted	Since Final review meeting is organized before deadline, a close-to-final version is submitted and approved by PO

Table 9. Project milestones due in month 36

Milestone no.	Milestone name	Means of verification (from Annex I)	Delivery date from Annex I	Achieved Yes/No	Actual / Forecast achievement date	Comments
MS1	Release of demonstration platform	Live demonstration of functionality + assessment by the consortium	20	Yes	20	M1.1
MS2	Completion of data collection prototype	Live demonstration of functionality + assessment by the consortium	18	Yes	18	M2.1
MS3	Release of the function block designer	Live demonstration of functionality + assessment by the consortium	26	Yes	26	M3.1
MS4	Release of setup planning module	Live demonstration of functionality + assessment by the consortium	18	Yes	18	M4.1
MS5	Release of simulation services for machining and factory-level process planning	Live demonstration of functionality + assessment by the consortium	24	Yes	24	M5.1
MS6	Completion of demonstrators	Deployment of functionality + assessment by the real manufacturing environment	34	Yes	35	M6.1
MS7	Workshops completion	Public workshop + assessment by both academia and industry audience	34	Yes	35	M7.1
MS8	Project Completion	Completion of all deliverables and project tasks, as defined in the DoW + assessment by PO and PTA	36	(Yes)	36	M8.1

8 Administrative Management

Work Package Number	8	Start date	M1
Work Package Title	Project Management		
Activity Type	*OTHER (Management)*		
Participant Name	KTH		
Person-months	6.5/9.51/12		

8.1 Management activities

The CAPP-4-SMEs consortium adopts a well-defined management structure. This contributes to the overall efficiency of the work. A complementarily well-balanced competencies and roles of eleven partners from five EU Member States guarantee a successful outcome of the partners' common work effort. The structure of the project management is presented in Figure 86. Separate work packages are dedicated to the dissemination & exploitation (WP7) and project management (WP8), and are carried out during all project phases to foster a conscientious project execution. The project management team is listed in Table 10. More details on management structure and methodology can be found in Annex I Description of Work.

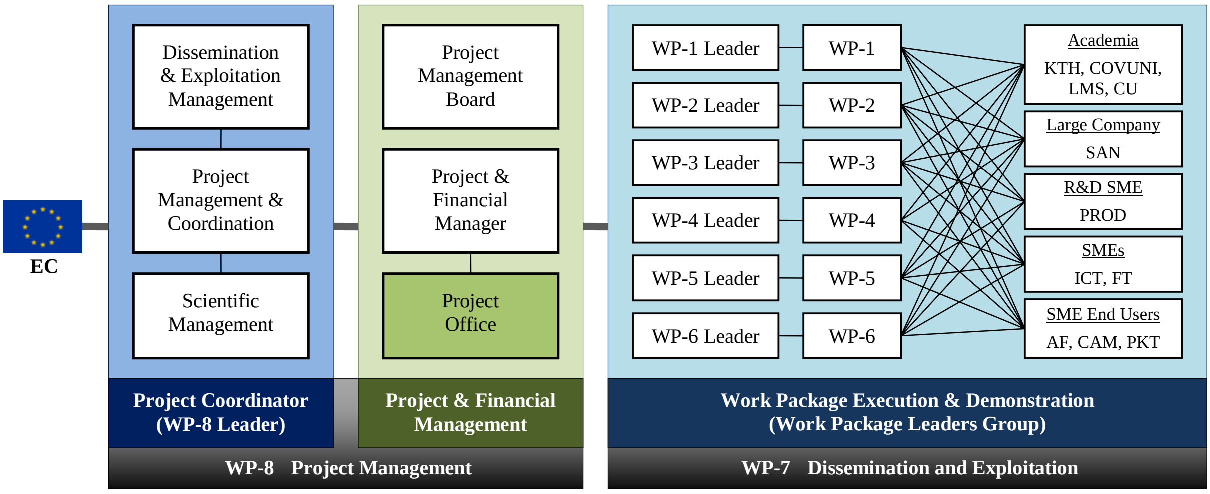


Figure 88. Project and technical management structure

Table 10. Project management team formation

Partner	Role	Representative
KTH	Project Manager	Dr Xi Vincent Wang
COVUNI	WP-1 Leader	Professor Weidong Li
LMS	WP-2 Leader	Professor George Chryssolouris
KTH	WP-3 Leader	Professor Lihui Wang
SAN	WP-4 Leader	Mr Kenneth Karlsson

CU	WP-5 Leader	Dr Jörn Mehnen
SAN	WP-6 Leader	Mr Kenneth Karlsson
FT	WP-7 Leader	Dr Joachim Friedhoff
KTH	WP-8 Leader, Project Coordinator	Professor Lihui Wang
PROD	Project Management Board member	Dr David González
ICT	Project Management Board member	Mr Andreas Hundsdörfer
AF	Project Management Board member	Mrs Cristina de la Rosa
CAM	Project Management Board member	Mr Nils-Olov Bäckström
PKT	Project Management Board member	Mr Peter Everitt

8.1.1 Consortium management tasks and achievements

8.1.1.1 *Project communication and meetings*

The communication strategy is aimed to keep all partners fully informed about the project status, planning, risk and contingency, change management requests and all other issues that are important to the partners in order to maintain maximum clarity for all involved partners and to increase the cooperation within the CAPP-4-SMEs project. The ultimate goal of communication is to **build trust and increase cooperation** among partners so as **to achieve win/win** at all time (Figure 87). The communication strategy also aims to effectively communicate with parties outside the consortium, such as with other European or national project consortia, initiatives, user groups, etc.

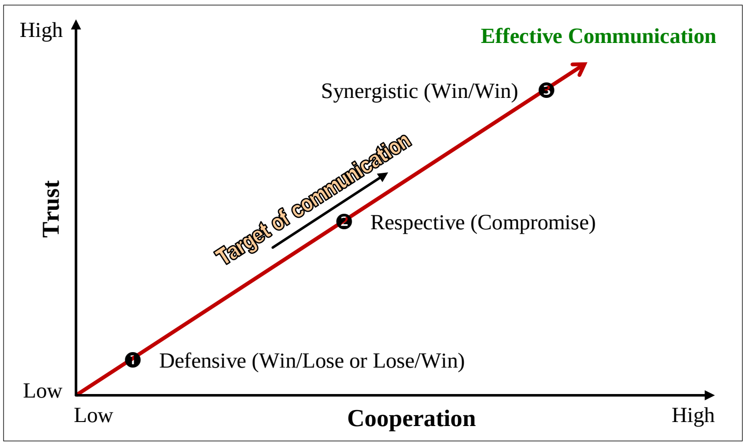


Figure 89. Communication strategy and target of CAPP-4-SMEs

The communication strategy, including planning for publications, trade fairs and conferences, is a topic at each Project Management Board meeting. Standard office technology is used for the core of the documentation deliverables and good Internet and virus protections are applied in each member organisation. All documents produced in the scope of the CAPP-4-SMEs project is synchronised with the help of an Internet-based content management system, providing the consortium with a good opportunity to manage huge amount of documents and knowledge. A Cloud-based project repository is built based on the ownCloud architecture, in which all the collaborative documents are dynamically maintained and managed.

In order to reach the target level❸, e-conferences (using GoToMeeting) are held on a regular basis. The e-conferences are mainly to support the consortium in coordinating technical development among work packages. The e-conferences are held every two weeks since the project kick-off. Additionally, to work on the technical issues closely, walkthrough meetings are organised weekly on

Thursdays to develop interfacing and interacting mechanisms among different modules and participated mainly by technical WP developers. This activity is led by CU. Moreover, individual meetings between different WPs are launched to discuss technical issues in detail.

Otherwise, general meetings take place as planned. These meetings occur at beginning in a kick-off meeting, near the completion of milestones, and at other major points of the project as summarised below:

- Each meeting consist of two parts – project management discussions (Part 1) and technical discussions (Part 2).
- Part 1 of the meetings focuses on project management issues, such as the review and evaluation of overall progress and achievement, financial update, co-ordinate project-related interactions among Work Packages and project partners, etc.
- The consecutive Part 2 of the meetings extend to invite key technical members of the project to update the technical development, to identify and contemplate any major technical bottlenecks, and deviation from the project time-schedule from the point of technology, and technical integration plans, etc.
- Intra-task meetings are called when specific needs arise to solve technical problems, including teleconferences and other remote means to solve problems efficiently.

The meeting agenda is broadcasted priory to every meeting and the minutes are noted and approved in the following one. All the meeting records are documented in the Cloud repository (Figure 88). Standardized meeting minutes and action tracking procedure is also defined:

- **Record** new minutes and send to partners in **MS word** via **email**
- In the next meeting, review and **approve** the last meeting minutes (**follow-up** actions)
- After the meeting, upload (approved) **.pdf** version on **ownCloud**

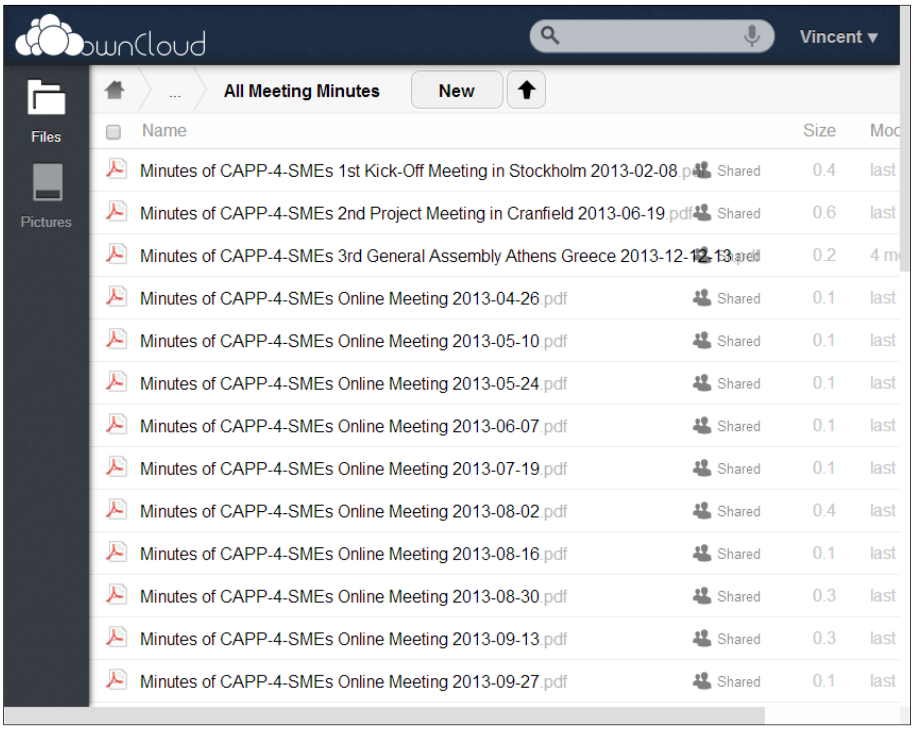


Figure 90. Cloud-based meeting documentation

As mentioned above, to collaboratively develop modules per WP, weekly walkthrough meetings are taken focusing on the data and physical flow among modules. Lead by CU, technical details are discussed especially regarding the interfacing and integration of the development outputs. As a result, effective and frequent communications are achieved since project kicked-off. The venue of regular meetings are circled and organised around the consortium, and the e-conferences are mainly called by KTH via GoToMeeting platform. As summarised in Table 11, more than 60 meetings have been arranged so far among partners to collaborate together.

Table 11. Summary of project meetings

Project meetings (GA)	Meetings Associate with Project Workshops	Bi-weekly e-conferences	Weekly walkthrough meeting
6	4	60+	80+

8.1.1.2 *Quality control and assurance*

The project establishes appropriate quality control and assurance mechanisms and procedures, which allow maximum flexibility while maintaining a clear distinction of roles and responsibilities of all partners involved. Work Package and Task Leaders formally report to the Project Coordinator every three months. Reporting includes information on the technical progress, results obtained, and compliance with the work plan. The progress is also checked in terms of percentage of completion, estimated time to completion, and actual vs. allocated person-months. Based on these reports, the Project Coordinator updates the project time-chart and the overall WP-person-month matrix. The Project Coordinator coordinates the preparation of the six-month progress reports, the mid-term and final review reports, the exploitation report and the synthesis report of the deliverables. Annually, the Project Coordinator also reports on the budgetary situation, based on the partners' cost statements and the payments made by the Commission. More detailed procedures were implemented and clearly described at the beginning of the project, which addressed the entire range of administrative, financial and technical issues, including issues such as internal reviews at WP level and standards for reporting and preparation of deliverables. In addition, the systematic review of these mechanisms is essential: such reviews are carried out throughout the duration of the project, involving representation and commitment from all partners. Finally, the quality control and assurance mechanisms ensure that the minimum possible bureaucratic overhead is imposed on the project consistent with necessary control to achieve quality.

At the end of each report and deliverable period, a peer review process is deployed to further guarantee the quality of the project outputs. As illustrated in Figure 89, the deliverable/reports are firstly discussed and reviewed by related partners. The comments and suggestions are fed back to the WP Leader to amend the results if any. After submitted to the project coordinator, the coordinator offers further comments and suggestion about modification before it can be officially approved.

The consortium guideline is also developed to make sure the quality and completeness of deliverables:

1. Always refer to the **Description of Actions**
2. Use Project **Template**
3. Draft submitted by the responsible partner **2 weeks** before deadline
4. Draft reviewed in **Online** meeting
5. Revised draft submitted to the coordinating team **1 week** before deadline
6. KTH approve deliverable **internally**
7. Final deliverable **submitted** to EC before deadline

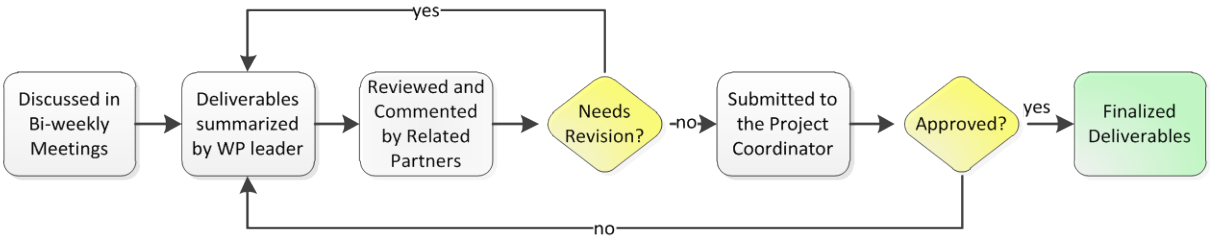


Figure 91. Deliverable/report quality control

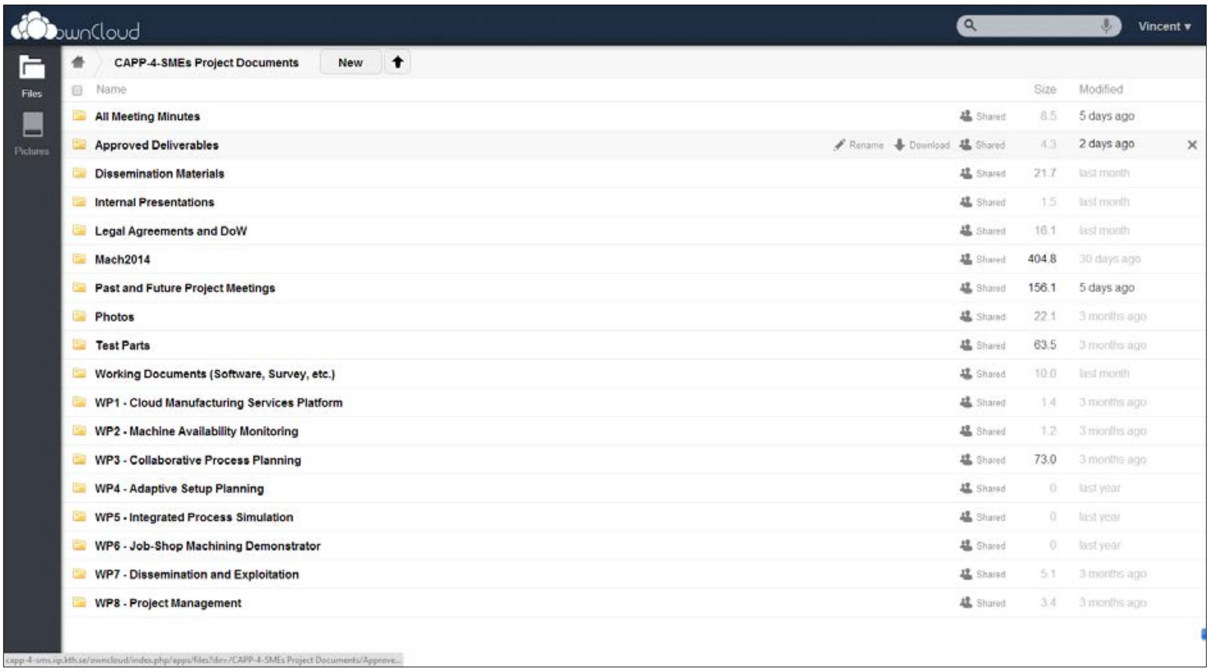


Figure 92. Cloud-based CAPP-4-SMEs repository

8.1.1.3 *Knowledge management*

The knowledge produced throughout the entire duration of the project is categorised as internal and external knowledge.

- Internally, knowledge is organised, stored and disseminated to all partners. The overall storage and internal dissemination of knowledge is the responsibility of the Project Coordinator while other Work Package Leaders are responsible for communicating knowledge produced for Work Packages or specific tasks that they have been assigned. The internal knowledge produced during the course of the project includes: knowledge products (e.g., deliverables, reports, training materials, meeting outcomes, proposals for international/national standards and application recommendations, etc.), and supportive knowledge material (e.g., background documentations, state-of-the-art material, surveys conducted, etc., which are required for the production of knowledge products). All the materials are stored in an organised manner in a shared workspace accessible by all partners. A **Cloud-based repository** server is built in KTH via ownCloud platform. Administrated by the Project Coordinator, all the internal knowledge are hosted and managed in the ownCloud in a structured and collaborative manner.
- Externally, research knowledge of the project is exposed to relevant communities. The project website (Figure 91) is built to broadcast project outlines and progresses. Responsibility for the details of dissemination resides with the partner responsible for the original content. It is on-going effort to update project reports, news, feedback and comments on the project's website,

regularly. Public documents are available for downloading also on the project website. The project website has approximate 28,000 hits per month.

- The knowledge management are coordinated by the Project Coordinator. Moreover, the necessary communication channels such as mailing list are set up and maintained for knowledge dissemination. The Project Management Board is responsible for handling any issues that may arise related to intellectual property rights and innovation activities.

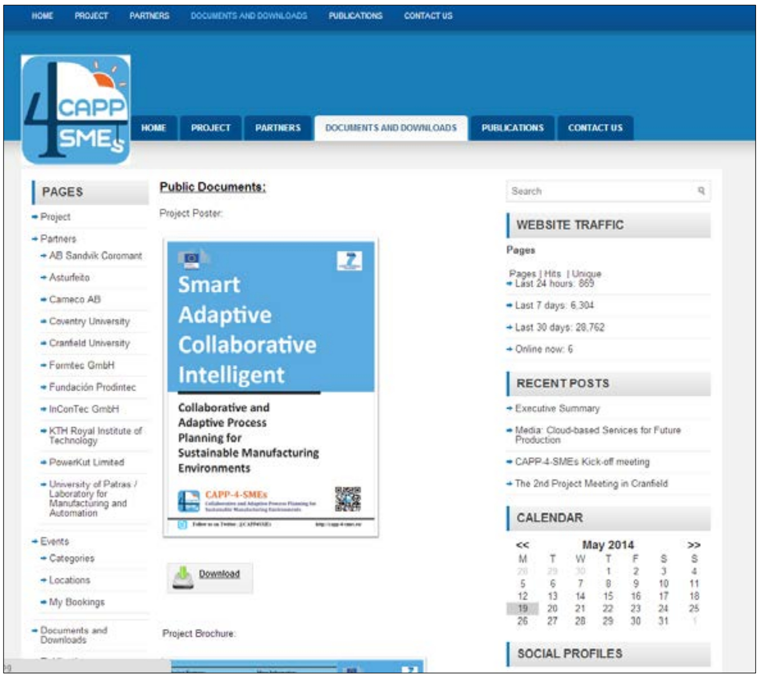
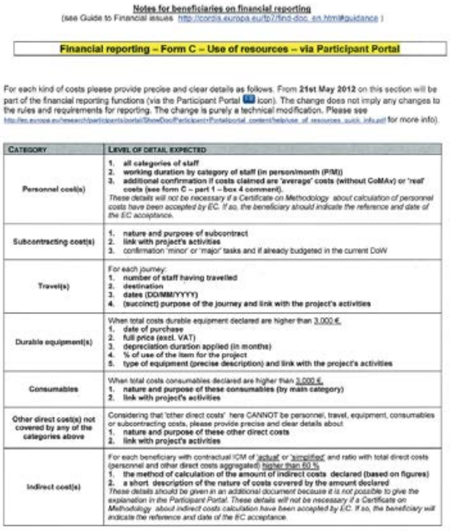


Figure 93. Public document downloads on project website

The overall objective of the exploitation of CAPP-4-SMEs is the commercialisation of the CAPP-4-SMEs Cloud manufacturing services. The main modules developers (WP Leaders), with support from all partners, ensure commercialisation of the CAPP-4-SMEs solutions. After an initial survey of IPR claims for all partners, including background/foreground information and exploitation claims, the necessary contractual agreements for the exploitation of the CAPP-4-SMEs are constructed to ensure continued use after the project end and proper commercialisation organisational setup.

Regarding the financial knowledge, the management board also supports all partners with essential assistance of financial management and reports developments. The instructions/tutorial documents from EC (Figure 92) are broadcasted in the consortium and the tips of avoiding comment errors are shared with relevant personals to prove better and effective reporting qualities.

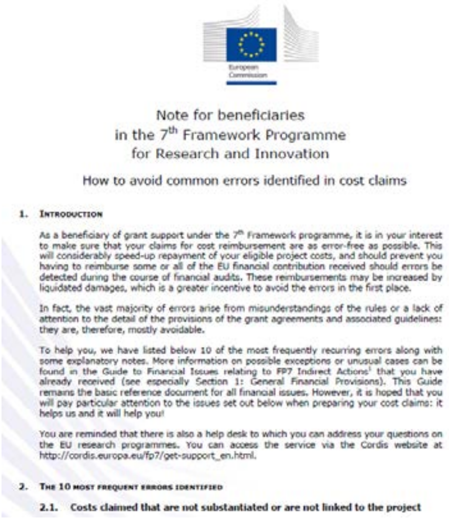


Notes for beneficiaries on financial reporting
(see Guide to Financial issues http://cordis.europa.eu/fp7/find-doc_en.html#guidance)

Financial reporting – Form C – Use of resources – via Participant Portal

For each kind of costs please provide precise and clear details as follows. From **21st May 2012** on this section will be part of the financial reporting functions (via the Participant Portal icon). The change does not imply any changes to the rules and requirements for reporting. The change is purely a technical modification. Please see [illegible] for more info).

CATEGORY	LEVEL OF DETAIL EXPECTED
Personnel cost(s)	1. **all categories of staff** 2. **working duration by category of staff (in person/month (P/M))** 3. **additional confirmation if costs claimed are 'average' costs (without CoMAv) or 'real' costs (see form C – part 1 – box 4 comment).** *These details will not be necessary if a Certificate on Methodology about calculation of personnel costs have been accepted by EC. If so, the beneficiary should indicate the reference and date of the EC acceptance.*
Subcontracting cost(s)	1. **nature and purpose of subcontract** 2. **link with project's activities** 3. confirmation 'minor' or 'major' tasks and if already budgeted in the current DoW
Travel(s)	For each journey: 1. **number of staff having travelled** 2. **destination** 3. **dates (DD/MM/YYYY)** 4. **(succinct) purpose of the journey and link with the project's activities**
Durable equipment(s)	When total costs durable equipment declared are higher than 3.000 €. 1. **date of purchase** 2. **full price (excl. VAT)** 3. **depreciation duration applied (in months)** 4. **% of use of the item for the project** 5. **type of equipment (precise description) and link with the project's activities**
Consumables	When total costs consumables declared are higher than 3.000 €. 1. **nature and purpose of these consumables (by main category)** 2. **link with project's activities**
Other direct cost(s) not covered by any of the categories above	Considering that 'other direct costs' here CANNOT be personnel, travel, equipment, consumables or subcontracting costs, please provide precise and clear details about 1. **nature and purpose of these other direct costs** 2. **link with project's activities**
Indirect cost(s)	For each beneficiary with contractual ICM of 'actual' or 'simplified' and ratio with total direct costs (personnel and other direct costs aggregated) higher than 60 % 1. **the method of calculation of the amount of indirect costs declared (based on figures)** 2. **a short description of the nature of costs covered by the amount declared** *These details should be given in an additional document because it is not possible to give the explanation in the Participant Portal. These details will not be necessary if a Certificate on Methodology about indirect costs calculation have been accepted by EC. If so, the beneficiary will indicate the reference and date of the EC acceptance.*



European Commission

Note for beneficiaries
in the 7th Framework Programme
for Research and Innovation

How to avoid common errors identified in cost claims

1. INTRODUCTION

As a beneficiary of grant support under the 7th Framework programme, it is in your interest to make sure that your claims for cost reimbursement are as error-free as possible. This will considerably speed-up repayment of your eligible project costs, and should prevent you having to reimburse some or all of the EU financial contribution received should errors be detected during the course of financial audits. These reimbursements may be increased by liquidated damages, which is a greater incentive to avoid the errors in the first place.

In fact, the vast majority of errors arise from misunderstandings of the rules or a lack of attention to the detail of the provisions of the grant agreements and associated guidelines: they are, therefore, mostly avoidable.

To help you, we have listed below 10 of the most frequently recurring errors along with some explanatory notes. More information on possible exceptions or unusual cases can be found in the Guide to Financial Issues relating to FP7 Indirect Actions[1] that you have already received (see especially Section 1: General Financial Provisions). This Guide remains the basic reference document for all financial issues. However, it is hoped that you will pay particular attention to the issues set out below when preparing your cost claims: it helps us and it will help you!

You are reminded that there is also a help desk to which you can address your questions on the EU research programmes. You can access the service via the Cordis website at http://cordis.europa.eu/fp7/get-support_en.html.

2. THE 10 MOST FREQUENT ERRORS IDENTIFIED

2.1. Costs claimed that are not substantiated or are not linked to the project

Figure 94. Tutorial document broadcasted within the consortium

8.1.2 Risk and conflict management

In the reporting period, there are no major problems/conflicts observed in the CAPP-4-SMEs project. However, the risk and conflict management method and strategy are considered as outline in Annex I, and are utilised to resolve the issues and conflicts along the way of project management.

8.1.3 List of project meetings, dates and venues

All partner project meetings are scheduled on a six-month basis. In the report period, three project meetings has been hold in M1, M6, and M12, respectively. More details of the project meeting arrangements can be found in Table 12.

Table 12. Project meeting information

Meeting	Month	Date	Venue	Status	Activities
Kick-off meeting (Meeting 1)	M3	07-08 Feb, 2013	Stockholm	Completed	The kick-off meeting was hold at KTH, Stockholm, on 7-8 February 2013. The main scope of this meeting is to achieve a common vision among all project partners, clarify the administrative processes, discuss upon the draft Consortium Agreement and the organisation of the project in terms of time planning towards the specified milestones. Identification of state-of-the-art models, as well as project dissemination and exploitation plans is also discussed.
Meeting 2	M7	17-18 Jun, 2013	Cranfield	Completed	The 2nd project meeting took place in Cranfield, UK, on 17-18 June 2013. The main objective of this meeting is to monitor and assess the progress of the project website and dissemination materials, define the technical requirements of the Work Packages of the project, re-check the core competence and complementary skills of the partners for the R&D tasks, and define the overall Cloud and service-oriented system architecture.

Meeting 3	M13	12-13 Dec, 2013	Athens	Completed	The 3rd project meeting aimed to address the end-user requirements and technical specifications for developing CAPP-4-SMEs solution as well as the detailed service functions defined in the Work Packages. This meeting also decides the technical position and tasks of each partner regarding the Work Packages and interfaces between them, the theoretical models of the functional modules, impact and Key Performance Indicators (KPIs) assessment methodology for the modules and system, dissemination and exploitation plan.
Meeting 4	M19	16 Jun, 2014	Brussels	Completed	The main scope of this meeting is to review the development and progress in the first 18M of the project period.
Meeting 5	M25	16 Dec, 2014	Asturias	Completed	The main scope of this meeting is to integrate the research as the first solution release (without integration of manufacturing simulation service yet) and discuss how to solve any bugs arisen during the development of demonstrators. Meanwhile, the development of manufacturing simulation services, development and integration is discussed. The meeting will discuss about the detailed arrangement of demonstration.
Meeting 6	M31	15 Jun, 2015	Dusseldorf	Completed	The meeting will discuss about the complete solution release, the end-user feedbacks and improvement solutions; and discuss upon the exploitation of the project results to tone step further, the stakeholder impact methodology, standards and software prototype.
Meeting 7	M36	23 Nov, 2015	Brussels	Planned	This meeting will assess the end results of the project and agree upon a strategy for further actions, including digital rights management.

8.1.4 Project planning and status

In the reporting period, CAPP-4-SMEs project is strictly executed according to Annex I of the grant agreement. The project planning and scheduling follows the commitments defined in deliverable tasks and milestones (Figure 93). As reported in Section 3, deliverables D1.1, D2.1, D3.1, D4.1, D5.1, and D7.1 are completed in time and in good quality (with slight delay for D1.1 and D7.1 due to the inexperience of the project coordinator in running the EU project the first time). Technical tasks are accomplished as reported in the deliverable documents. Furthermore, additional research topics and industrial gaps are discovered along the way of project development. These research tasks may not be included in the original scope of the work description but relevant and valuable. Thus, extra works are taken and well accomplished to provide a comprehensive and complete solution, e.g. a facility planning and scheduling platform developed by WP2, and an adaptive process control system under development by KTH and SAN, collaboratively.

In the reporting period, the project consortium have continuously developed the task compliant with the schedule in Annex I. The focus of the project has been gradually shifted from finalising the modules per WP to integrating all research outputs, and providing a holistic solution. In the last 10 project months, 3 industrial demonstrators have be developed in three shop floors to test and validate the robustness of the decision-making algorithms and the functionality of services, and to showcase the knowledge-based tool through real-world job-shop machining demonstrations. As results all objectives and tasks are achieved successfully.

8.1.5 Communication between beneficiaries and cooperation with other projects

As mentioned in Section 4.1.1.1, a weekly communication platform has been used for efficient and effective dialogues among project partners. The consortium continuously makes an effort in project dissemination and exploitation, and in seeking cooperation with other relevant projects for cross-fertilisation. One of the extraordinary results is the collaboration with the finished EU EGI project. As shown in Figure 94, the European Grid Infrastructure (EGI) is a series of efforts to provide access to high-throughput computing resources across Europe using grid computing techniques (contract number: RI-261323). The EGI links centres in different European countries to support international research in many scientific disciplines. Following a series of research projects such as DataGrid and Enabling Grids for E-sciencE, the EGI.eu organisation was formed in 2010 to sustain the services of the EGI.

WP n°	Deliverable N°	Title	Nature	Dissemination level	Delivery date from Annex I (proj month)	Actual date	Status
1	1	Technical report	Report	PP	31/07/2013 (8 months)	11/11/2013	**Accepted**
1	2	Demonstration platform	Demonstrator	PU	31/07/2014 (20 months)	31/07/2014	**Accepted**
2	1	Prototype for data collection and visualisation	Prototype	PP	31/05/2014 (18 months)	31/05/2014	**Accepted**
2	2	Prototype for web-based real-time monitoring	Demonstrator	PU	30/11/2014 (24 months)	30/11/2014	**Accepted**
3	1	Web portal for end users	Demonstrator	PU	31/05/2014 (18 months)	31/05/2014	**Accepted**
3	2	Function block designer	Prototype	PP	31/01/2015 (26 months)	30/01/2015	**Submitted**
4	1	Software tool for setup grouping and merging	Prototype	PP	31/05/2014 (18 months)	31/05/2014	**Accepted**
4	2	A toolbox of smart optimisation algorithms	Prototype	PP	30/11/2014 (24 months)	30/11/2014	**Accepted**
5	1	Simulation service for designers	Demonstrator	PU	31/05/2014 (18 months)	31/05/2014	**Accepted**
5	2	Simulation service for machining and factory-level process planning	Demonstrator	PU	30/11/2014 (24 months)	30/11/2014	**Accepted**
5	3	Visualisation algorithms	Other	CO	31/01/2015 (26 months)	30/01/2015	**Submitted**
6	1	CAPP-4-SMEs test bed	Demonstrator	PU	31/03/2015 (28 months)	30/03/2015	**Submitted**
6	2	Three demonstrators	Demonstrator	PU	30/09/2015 (34 months)	10/11/2015	**Submitted**
6	3	Technical report	Report	PU	30/09/2015 (34 months)	10/11/2015	**Submitted**
7	1	Dissemination plan	Report	CO	31/05/2013 (6 months)	11/11/2013	**Accepted**
7	2	Exploitation plan	Report	CO	30/11/2014 (24 months)	30/01/2015	**Submitted**
7	3	Three workshops	Other	PU	30/09/2015 (34 months)	10/11/2015	**Submitted**
8	1	Project management & mid-term report	Report	PU	31/05/2014 (18 months)	31/07/2014	**Accepted**
8	2	Project management & final report	Report	PU	30/11/2015 (36 months)	30/11/2015	**Pending**

Figure 95. Status of deliverables

In order to further exploit the results of the CAPP-4-SMEs project and connect them with previous EU project, i.e. EGI, the consortium finalised a Memo of Understanding with KTH PDC, a member of EGI consortium. It is agreed that EGI has considered the CAPP-4-SMEs as a specific type of end user to evaluate the Cloud infrastructure, and CAPP-4-SMEs has deployed the manufacturing-based modules on EGI cloud to assess the robustness and extendibility of the developments.

Since PDC is part of the Computer Science Department of KTH, this arrangement has received strong support internally at KTH.

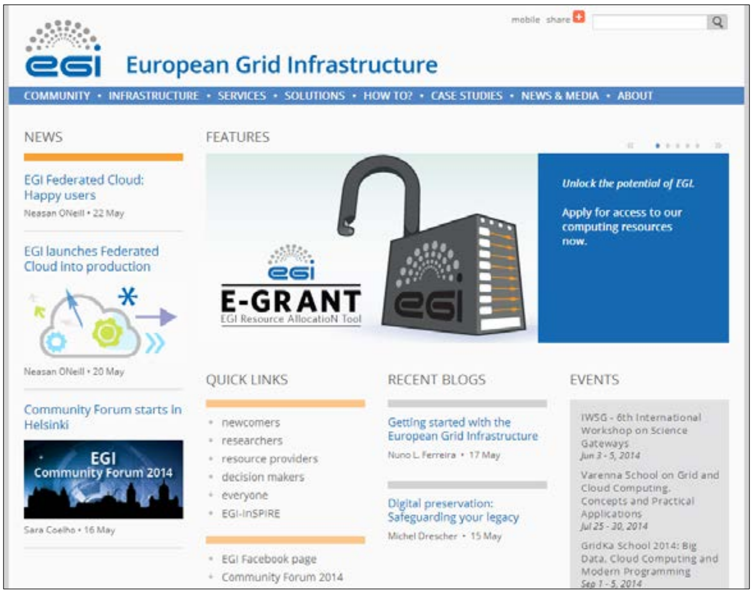


Figure 96. EGI Cloud

8.2 Dissemination and use of the knowledge

8.2.1 Dissemination of project results

The objectives of the dissemination strategy are: (a) to inform the industrial and research community of the CAPP-4-SMEs results, (b) to ensure maximum impact of CAPP-4-SMEs within and outside the project consortium, (c) to stimulate adaptation of advanced technology within the industry and consequently stimulate markets for the support of the exploitation activities, (d) to provide impact on improved image of Science in the Society. The target audience for dissemination includes: (a) industry as users including SMEs with machining intensive processes, (b) industrial associations, and (c) RTD community. For a successful dissemination, not only the internal dissemination is a key for success, but also a sound external dissemination strategy is required to widely spread the awareness on the CAPP-4-SMEs achievements and especially to ensure a long-term impact and to inform the potential European target audiences.

The dissemination plan is carried out for the overall project, relevant to the partners' research involvement in the project, and setting out how they intend to progress their activity in this area following the completion of the project. The dissemination plan covers the following aspects:

- All consortium partners organise internal seminars and meetings along the project to inform their employees about project achievements and business benefits for their organisation, specifically addressing potential multipliers, able to spread the messages over the entire partner networks;
- During the project, knowledge sharing and outreach activities are organised for relevant industrial communities and stakeholders (e.g., manufacturers, regulation bodies, policy makers, relevant ICT companies, etc.) in the EU to increase the awareness of the developed solutions and evaluate the impact of the research activities/outcomes on the development and

implementation of national and international manufacturing regulations and policies; project partners participate directly in influential organisations and standardisation bodies;

- The project also enables researchers to work together to make recommendations based on the outcomes of the project to international standardisation bodies for technical dissemination and exploitation worldwide; depending upon the established networks and communication channels of the partners in the project, research outcomes are contributed to standardisation bodies in the EU and international bodies (to be submitted to the European Committee of Standardisation and Integrated Product Policy (IPP), etc.;
- A brochure for the final research outcomes have been prepared and distributed to all potential users, as well as at related workshops, industry meetings and events; this brochure stress the actual benefits of the framework, along with the respective incentives for actor involvement; the project web portal was also developed at early stage and is used as a gateway to highlight the project objectives and diffuses the project results as widely as possible including scientific papers and all public deliverables; relevant multimedia content are developed, and user guides are set up, clearly describing the advantages of the approach;
- Three demonstrations are planned to demonstrate the usability of the developed solutions and their viability in terms of cost-benefits. The demonstrators will be documented in case studies for dissemination and developed into multimedia showcases. These e-demonstrations will be hosted on the project website and used at workshops, seminars, exhibitions, and conferences;
- In the aspect of academic dissemination of research outcomes, the research issues and findings are shared with other European and international academic members through discussions in seminars and publications in well-established conferences and journals;
- Finally, course materials will be developed and used in interdisciplinary postgraduate (MSc or PhD) courses, summer schools, and seminars for engineers and decision makers of SMEs.

8.2.1.1 *Dissemination channels*

The Consortium is formed by a well-balanced group of universities, industries and organisations sharing a joint vision of knowledge-based process planning, fully enabled by innovative and effective supporting technologies. Based on the project's dissemination strategy, each project partner reaches different target groups according to the organisation's profile, with information adjusted carefully to the audience level of need/involvement. The main goal is to approach relevant sectors, researchers, potential end-users and customers. Table 13 lists the target audience that each partner approaches during the dissemination activities as well as the impact that offers to the project through the dissemination activity. Table 14 shows the academic dissemination channels.

Table 13. Dissemination plan and partners' role

Partner	Type of organisation	Target audience	Dissemination plan
KTH	University	Scientific journals and societies, international conferences	• Disseminate research findings to research communities through the editorial involvements of the Project Coordinator. • Publish research results in international journals and conferences worldwide. • Promote project solutions to researchers and engineers via professional societies.
COVUNI	University	Researchers, potential manufacturing end users, policy makers	• Disseminate the research outcomes to potential end users through the industrial networks of the Coventry University Enterprise Ltd. and Enterprise Europe Network Midlands (Coventry University). The dissemination forms include public industrial workshops/seminars, courses and consultancies. • Education course materials to be used in MSc and PhD

			modules, summer schools, and short training courses.
LMS	University	Professional associations and European industries	• Disseminate the project outcomes to international professional associations such as International Academy for Production Engineering. • Organise industry-oriented tutorials and workshops for wide acceptance of the project solutions, particularly aiming at European SME companies.
CU	University	Scientific journals and societies, manufacturing industry in Europe	• Dissemination of the research to scientific communities through publication in journals and presentations at high-impact conferences (e.g. CIRP) worldwide. • Support EU industry through providing a Cloud Service via the Internet and direct communications. • Dissemination of the research through books and dedicated workshops (e.g. Evolutionary Computation in Practice track at the international GECCO conferences) and short courses.
SAN	Large company	End users and industrial networks	• Organise industry-oriented seminars and workshops through Sandvik's international network to promote the project outcomes to manufacturing SMEs worldwide. • Disseminate the project concept and benefits to potential end users through trade shows, magazines and industrial associations.
PROD	R&D SME	End users and industrial networks	• Technology-oriented seminars with potential end-users. • Dissemination of project outputs via electronic newsletters to more than 5000 companies at national and European level. • Dissemination of project outputs in other regions than Europe (e.g. Latin-American) to raise awareness among industrial companies. • Dissemination web 2.0 via PRODINTEC accounts in Xing, LinkedIn, Twitter, Facebook, website, etc.
ICT	SME	Business partners and customers	• Electronic dissemination of CAPP-4-SMEs results to ICT's business partners and customers to raise awareness. • Hosting demos to clients and visitors during the beyond the project.
FT	SME	Peers and industrial networks	• Lead the Dissemination and Exploitation WP • Disseminate the project outcomes at trade fairs. • Inform customers the new technologies of CAPP-4-SMEs.
AF	SME	Industrial networks	• Dissemination of project outputs to industrial stakeholders. AF belongs to several industrial associations at national level.
CAM	SME	National industrial networks	• Disseminate machining sample and test parts to regional and national industrial networks with fact sheets on cost saving. • Promote and encourage peers to try the new technology.
PKT	SME	Trade fairs and industrial associations	• Organise industry-oriented seminars and workshops through the company network to promote the project outcomes to manufacturing SMEs in the UK. • Disseminate the project outcomes at trade fairs and its industrial associations.

Table 14. Academic dissemination channels

Academic journals	• *CIRP Annals - Manufacturing Technology* • *CIRP Journal of Manufacturing Science and Technology* • *Computers in Industry* • *IEEE Transactions on Systems, Man and Cybernetics*

	• *Energy for Sustainable Development* • *Engineering Applications of Artificial Intelligence* • *European Journal of Operational Research* • *International Journal of Advanced Manufacturing Technology* • *International Journal of Computer Integrated Manufacturing* • *International Journal of Manufacturing Research* • *International Journal of Production Economics* • *International Journal of Production Research* • *Journal of Cleaner Production* • *Journal of Intelligent Manufacturing* • *Journal of Manufacturing Systems* • *Materials and Manufacturing Processes* • *Simulation Modelling Practice and Theory*
Academic conferences	• *CIRP Conference on High Performance Cutting* • *CIRP Conference on Industrial Product Service Systems* • *CIRP Conference on Life Cycle Engineering* • *CIRP Conference on Manufacturing Systems* • *CIRP Conference on Modelling of Machining Operations* • *CIRP Conference on Process Machine Interactions* • *CIRP General Assembly* • *Conference on Supervising and Diagnostics of Machining Systems* • *International Conference on Virtual Machining Process Technology* • *International Conference on Flexible Automation and Intelligent Manufacturing* • *Joint International Symposium on System-integrated Intelligence: New Challenges for Product and Production Engineering*
Monographs/ books	• *Monograph on Cloud Manufacturing (Springer)* • *Monograph on Collaborative and Knowledge-based Process Planning (Springer)*
Academic societies	• *Institute of Electrical and Electronics Engineers (IEEE)* • *Institute of Industrial Engineers (IIE)* • *International Academy for Production Engineering (CIRP)* • *Society of Manufacturing Engineers (SME)*

The dissemination and exploitation of project results are managed in WP7. All project participants contribute extensively to the dissemination of the project results to the wider European audience and to the exploitation of the CAPP-4-SMEs services, its modules and its use. Demonstration activities in WP6 also provide major input to the final dissemination strategies, and to the commercialisation of the CAPP-4-SMEs solutions. The plan for using and disseminating knowledge was developed in WP7 by FT and KTH in D7.1, which has revised periodically as a live document. The plan for exploitation of project results is managed in WP7 by FT and SAN, and have been delivered as D7.2.

8.2.1.2 *Dissemination results*

Publications:

[2015]

- M. Givehchi, A. Haghighi, L. Wang, "Generic machining process sequencing through a revised enriched machining feature concept," Journal of Manufacturing Systems, Available online 15 April 2015, ISSN 0278-6125, http://dx.doi.org/10.1016/j.jmsy.2015.04.004. (http://www.sciencedirect.com/science/article/pii/S0278612515000369)
- M. Givehchi, A. Haghighi and L. Wang, "Latest Advances in Function Block Enabled Adaptive Process Planning," Proceedings of the 4th International Conference on Virtual Machining Process Technology, June 2015.

- M. Givehchi, A. Haghighi, L. Wang, "Adaptive distributed proess planning and executions for multi-tasking machining centers with special functionalities," Flexible Automation and Intelligent Manufacturing (FAIM), June 2015
- X.X. Li, W.D. Li, X.T. Cai, F.Z. He, A hybrid honey-bee mating optimization and simulated annealing approach for sustainable process planning and scheduling, Integrated Computer Aided Engineering, accepted, 2015.
- X.T. Cai, F.Z. He, W.D. Li, X.X. Li, Encryption based partial sharing of CAD models, Integrated Computer Aided Engineering, accepted, 2015.
- S. Wang, X. Lu, X.X. Li, W.D. Li, A systematic approach of process planning and scheduling optimization for sustainable machining, Journal of Cleaner Production, 2015, 87, 914-929.
- X.T. Cai, W.D. Li, F.Z. He, X.X. Li, A customised encryption approach for collaboration in Cloud manufacturing, ASME Transactions Journal of Mechanical Science and Engineering, accepted, 2015.
- Tapoglou, N., Mehnen, J., Vlachou, A., Doukas, M., Milas, N., Mourtzis, D. (2015) "Cloud based platform for optimal machining parameter selection based on function blocks and real time monitoring" (in press), Journal of Manufacturing Science and Engineering, Transactions of the ASME, doi:101115/1.4029806.
- Tapoglou, N., Mehnen, J., "A Framework for Cloud Manufacturing Enabled Optimisation for Machining", APMS 2015 International conference Advances in production management systems. (accepted)
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- Tapoglou, N., Mehnen, J., "Cloud-Based Job Dispatching Using Multi-Criteria Decision Making", 48th CIRP Conference on Manufacturing Systems – CIRP CMS 2015, 24 – 26 June 2015, Ischia, Italy.
- Tapoglou, N., Mehnen, J., Doukas, M., Mourtzis D., "Optimal Machining Parameter Selection Based On Real-Time Machine Monitoring Using IEC 61499 Function Blocks for Use in A Cloud Manufacturing Environment: A Case Study for Face Milling" ASME 2014 Manufacturing Science and Engineering Conference, Detroit, USA, 9-13 June 2014, doi:10.1115/MSEC2014-4022, ISBN: 978-0-7918-4580-6.
- Gernhardt, B., Miltner, F. Vogel, T., Brocks, H., Hemmje, M., Wang, L. A Semantic Representation for Process-oriented Knowledge Management based on Functionblock Domain Models Supporting Distributed and Collaborative Production Planning. ASME 2015 Manufacturing Science and Engineering Conference (MSEC2015), in Charlotte, NC, USA.
- Gernhardt, B., Miltner, F. Vogel, T., Brocks, H., Hemmje, M., Wang, L. A semantic representation for process-oriented knowledge management based on functionblock domain models supporting distributed and collaborative production planning. ICAT 2015 International on Advanced Technology & Sciences, in Antalya, Turkey.
- Gernhardt, B., Miltner, F. Vogel, T., Brocks, H., Hemmje, M., Wang, L. A Semantic Representation for Process-oriented Knowledge Management based on Functionblock Domain Models Supporting Distributed and Collaborative Production Planning. International Journal of Advanced Computer Technology, Vol.4, Issue 3, pp.05-18, 2015 (IJACT)

[2014]

- Mourtzis D. Doukas M. Vlachou A. Xanthopoulos N., 2014. Machine availability monitoring for adaptive holistic scheduling: A conceptual framework for mass customisation. 8th International Conference on Digital Enterprise Technology – DET 2014 in Stuttgart, Germany.
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- Yaser Yadekar, Essam Shehab, and Jorn Mehnen.Uncertainties in Cloud Manufacturing. CE 2014, The 21st ISPE International Conference on Concurrent Engineering, 8-10 September 2014, Beijing, China.
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- X.T. Cai, F.Z. He, W.D. Li, X.X. Li, Y.Q. Wu. 2013. Multi-granularity partial encryption method of CAD model. 17th IEEE International Conference Computer Supported Cooperative Work in Design.in Whistler, BC, Canada.

Project website:

The project website (Figure 95) is developed by the Project Manager with the help of FT. In the reporting period, there are more than 29,000 hits per month on the project homepage. The website is regularly updated to broadcast the project news, external interviews and activities, and summaries. Contacts and biography are also broadcasted and updated on the website to effectively disseminate the project achievements and seeking future partners.

Project Twitter:

The CAPP-4-SMEs twitter (Figure 96) is also created by the end of 2013. To better interact with other EU projects and potential connections, popular online social networking and microblogging service is utilised. @CAPP4SMEs listens and delivers the lasted news and activities of the project. The Twitter account is managed by the KTH team, currently.

Figure 97. Project website

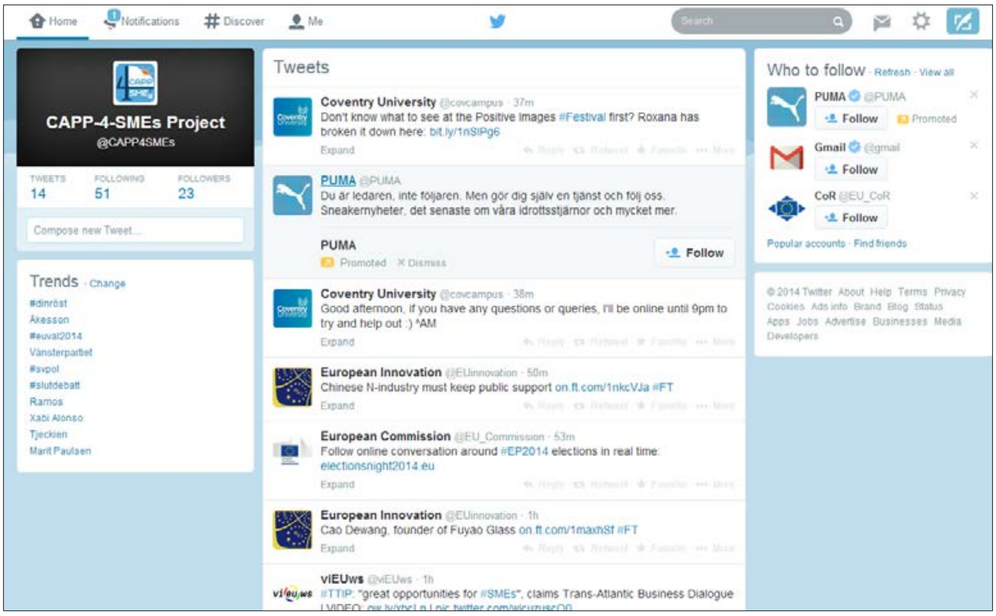

Figure 98. Project Twitter

Project brochure:

As another effort on project dissemination, 500 project brochures (Figure 97) are designed and printed to invite attentions to the CAPP-4-SMEs project. The brochures are distributed to all partners and brought to all possible events, e.g. conferences, expos, meetings, workshops, etc. These flyers are observed very popular at these events. Communications and phone calls have been received as the follow-up actions.

Figure 99. Project brochure

MACH 2014 Expo:

From 7th to 11th of April 2014, the CAPP-4-SMEs project was presented in MACH 2014, the UK's largest event for Manufacturing Technologies. Stands, posters and presentations were displayed on the exhibition. The activity was led by CU and supported by COVUNI and other partners. The project concept and developments were delivered to the exhibition audiences along with new project brochures. The active effort and success of the consortium has also attracted the attention of the European Factories of the Future Research Association (EFFRA). The dissemination event is featured in the next EFFRA newsletters. Figure 98 records the moments of CAPP-4-SMEs at MACH 2014 exposition.

Figure 100. CAPP-4-SMEs at MACH 2014

EC Impact Workshops 2014 and 2015:

On 25 and 26 March 2014, the project manager attended the Workshop on Impact of the Factories of the Future PPP in Brussels. Building on the progress of the activities promoted at the 3rd workshop in March 2013, this workshop focused on increasing cross-project clustering. Different from the previous year, the projects were grouped thematically, rather than by the call topics themselves. Joint presentations were prepared and delivered in three parallel sessions, where discussions were encouraged to further identify common synergies and ideas. During the workshop, the lasted development from CAPP-4-SMEs project was broadcasted.

The second day was organised as a plenary session, with keynote speakers from the EC and industry, where success stories were presented, followed by a panel of EC and private sector representatives talking about their views on the Factories of the Future PPP. The project manager shared the experience and knowledge on enhancing the external impacts with other participants, the issues and challenges related to CAPP-4-SMEs were also discussed in the Q&A session.

The previous Impact Workshop was attended by the project coordinator in March 2013.

External presentations:

The project consortium has been active in promoting the CAPP-4-SMEs project externally. Table 10 summarises the major activities of external presentations, excluding combined presentations with the project introduction as a part.

Media and interviews:

The consortium of CAPP-4-SMEs also strives for the broad impact on general public, regarding the state-of-the-art manufacturing technologies and project developments. The works of the project are reported in multiple occasions, including the XPRES interview in May 2013 and news on LA NUEAVA ESPANA in May 2014. Additionally, an interview regarding CAPP-4-SMEs Cloud is also under progress.

HORIZON 2020
The EU Framework Programme for Research and Innovation

From design to product with a mouse click

Using digital machining, companies can turn a digital design into an object with the click of a mouse. An EU-funded project has come up with a new and innovative way to do this, bringing the technology within reach of smaller companies with limited budgets.

The EU-funded CAPP-4-SMEs project goes beyond what competitors in China and the United States are doing in the sphere of cloud manufacturing – a set-up enabling universal, convenient, on-demand access to a shared pool of manufacturing resources (such as software tools, equipment and capabilities).

CAPP-4-SMEs brings together business planning and product design with an innovative method of machining – the process of cutting a raw material into a shape. It promises to be a winning formula. At the heart of CAPP-4-SMEs is Cloud-based Distributed Process Planning (Cloud-DPP) – an online planning system that collects real-time information on the availability of machines, available cutters and tools, as well as guidance on design.

"Diagram shows the logical relationship of five different services around one cloud in CAPP-4-SMEs

XPRES / NEWS

Cloud-based services for future production

Published May 07, 2013

Collaborative and Adaptive Process Planning for Sustainable Manufacturing Environments (CAPP-4-SME) is a consortium of eleven partners including four universities, a multinational manufacturing company as well as six small and medium-sized companies from five European countries.

The consortium's main goal is to promote technological innovations for future factories. The diversity of experience and knowledge available within the consortium enables a unique knowledge sharing both technical expertise for industrial applications and the dissemination of research results across Europe.

- Cloud-based services will have a significant impact on production planning and control of dynamic and decentralized manufacturing environments in the future, especially for small and medium-sized businesses. Professor at the Department of Industrial Engineering, KTH, Lihui Wang says.

Learn more about CAPP-4-SME here

To the news list

Professor Lihui Wang believes that cloud-based services will have a significant impact on future production planning.

Prodintec genera herramientas para impulsar fábricas digitales

Un consorcio europeo en el que participa Asturfeito desarrolla un software para optimizar procesos industriales

C. JIMÉNEZ

Con el ánimo de poner a disposición del tejido industrial una herramienta que permita simular todas las tareas que tienen lugar en una planta de fabricación, el centro tecnológico Prodintec se embarcó meses atrás en un consorcio europeo que implica a once entidades de cinco países distintos para abordar las posibilidades de reducción de tiempos y costes en la industria manufacturera. El objetivo era obtener herramientas avanzadas inteligentes que permitieran reducir y simplificar la planificación y la programación en una planta industrial. Y esta pasada semana, en las instalaciones del centro tecnológico, se dieron a conocer los primeros resultados de ese

Alejandro Muñoz, a la derecha, durante la jornada en Prodintec. | JUAN PLAZA

KTH / ITM / RESEARCH / FORSKNING PÅ DJUPET

Cloud Manufacturing

Published Jun 27, 2014

Are you tired of buying expensive IT equipment and complicated applications? Have you had enough of hardware and software that you constantly need to install, configure, test, run, protect and upgrade? Then cloud manufacturing is for you. Shut down your IT department and move your business to the cloud!

Cloud manufacturing means that you as a manufacturer use cloud technology. You buy software, information storage, and processing power as services from a cloud provider. Instead of storing applications and data on your company computer, you store them on external servers that can be accessed over the Internet. The cloud provider may use a large number of interconnected servers, often distributed over a large area, sometimes in different countries. You don't know, and you don't need to know, where in the cloud the information is stored. Cloud services are sold on demand and you can have as much or as little of a service as you want at any given time. That way you can adjust you IT-capacity to exactly the right level.

The cloud is well suited to be used by manufacturing companies. We have had a chat with Dr. Xi Wang, a researcher in the Department of Production Engineering at KTH, to learn more about cloud manufacturing.

- The use of cloud services can be very advantageous for a manufacturing company, says Dr. Xi Wang.

Xi Wang, Post Doctor

Figure 101. Media reports on CAPP-4-SMEs

8.2.2 Exploitation of project results

FT as the WP7 Leader and SAN as the leading industrial partner are responsible for the management of the exploitation work, being supported throughout the project by the other industrial partners. CAPP-4-SMEs provides theoretical development and software- and process-related technologies as effective solutions for manufacturing SMEs. It should be underlined that the know-hows gained within the project are of crucial importance for users in their future strategy regarding new ways of doing business. All RTD partners will use the know-hows for their further RTD and industrial projects. In order to facilitate the expected impact, both internal and joint exploitation strategies are applied. The exploitation can be generally categorised as follows.

8.2.2.1 *Exploitation plan*

Partners from research and academia exploit the CAPP-4-SMEs solutions to analyse the collaborative, knowledge-based adaptive process planning and the applications for SMEs. Scientific outcomes of the project are used to strengthen scientific excellence and experiences. The exploitation results arise in many forms, including:

- Feeding results and know-how into the current research activities such as modelling and planning of manufacturing processes, sustainable manufacturing, Cloud-based platform development for manufacturing applications, adaptive and knowledge-based collaboration among SMEs, etc.;
- Feeding results and know-how further into EU and national RTD projects; and
- Forming active groups under academic societies.

The relevant potential beneficiaries include manufacturing SMEs, which are facing dynamic markets, varied product demands and complex manufacturing environment and supply chain, and service providers and software developing companies, which provide technical support to the SMEs. Through the industrial networks and commercial partners in the consortium, a significant portion of the target group is invited for research dissemination and exploitation. Furthermore, the exploitation results also include the wider spectrum:

- Inputting to industrial standardisation activities.
- Forming industrial societies for dissemination and exploitation, and developing dissemination and exploitation materials for industrial seminars, user workshops and conferences, focus group meetings, industrial short courses and consultancy.
- Feeding results and know-how into further industrial projects.
- Creating start-up businesses to commercialise research results.

The exploitation plan for project partners is explained in Table 15.

Table 15. Exploitation plan

Organisation	Exploitation plan
KTH	• KTH Royal Institute of Technology has signed a strategic partnership agreement to create stronger relationship regarding research activities. Through this connection, the CAPP-4-SMEs outcomes can be further exploited among Sandvik companies, worldwide. This exploitation can go beyond Sandvik to their suppliers. • The XPRES initiative of KTH has ready access to Swedish industries for exploitation.
COVUNI	• Coventry University Enterprise Ltd. and Enterprise Europe Network Midlands (Coventry University) are industrial interfaces backed by the academic support of Coventry University to support companies mainly SMEs in design and manufacturing in the UK. Through the networks, the project outcomes will be exploited by existing customers by providing the state-of-the-art technologies, know-how and services. It can also facilitate Coventry University and its Enterprise Ltd. to provide new training and knowledge transfer services

	in the relevant research areas. • The project will be exploited through research activities to provide incentives and benefits to the researchers/research students in the University.
LMS	• The experience and knowledge acquired by CAPP-4-SMEs project are incorporated in educational courses, both at undergraduate and postgraduate levels, and support two PhD theses. • Results of CAPP-4-SMEs also enhance the R&D consultation capabilities of LMS, to several national and European industrial partners. The outcomes of the project form the basis for further research and development actions. • Initialising and launching R&D projects in the future, in collaboration with existing partners and/or similar organisations.
CU	• Cranfield University has strong ties with UK industry through various routes. Cranfield was just recently awarded four Centres of Innovative Manufacturing (CIM) through which Cranfield became a national hub for UK manufacturing industry. Dr Mehnen is involved in one such centre directly and utilise this network for the CAPP-4-SMEs project. • Cranfield has its own TTO (Technical Transfer Office) which offers industry "incubation" facilities for helping new enterprises with starting new businesses. The TTO is also helping University spin off companies to exploit their new ideas. • Cranfield University is an internationally renowned research institute with many international (especially EU) students and researchers. The knowledge gained through this project is disseminated through lectures on cutting-edge research EU wide.
SAN	• Sandvik has a broad supplier network and end-user network, through which the project results can be further exploited. • Sandvik also has a large number of customer service centres and business offices, worldwide. The customer connections are the unique points for Sandvik to exploit future business opportunities and influence customers towards Cloud-based process planning services.
PROD	• New RTD offerings anticipated by PROD include the transfer of knowledge to Spanish industrial companies interested in implementing novel process planning tools. Moreover, participation in the project enables PROD to acquire key knowledge on process planning and integrated process simulation. This, in turn, enables new types of national and local projects with Spanish industrial sector companies and Spanish social sector organisations. • PROD has already a consolidated experience in Latin-American countries, (via its previous experience in funding mechanisms such as EKA, Iberoeka), that can be benefit from project outputs. PROD's conservative estimate is that its increased activity leads to an increase in its annual financial turnover of up to 15 %, and an increase its number of employees of up to 10%.
ICT	• Located in Germany, ICT has connections to a large number of German SME companies and exploit the project offerings to these SMEs. • ICT has good relationship with previous project partners through MERCI (FP6), SHAMAN and SmartVortex (FP7), and is member of the ProStep iViP organisation related to standardisation activities. ICT explore and exploit the CAPP-4-SMEs outcomes through these channels.
FT	• Leading the Dissemination and Exploitation WP in this project. • Increasing the scalability of the FORMTEC software by incorporating the new technologies available from the project. • Improving the adaptability of the software to match the different requirements of small and large companies. • Enhance the robustness of the software.
AF	• AF benefits from project outputs by having first-hand knowledge about the implementation of totally novel approaches for process planning and simulation at shop floor level. • AF could also benefit by contributing to consulting and training services to other interested companies along with other members of the consortium.

	• AF's participation in the project likely increases its productivity of up to 25 %.
CAM	• As the end user of the project, CAM applies the new technologies to its own machining business through the low-cost process planning services. • CAM also teams up with SAN to explore the domestic market in Sweden and exploit the new business possibility of being a part of machining-as-a-service linked to the CAPP-4-SMEs.
PKT	• PKT deploys and exploit the developed technology to improve their daily operations.

8.2.2.2 *Exploitation seminars*

To let all partners better understand the exploitation process, an exploitation seminar was taken on 11 December 2013. Assisted by Kinno, the professional consulting group, the exploitable modules from the project are assessed from multiple scales, including Innovativeness, Unique Selling Point, Product/Service Market Size, Product/Service Positioning, etc. The Cloud-DPP, Machine Availability Monitoring Module and Optimisation Service are primarily targeted as exploitable results that can be commercialised in the future. Additionally, the next exploitation seminar is planned in mid-December 2014 as a part of the all-partner project meeting in Spain. New exploitable modules and services are identified together with the discussions on the project exploitation strategy.

	Key Exploitable Results	Degree of importance of the risk related to the final achievement of this Key Exploitable Result. Please rate from 1 to 10 (1 low- 10 high)	Probability of risk happening Please rate from 1 to 10 (1 low - 10 high)	Risk Grade	Scope and type of potential intervention	Feasibility/Success of Intervention Please rate from 1 to 10 (1 low- 10 high)	Priority Level
1	**Partnership Risk Factors**	5	4	21		6	135
	Disagreement on further investments: some partners may leave.	7	5			7	
	Industrialization at risk: no manufacturer for the exploitable result.	5	3			6	
	Disagreement on ownership rules	4	4			6	
2	**Technological Risk Factors**	4	4	14		7	91
	Worthless result: ill-timed disclosure.	4	3			5	
	Worthless result: earlier patent exists.	5	5			6	
	The life cycle of the new technology is too short.	4	3			7	
	Significant dependency on other technologies.	3	3			8	
3	**Market Risk Factors**	6	3	17		7	116
	Exploitation disagreement: partners on the same market.	6	2			8	
	Worthless result: performance lower than market needs.	6	2			7	
	Nobody buys the product. Too expensive.	4	5			7	
	Nobody buys the product. Problems at the time of the first sales.	6	3			6	
4	**IPR/legal Risk Factors**	3	1	3		9	29
	Legal problems: proceeding against us.	3	1			8	
	Know- how risks: it is easy to counterfeit the patent.	3	1			9	
	Know- how risks: the patent application is rejected.	4	1			9	
5	**Financial/management Risk Factors**	5	5	27		7	178
	Nobody buys the product. Our licensee is not exploiting his exclusive license.	5	5			6	
	Multiple changes to original objectives.	4	6			7	
	Inadequate communication among partners.	6	5			7	
6	**Environmental/regulatory Risk Factors**	2	2	4		6	25
	Nobody buys the product. Does not comply with the standards.	4	2			7	
	Research is socially or ethically unacceptable.	1	1			6	
	Influence of laws and regulations.	2	2			6	

Figure 102. Exploitation Roadmap (1 out of 7)

8.2.2.3 *Exploitation activities with overseas companies*

FT as leader of WP7 (Dissemination and Exploitation) analysed the result of the exploitation seminar during the Athens meeting in December 2013. Some materials have been developed, pointing out the benefits of the CAPP-4-SMEs approach. The goal is to use the vocabulary of SMEs and to address typical problems of SMEs. FT used the materials for face-to-face in-depth discussions with several companies. The results are summarised in Table 12.

Table 16. Exploitation activities

4 SMEs in Germany (having parts of manufacturing using milling)
<u>*Summary:*</u> The key benefits of CAPP-4-SMEs ("late tooling", more flexibility in shop floor to optimise machine utilisation, tools for assisted decisions on schedule) have been understood immediately. There is a big demand for tools assisting the shop floor. Especially, tools having a wide range perspective – technical and administrative – are highly welcome. The SMEs are aware of the pressure to optimise manufacturing - keeping the things like today may be dangerous. There have been different approaches to solve the problems (like CAM to the machine, several minor tools, special organisation). Special remarks have to be made for two companies below.
<u>*SME 1:*</u> The SME has developed a special software tool dealing with certain aspects of the CAPP-4-SMEs concept. The input for this tool is the CAM-system output. Every milling operation is handled like a feature in CAPP-4-SMEs but the coverage is much limited in comparison to CAPP-4-SMEs. However, even the limited approach seems to have big benefits for the company, which the self-driven development of an individual solution is rewarding.
<u>*SME 2:*</u> The SME is interested in a shop floor assistant tool like CAPP-4-SMEs but more capable of interfacing with already used CAD/CAM systems and legacy machines. FT was asked to offer a tool like this – discussions are ongoing.

Overseas companies as counterpart to European SMEs
<u>*Company 1: Big manufacturer (People's Republic of China)*</u> The company uses its way of organising manufacturing as an advantage over other market participants. They have already implemented concepts like CAPP-4-SMEs. If special software or automatism is missing the workflow is supported by organisational means and if necessary even by manual input. The gaps will be closed in the future. The manufacturing process is completely described in sort of feature way. A CAM system is used to fill the features with convenient traditional NC-code – but the features are not limited to milling. A simulation is run before the process plan is deployed to the machines.
<u>*Company 2: Software provider for manufacturing companies*</u> They have developed a software tool, supporting full process description using a sort of features. A simulation is also run before deploying the process plan to the machines. There are big manufacturers interested in the solution.

The number of picked samples is of course not representative. The general trend needs to be verified by additional surveys. The trend: Small companies are highly interested in solutions but a lack of readiness to go as products convenient to SME's financial situation is a problem. Big companies for example in Asia are already on the way but the solutions are very special and do not have the requested flexibility for European SME's.

8.2.3 Route to commercialisation

The commercialisation is driven by the soaring manufacturing software service industries. This CAPP-4-SMEs system can be an essential technical enabler to support this innovative service business model and stimulate the further growth of the sector and relevant industries, including many existing manufacturing companies, application software companies, manufacturing consultancy companies, start-ups and spin-offs to enter into this new market as manufacturing service providers.

The commercialisation is also driven by the intensive requirements from manufacturing SME end users. More than 90% manufacturing companies in the EU are SMEs. They lack resources and expertise to set up and maintain advanced collaborative and adaptive CAPP systems to address the dynamics from customised product demands and complex machining shop floor management. The service provision models through the CAPP-4-SMEs system ensures uptake of the collaborative and adaptive process planning functions and simplifies adaptation to the widest possible regions with high acceptability by SMEs in the EU.

The commercialisation can be stimulated by open interface and reference standards of the CAPP-4-SMEs system. This is aligned with the recommendation of the EC to promote the European leadership position in developing and adopting industrial application software systems through commercially relevant open approaches. The standards should encourage all end users to be able to interoperate, and allow plug-tests to prove standards compliance.

The financial return of the above solution comes from the subscription to services as pay-as-you-go by end users, as well as providing training, technical support and consultancy by service providers to end users. The route to commercialisation of the CAPP-4-SMEs system is:

- The CAPP-4-SMEs services are hosted by KTH and SAN collaboratively, disseminated to and exploited by various manufacturing SME end users from the industrial networks of the consortium. During the incubation phase, the initial system is made of the CAPP-4-SMEs partners and contributors;
- The initial team grows during the course of the project development. With dissemination, demonstration and exploitation, the CAPP-4-SMEs will rapidly migrate to the open standard status and mature service business models;
- The open standard assets be maintained by SAN, FT and ICT as professional service providers, and the financial sustainability will be maintained through training, technical support and consultancy services; and
- It is anticipated that the CAPP-4-SMEs system facilitates SAN, FT and ICT to enter into the new markets. Through technology transfer and software licensing, new service business division in existing manufacturing, application software and consultancy companies, start-ups and spin-offs will grow.

8.2.4 Management of intellectual properties

Innovation related activities are significant in order to meet the project objectives and achieve specific goals that are quantified according to a set of rules to measure success. The success of CAPP-4-SMEs involves both technical success and acceptance of the platform in user and developer communities. WP7 is entirely dedicated to the activities of dissemination, assessment of deliverables and exploitation of results. The project has planned activities relating to the protection and dissemination of knowledge and, when relevant, studies on the wider societal impact of that knowledge, activities to promote the exploitation of the results, and "take-up" actions, mainly through WP7. IPR is handled in line with general Commission policies regarding ownership, exploitation rights and confidentiality. In principle, foreground IPR is managed accordingly with the provisions of the Commission, and the access to the foreground created throughout the project lifetime is ruled by the Consortium Agreement of the project prepared in WP8 prior to the project kick-off. Such a consortium agreement was signed in the early phases of the project, allowing for all participants to be granted with exploitation opportunities, with respect to the IPR and individual exploitation interests. The consortium agreement makes explicit reference to important administrative issues, such as project management and decision-making within the project, as well as the various dissemination and exploitation procedures. Concerning IPR, in particular, the following issues are addressed:

- Commercial utilisation of results, also taking into account joint ownership of the results;
- Availability of the information, deliverables, results etc. to other EU funded projects;
- Disclaiming rules;
- Research publication rights to be owned by those who produce them (either employers or employees depending on their country's regime), and distribution within the project should be granted for free (decision of non-disclosure should be taken by the Project Management Board with adequate compensation to the partners);
- Software produced for the project to be the property of the producers;
- The distribution of financial contribution to the commercialisation;
- The settlement of internal disputes, if any.

Foreground knowledge management and management of innovation-related activities, including exploitation of results are handled by the Project Management Board, following established guidelines and processes.

Ownership and protection of knowledge: As a general rule, the foreground shall be considered as a property of the partner generating it, and in this sense the originator is entitled to use and to license such right without any financial compensation to or the consent of the other contributors. If the features of a joint invention are such that it is not possible to separate them, the contributors could agree that they may jointly apply to obtain and/or maintain the relevant rights and shall strive to set up amongst themselves appropriate agreements in order to do so.

Publication and dissemination of foreground: Publication and dissemination of foreground are granted with the approval of the Consortium, making sure that the period of secrecy needed for a successful patent application is respected. Partner has to inform the Consortium of its intention to publish on its foreground. Publication can be delayed if another partner can show that the secrecy of the foreground is not guaranteed.

Access rights: Each partner shall take appropriate measures to ensure that it can grant access rights and fulfil the obligations under the EU contract. Partners have also to agree that access rights are granted on a non-exclusive basis, and that, if not otherwise provided in the Consortium Agreement or granted by the owner of the Foreground or Background, the access rights do not include the right to grant sub-licenses. The Consortium Agreement dedicates one section or one appendix to define which access rights to the background may be granted.

9 Use of Resources

Resources Monitoring Table

Instructions for use:

Contract N°:	314024	Acronym:	CAPP-4-SMEs	Period:	2	Date:	1/29/2016

PARTICIPANTS	UNIT (PERSON-MONTHS or EUROS)	TYPE of EXPENDITURE	PLANNED	ACTUAL EXPENDITURE					Pct. Spent	REMAINING RESOURCES	COMMENTS
				Period 1	Period 2	Period 3	Period 4	Total	TOTAL		
			e	a1	b1	c1	d1	e1	a1+b1+c1+d1/e	e-e1	
Beneficiary 1	P-M	Work Package 1	5.00	0.30	0.00			0.30	6%	4.70	
KTH	P-M	Work Package 2	12.00	1.80	0.00			1.80	15%	10.20	
	P-M	Work Package 3	18.00	12.30	69.04			81.34	452%	-63.34	
	P-M	Work Package 4	10.00	4.10	17.42			21.52	215%	-11.52	
	P-M	Work Package 5	6.00	0.00	0.00			0.00	0%	6.00	
	P-M	Work Package 6	7.00	0.00	8.96			8.96	128%	-1.96	
	P-M	Work Package 7	2.00	0.50	0.00			0.50	25%	1.50	
	P-M	Work Package 8	12.00	6.50	9.51			16.01	133%	-4.01	
	P-M	Work Package 9						0.00	0%	0.00	
	P-M	Work Package 10						0.00	0%	0.00	
	P-M	Total	72.00	25.50	104.93	0.00	0.00	130.43	181%	-58.43	
	Euros	Personnel costs	565,200.00	125,747.55	512,093.06			637,840.61	113%	-72,640.61	
	Euros	Subcontracting	3,000.00	0.00	3,028.72			3,028.72	101%	-28.72	
	Euros	Other direct costs	38,000.50	6,384.41	30,100.35			36,484.76	96%	1,515.74	
	Euros	Indirect Costs	361,920.30	79,279.17	325,216.04			404,495.21	112%	-42,574.91	
	Euros	Total Costs	968,120.80	211,411.13	870,438.17	0.00	0.00	1,081,849.30	112%	-113,728.50	
	Euros	Requested EU funding	753,220.40	175,470.48	661,535.36			837,005.84	111%	-83,785.44	
Beneficiary 2	P-M	Work Package 1	17.00	18.74	5.12			23.86	140%	-6.86	
COV	P-M	Work Package 2	7.00	8.53	16.28			24.81	354%	-17.81	
	P-M	Work Package 3	7.00	6.26	1.08			7.34	105%	-0.34	
	P-M	Work Package 4	8.00	2.58	0.42			3.00	38%	5.00	
	P-M	Work Package 5	11.00	2.59	10.82			13.41	122%	-2.41	
	P-M	Work Package 6	7.00	0.00	17.54			17.54	251%	-10.54	
	P-M	Work Package 7	2.00	1.17	3.62			4.79	240%	-2.79	
	P-M	Work Package 8	0.00	0.00	0.00			0.00	0%	0.00	
	P-M	Work Package 9						0.00	0%	0.00	
	P-M	Work Package 10						0.00	0%	0.00	
	P-M	Total	59.00	39.87	54.88	0.00	0.00	94.75	161%	-35.75	
	Euros	Personnel costs	383,500.00	163,425.39	272,891.11			436,316.50	114%	-52,816.50	
	Euros	Subcontracting	3,000.00		2,814.10			2,814.10	94%	185.90	
	Euros	Other direct costs	25,000.00	7,760.65	17,622.64			25,383.29	102%	-383.29	
	Euros	Indirect Costs	245,100.00	102,711.62	174,308.25			277,019.87	113%	-31,919.87	
	Euros	Total Costs	656,600.00	273,897.66	467,636.10	0.00	0.00	741,533.76	113%	-84,933.76	
	Euros	EU funding	479,400.00	209,605.17	323,286.13			532,891.30	111%	-53,491.30	
Beneficiary 3	P-M	Work Package 1	3.00	2.97	0.00			2.97	99%	0.03	
LMS	P-M	Work Package 2	17.00	14.89	1.50			16.39	96%	0.61	
	P-M	Work Package 3	10.00	2.24	7.66			9.90	99%	0.10	
	P-M	Work Package 4	7.00	0.67	6.00			6.67	95%	0.33	
	P-M	Work Package 5	4.00	1.39	2.24			3.63	91%	0.37	
	P-M	Work Package 6	7.00	0.00	7.45			7.45	106%	-0.45	
	P-M	Work Package 7	2.00	0.81	1.71			2.52	126%	-0.52	
	P-M	Work Package 8	0.00	0.00	0.00			0.00	0%	0.00	
	P-M	Work Package 9						0.00	0%	0.00	
	P-M	Work Package 10						0.00	0%	0.00	
	P-M	Total	50.00	22.97	26.56	0.00	0.00	49.53	99%	0.47	
	Euros	Personnel costs	325,000.00	152,340.00	172,445.00			324,785.00	100%	215.00	
	Euros	Subcontracting	3,000.00		4,000.00			4,000.00	133%	-1,000.00	
	Euros	Other direct costs	31,500.00	10,049.17	23,065.95			33,115.12	105%	-1,615.12	
	Euros	Indirect Costs	213,900.00	97,433.50	117,306.57			214,740.07	100%	-840.07	
	Euros	Total Costs	573,400.00	259,822.67	316,817.52	0.00	0.00	576,640.19	101%	-3,240.19	
	Euros	Requested EU funding	418,200.00	196,463.00	227,609.98			424,072.98	101%	-5,872.98	
Beneficiary 4	P-M	Work Package 1	7.00	4.00	4.00			8.00	114%	-1.00	
CU	P-M	Work Package 2	5.00	2.50	4.00			6.50	130%	-1.50	
	P-M	Work Package 3	5.00	0.00	6.00			6.00	120%	-1.00	
	P-M	Work Package 4	5.00	2.00	4.00			6.00	120%	-1.00	
	P-M	Work Package 5	17.00	5.00	17.00			22.00	129%	-5.00	
	P-M	Work Package 6	8.00	0.00	9.00			9.00	113%	-1.00	
	P-M	Work Package 7	2.00	0.00	1.50			1.50	75%	0.50	
	P-M	Work Package 8	0.00	0.00	0.00			0.00	0%	0.00	
	P-M	Work Package 9						0.00	0%	0.00	
	P-M	Work Package 10						0.00	0%	0.00	
	P-M	Total	49.00	13.50	45.50	0.00	0.00	59.00	120%	-10.00	
	Euros	Personnel costs	337,561.00	48,540.72	224,592.85			273,133.57	81%	64,427.43	
	Euros	Subcontracting	3,000.00		2,274.02			2,274.02	76%	725.98	
	Euros	Other direct costs	28,400.00	13,566.38	28,783.55			42,349.93	149%	-13,949.93	
	Euros	Indirect Costs	219,576.60	37,264.26	152,025.84			189,290.10	86%	30,286.50	
	Euros	Total Costs	588,537.60	99,371.36	407,676.26	0.00	0.00	507,047.62	86%	81,489.98	
	Euros	Requested EU funding	424,019.60	78,201.81	306,809.41			385,011.22	91%	39,008.38	

Beneficiary 5	*P-M*	Work Package 1	8.00	2.17	1.07			3.24	41%	4.76
SAN	*P-M*	Work Package 2	7.00	1.07	0.40			1.47	21%	5.53
	P-M	Work Package 3	6.00	3.48	0.75			4.23	71%	1.77
	P-M	Work Package 4	17.00	3.34	0.88			4.22	25%	12.78
	P-M	Work Package 5	5.00	1.07	0.26			1.33	27%	3.67
	P-M	Work Package 6	18.00	3.67	12.89			16.56	92%	1.44
	P-M	Work Package 7	3.00	1.41	0.00			1.41	47%	1.59
	P-M	Work Package 8	0.00	0.00	0.67			0.67	#DIV/0!	-0.67
	P-M	Work Package 9						0.00	0%	0.00
	P-M	Work Package 10						0.00	0%	0.00
	P-M	*Total*	64.00	16.21	16.92	0.00	0.00	33.13	52%	30.87
	Euros	Personnel costs	566,400.00	98,149.00	107,280.00			205,429.00	36%	360,971.00
	Euros	Subcontracting	3,000.00	0.00	0.00			0.00	0%	3,000.00
	Euros	Other direct costs	47,165.00	9,996.00	24,667.16			34,663.16	73%	12,501.84
	Euros	Indirect Costs	122,713.00	78,910.00	86,199.50			165,109.50	135%	-42,396.50
	Euros	Total Costs	739,278.00	187,055.00	218,146.66	0.00	0.00	405,201.66	55%	334,076.34
	Euros	Requested EU funding	390,168.00	97,786.00	113,096.20			210,882.20	54%	179,285.80
Beneficiary 6	*P-M*	Work Package 1	6.00	6.07	0.00			6.07	101%	-0.07
PROD	*P-M*	Work Package 2	6.00	4.13	2.21			6.34	106%	-0.34
	P-M	Work Package 3	6.00	4.97	1.59			6.56	109%	-0.56
	P-M	Work Package 4	0.00	0.00	0.00			0.00	0%	0.00
	P-M	Work Package 5	3.00	1.08	2.29			3.37	112%	-0.37
	P-M	Work Package 6	8.00	0.00	7.97			7.97	100%	0.03
	P-M	Work Package 7	3.00	1.05	2.13			3.18	106%	-0.18
	P-M	Work Package 8	0.00	0.00	0.00			0.00	0%	0.00
	P-M	Work Package 9						0.00	0%	0.00
	P-M	Work Package 10						0.00	0%	0.00
	P-M	*Total*	32.00	17.30	16.19	0.00	0.00	33.49	105%	-1.49
	Euros	Personnel costs	144,000.00	71,480.37	72,012.71			143,493.08	100%	506.92
	Euros	Subcontracting	0.00	0.00	0.00			0.00	0%	0.00
	Euros	Other direct costs	17,000.00	6,968.78	9,282.04			16,250.82	96%	749.18
	Euros	Indirect Costs	64,400.00	31,379.66	32,517.88			63,897.54	99%	502.46
	Euros	Total Costs	225,400.00	109,828.81	113,812.63	0.00	0.00	223,641.44	99%	1,758.56
	Euros	Requested EU funding	160,125.00	83,741.39	77,275.19			161,016.58	101%	-891.58
Beneficiary 7	*P-M*	Work Package 1	2.00	1.50	0.50			2.00	100%	0.00
ICT	*P-M*	Work Package 2	0.00	0.00	0.00			0.00	0%	0.00
	P-M	Work Package 3	4.00	2.50	1.50			4.00	100%	0.00
	P-M	Work Package 4	2.00	2.25	0.00			2.25	113%	-0.25
	P-M	Work Package 5	4.00	3.25	0.50			3.75	94%	0.25
	P-M	Work Package 6	5.00	0.00	3.30			3.30	66%	1.70
	P-M	Work Package 7	3.00	1.00	2.00			3.00	100%	0.00
	P-M	Work Package 8	0.00	0.00	0.00			0.00	0%	0.00
	P-M	Work Package 9						0.00	0%	0.00
	P-M	Work Package 10						0.00	0%	0.00
	P-M	*Total*	20.00	10.50	7.80	0.00	0.00	18.30	92%	1.70
	Euros	Personnel costs	220,000.00	116,403.00	86,474.00			202,877.00	92%	17,123.00
	Euros	Subcontracting	0.00		0.00			0.00	0%	0.00
	Euros	Other direct costs	8,400.00	8,015.00	6,689.79			14,704.79	175%	-6,304.79
	Euros	Indirect Costs	45,680.00	24,883.60	18,632.76			43,516.36	95%	2,163.64
	Euros	Total Costs	274,080.00	149,301.60	111,796.55	0.00	0.00	261,098.15	95%	12,981.85
	Euros	Requested EU funding	198,120.00	117,381.90	80,947.41			198,329.31	100%	-209.31
Beneficiary 8	*P-M*	Work Package 1	4.00	3.31	0.69			4.00	100%	0.00
FT	*P-M*	Work Package 2	2.00	1.33	0.67			2.00	100%	0.00
	P-M	Work Package 3	2.00	1.20	0.80			2.00	100%	0.00
	P-M	Work Package 4	3.00	1.80	1.20			3.00	100%	0.00
	P-M	Work Package 5	5.00	3.00	2.00			5.00	100%	0.00
	P-M	Work Package 6	6.00	0.00	6.00			6.00	100%	0.00
	P-M	Work Package 7	9.00	4.12	4.88			9.00	100%	0.00
	P-M	Work Package 8	0.00	0.00				0.00	0%	0.00
	P-M	Work Package 9						0.00	0%	0.00
	P-M	Work Package 10						0.00	0%	0.00
	P-M	*Total*	31.00	14.76	16.24	0.00	0.00	31.00	100%	0.00
	Euros	Personnel costs	164,610.00	78,392.00	86,256.00			164,648.00	100%	-38.00
	Euros	Subcontracting	0.00		0.00			0.00	0%	0.00
	Euros	Other direct costs	21,500.00	3,509.00	19,197.00			22,706.00	106%	-1,206.00
	Euros	Indirect Costs	111,666.00	49,140.60	63,271.80			112,412.40	101%	-746.40
	Euros	Total Costs	297,776.00	131,041.60	168,724.80	0.00	0.00	299,766.40	101%	-1,990.40
	Euros	Requested EU funding	229,107.00	107,297.20	123,690.00			230,987.20	101%	-1,880.20

Beneficiary 9	*P-M*	Work Package 1	2.00	2.00	0.00			2.00	100%	0.00
AF	*P-M*	Work Package 2	2.00	0.50	1.00			1.50	75%	0.50
	P-M	Work Package 3	0.00	0.00	0.00			0.00	0%	0.00
	P-M	Work Package 4	2.00	0.50	1.00			1.50	75%	0.50
	P-M	Work Package 5	2.00	0.00	1.25			1.25	63%	0.75
	P-M	Work Package 6	8.00	0.00	6.00			6.00	75%	2.00
	P-M	Work Package 7	3.00	0.25	2.00			2.25	75%	0.75
	P-M	Work Package 8	0.00	0.00	0.00			0.00	0%	0.00
	P-M	Work Package 9						0.00	0%	0.00
	P-M	Work Package 10						0.00	0%	0.00
	P-M	*Total*	19.00	3.25	11.25	0.00	0.00	14.50	76%	4.50
	Euros	Personnel costs	85,500.00	16,187.85	59,475.01			75,662.86	88%	9,837.14
	Euros	Subcontracting	0.00	0.00	0.00			0.00	0%	0.00
	Euros	Other direct costs	16,000.00	271.57	4,002.04			4,273.61	27%	11,726.39
	Euros	Indirect Costs	60,900.00	9,875.65	38,086.24			47,961.89	79%	12,938.11
	Euros	Total Costs	162,400.00	26,335.07	101,563.29	0.00	0.00	127,898.36	79%	34,501.64
	Euros	Requested EU funding	110,200.00	20,249.39	66,179.05			86,428.44	78%	23,771.56
Beneficiary 10	*P-M*	Work Package 1	2.00	0.20	1.40			1.60	80%	0.40
CAM	*P-M*	Work Package 2	2.00	0.20	2.60			2.80	140%	-0.80
	P-M	Work Package 3	2.00	0.20	2.10			2.30	115%	-0.30
	P-M	Work Package 4	3.00	0.30	2.10			2.40	80%	0.60
	P-M	Work Package 5	2.00	0.20	1.20			1.40	70%	0.60
	P-M	Work Package 6	6.00	0.60	2.50			3.10	52%	2.90
	P-M	Work Package 7	3.00	0.20	3.60			3.80	127%	-0.80
	P-M	Work Package 8	0.00	0.00	0.00			0.00	0%	0.00
	P-M	Work Package 9						0.00	0%	0.00
	P-M	Work Package 10						0.00	0%	0.00
	P-M	*Total*	20.00	1.90	15.50	0.00	0.00	17.40	87%	2.60
	Euros	Personnel costs	164,000.00	20,512.00	82,250.00			102,762.00	63%	61,238.00
	Euros	Subcontracting	0.00	103.00	0.00			103.00	#DIV/0!	-103.00
	Euros	Other direct costs	13,700.00	1,603.00	863.00			2,466.00	18%	11,234.00
	Euros	Indirect Costs	106,620.00	13,269.00	49,867.80			63,136.80	59%	43,483.20
	Euros	Total Costs	284,320.00	35,487.00	132,980.80	0.00	0.00	168,467.80	59%	115,852.20
	Euros	Requested EU funding	200,400.00	25,384.45	104,004.80			129,389.25	65%	71,010.75
Beneficiary 11	*P-M*	Work Package 1	2.00	2.00	2.50			4.50	225%	-2.50
PKT	*P-M*	Work Package 2	2.00	2.00	2.00			4.00	200%	-2.00
	P-M	Work Package 3	0.00	0.00	0.00			0.00	0%	0.00
	P-M	Work Package 4	2.00	1.00	11.00			12.00	600%	-10.00
	P-M	Work Package 5	2.00	0.00	0.00			0.00	0%	2.00
	P-M	Work Package 6	8.00	1.50	0.00			1.50	19%	6.50
	P-M	Work Package 7	3.00	2.00	0.00			2.00	67%	1.00
	P-M	Work Package 8	0.00	0.00	0.00			0.00	0%	0.00
	P-M	Work Package 9						0.00	0%	0.00
	P-M	Work Package 10						0.00	0%	0.00
	P-M	*Total*	19.00	8.50	15.50	0.00	0.00	24.00	126%	-5.00
	Euros	Personnel costs	104,500.00	46,750.00	85,250.00			132,000.00	126%	-27,500.00
	Euros	Subcontracting	0.00		0.00			0.00	0%	0.00
	Euros	Other direct costs	20,000.00	11,267.32	12,600.43			23,867.75	119%	-3,867.75
	Euros	Indirect Costs	74,700.00	34,810.39	58,710.26			93,520.65	125%	-18,820.65
	Euros	Total Costs	199,200.00	92,827.71	156,560.69	0.00	0.00	249,388.40	125%	-50,188.40
	Euros	Requested EU funding	134,400.00	67,693.34	105,884.52			173,577.86	129%	-39,177.86
Totals	*P-M*	Work Package 1	58.00	43.26	15.28	0.00	0.00	58.54	101%	-0.54
	P-M	Work Package 2	62.00	36.95	30.66	0.00	0.00	67.61	109%	-5.61
	P-M	Work Package 3	60.00	33.15	90.52	0.00	0.00	123.67	206%	-63.67
	P-M	Work Package 4	59.00	18.54	44.02	0.00	0.00	62.56	106%	-3.56
	P-M	Work Package 5	61.00	17.58	37.56	0.00	0.00	55.14	90%	5.86
	P-M	Work Package 6	88.00	5.77	81.61	0.00	0.00	87.38	99%	0.62
	P-M	Work Package 7	35.00	12.51	21.44	0.00	0.00	33.95	97%	1.05
	P-M	Work Package 8	12.00	6.50	10.18	0.00	0.00	16.68	139%	-4.68
	P-M	Work Package 9	0.00	0.00	0.00	0.00	0.00	0.00	0%	0.00
	P-M	Work Package 10	0.00	0.00	0.00	0.00	0.00	0.00	0%	0.00
	P-M	*Total*	435.00	174.26	331.27	0.00	0.00	505.53	116%	-70.53
	Euros	Personnel costs	3,060,271.00	937,927.88	1,761,019.74	0.00	0.00	2,698,947.62	88%	361,323.38
	Euros	Subcontracting	15,000.00	103.00	12,116.84	0.00	0.00	12,219.84	81%	2,780.16
	Euros	Other direct costs	266,665.50	79,391.28	176,873.95	0.00	0.00	256,265.23	96%	10,400.27
	Euros	Indirect Costs	1,627,175.90	558,957.45	1,116,142.94	0.00	0.00	1,675,100.39	103%	-47,924.49
	Euros	Total Costs	4,969,112.40	1,576,379.61	3,066,153.47	0.00	0.00	4,642,533.08	93%	326,579.32
	Euros	Requested EU funding	3,497,360.00	1,179,274.13	2,190,318.05	0.00	0.00	3,369,592.18	96%	127,767.82

10 Financial Statements — Summary Financial Report

Table 17. Project Period 1

FP7 - Grant Agreement - Annex VI - Collaborative project

Summary Financial Report - Collaborative project

Project acronym	CAPP-4-SMEs	Project nr.	314024	Reporting period from	01/12/2012	to	31/05/2014	Page	1/1

Funding scheme	CP

Beneficiary nr.	If 3rd Party, linked to beneficiary	Adjustment (Yes/No)	Organization Short Name	RTD (A) Total	RTD (A) Max EU Contribution	Demonstration (B) Total	Demonstration (B) Max EU Contribution	Management (C) Total	Management (C) Max EU Contribution	Other (D) Total	Other (D) Max EU Contribution	Total (A)+(B)+(C)+(D) Total	Total (A)+(B)+(C)+(D) Max EU Contribution	Receipts	Interest
1		No	KTH	143,762.62	107,821.97	0.00	0.00	62,133.89	62,133.89	5,514.62	5,514.62	211,411.13	175,470.48	0.00	0.00
2		No	COVUNI	257,169.98	192,877.49	0.00	0.00	0.00	0.00	16,727.68	16,727.68	273,897.66	209,605.17	0.00	0.00
3		No	LMS	253,438.67	190,079.00	0.00	0.00	0.00	0.00	6,384.00	6,384.00	259,822.67	196,463.00	0.00	0.00
4		No	CU	84,678.21	63,508.66	0.00	0.00	0.00	0.00	14,693.15	14,693.15	99,371.36	78,201.81	0.00	0.00
5		No	SAN	156,308.00	78,154.00	22,230.00	11,115.00	0.00	0.00	8,517.00	8,517.00	187,055.00	97,786.00	0.00	0.00
6		No	PROD	104,349.70	78,262.28	0.00	0.00	0.00	0.00	5,479.11	5,479.11	109,828.81	83,741.39	0.00	0.00
7		No	ICT	127,678.80	95,759.10	0.00	0.00	0.00	0.00	21,622.80	21,622.80	149,301.60	117,381.90	0.00	0.00
8		No	FT	94,977.60	71,233.20	0.00	0.00	0.00	0.00	36,064.00	36,064.00	131,041.60	107,297.20	0.00	0.00
9		No	AF	24,342.72	18,257.04	0.00	0.00	0.00	0.00	1,992.35	1,992.35	26,335.07	20,249.39	0.00	0.00
10		No	CAM	20,717.40	15,538.05	9,846.40	4,923.20	0.00	0.00	4,923.20	4,923.20	35,487.00	25,384.45	0.00	0.00
11		No	PKT	49,917.90	37,438.43	25,309.81	12,654.91	0.00	0.00	17,600.00	17,600.00	92,827.71	67,693.34	0.00	0.00
TOTAL				1,317,341.60	948,929.22	57,386.21	28,693.11	62,133.89	62,133.89	139,517.91	139,517.91	1,576,379.61	1,179,274.13	0.00	0.00

Requested EU contribution for the reporting period (in €)	1,179,274.13

Table 18. Project Period 2

FP7 - Grant Agreement - Annex VI - Collaborative project

Summary Financial Report - Collaborative project

Project acronym	CAPP-4-SMEs	Project nr.	314024	Reporting period from	01/06/2014	to	30/11/2015	Page	1/1

Funding scheme	CP

Beneficiary nr.	If 3rd Party, linked to beneficiary	Adjustment (Yes/No)	Organization Short Name	Type of activity: RTD (A)		Demonstration (B)		Management (C)		Other (D)		Total (A)+(B)+(C)+(D)			
				Total	Max EU Contribution	Total	Max EU Contribution	Total	Max EU Contribution	Total	Max EU Contribution	Total	Max EU Contribution	Receipts	Interest
1		No	KTH	629,250.40	471,937.80	103,380.43	51,690.22	107,890.27	107,890.27	30,017.07	30,017.07	870,538.17	661,535.36	0.00	0.00
2		No	COVUNI	268,505.31	201,378.98	154,447.30	77,223.65	2,814.10	2,814.10	41,869.39	41,869.39	467,636.10	323,286.12	0.00	0.00
3		No	LMS	199,073.58	149,305.19	76,933.12	38,466.56	4,000.00	4,000.00	22,636.48	22,636.48	302,643.18	214,408.23	0.00	0.00
3		Yes	LMS	3,890.37	2,917.78	0.00	0.00	0.00	0.00	10,283.97	10,283.97	14,174.34	13,201.75	0.00	0.00
4		No	CU	398,909.71	299,182.28	0.00	0.00	2,274.02	2,274.02	1,934.85	1,934.85	403,118.58	303,391.15	0.00	0.00
4		Yes	CU	4,557.68	3,418.26	0.00	0.00	0.00	0.00	0.00	0.00	4,557.68	3,418.26	0.00	0.00
5		No	SAN	41,874.80	20,937.40	168,226.12	84,113.06	0.00	0.00	8,045.74	8,045.74	218,146.66	113,096.20	0.00	0.00
6		No	PROD	40,263.79	30,197.84	52,942.99	26,471.50	0.00	0.00	20,605.85	20,605.85	113,812.63	77,275.19	0.00	0.00
7		No	ICT	34,368.74	25,776.56	44,513.93	22,256.97	0.00	0.00	32,913.88	32,913.88	111,796.55	80,947.41	0.00	0.00
8		No	FT	59,166.40	44,374.80	60,486.40	30,243.20	0.00	0.00	49,072.00	49,072.00	168,724.80	123,690.00	0.00	0.00
8		Yes	FT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9		No	AF	27,712.13	20,784.10	56,912.42	28,456.21	16,938.74	16,938.74	0.00	0.00	101,563.29	66,179.05	0.00	0.00
10		No	CAM	76,390.40	57,292.80	19,756.80	9,878.40	0.00	0.00	36,833.60	36,833.60	132,980.80	104,004.80	0.00	0.00
11		No	PKT	110,416.69	82,812.52	46,144.00	23,072.00	0.00	0.00	0.00	0.00	156,560.69	105,884.52	0.00	0.00
TOTAL				1,894,380.00	1,410,316.31	783,743.51	391,871.77	133,917.13	133,917.13	254,212.83	254,212.83	3,066,253.47	2,190,318.04	0.00	0.00

Requested EU contribution for the reporting period (in €)	2,190,318.04

11 Certificates

As requested in the Grant Agreement, only partners requesting over 375 000 euro need certificate. The audit certificate progress is organized accordingly and the hard copies are submitted to Brussels via posts along with FormCs.

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