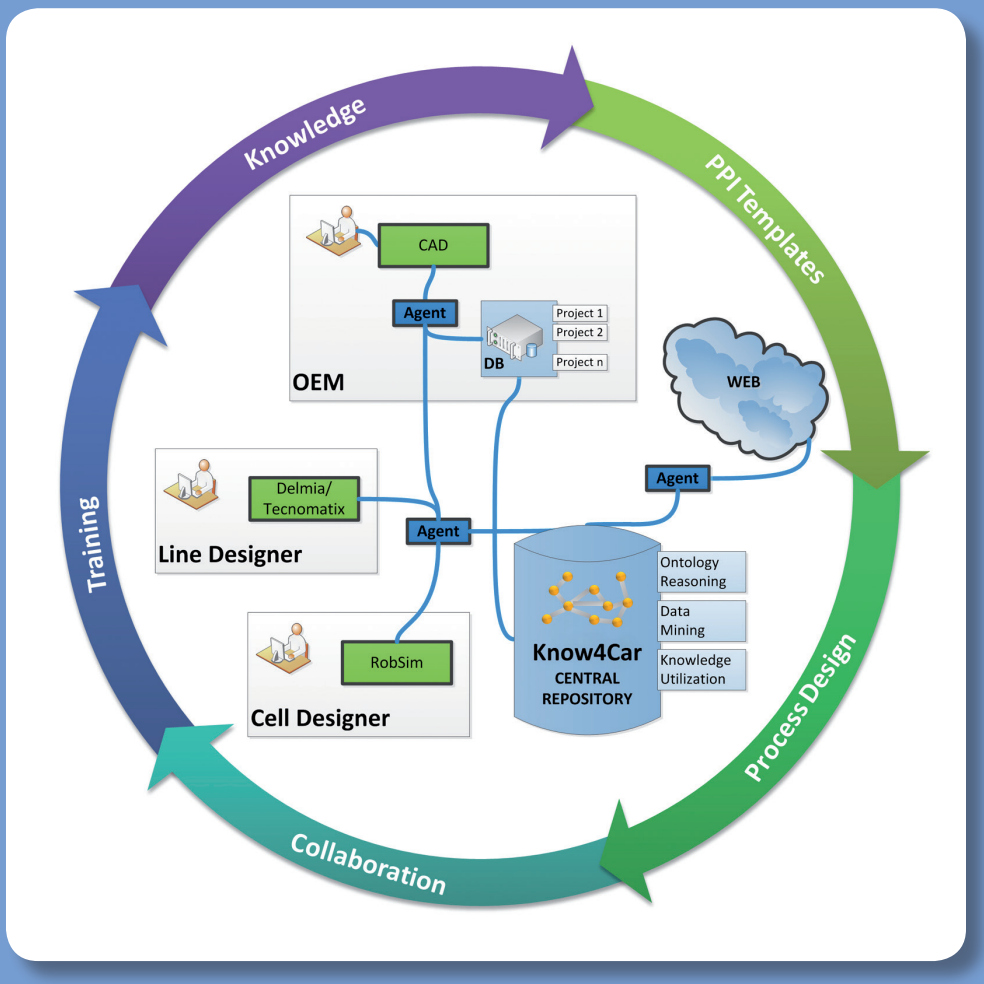
Know4Car

An Internet-based Collaborative Platform for Managing Manufacturing Knowledge



KNOW4CAR

Manufacturing is still the driving force of the European economy, contributing over 6,500 billion Euros in GDP and providing more than 30 million jobs. It covers more than 25 different industrial sectors, largely dominated by SMEs, and generates annually 1,500 billion Euros of added value. In addition, the PLM market (2009 fiscal year) is another 6.1 billion Euros. The enterprise PLM products focus on reinforcing the competitiveness of manufacturing industries.

Current digital manufacturing information and communication platforms suffer from two main shortcomings: Firstly, pro-active support for efficient collaboration across the engineering supply chain is still lacking. Secondly, today's higher level management systems are often detached from the engineering knowledge they are associated with, while product life management systems provide no link to actual performance indicators, such as cost, time, and quality parameters.

The Know4Car project attempts to make collaboration and knowledge management more effective throughout the product lifecycle, supporting on the one hand pro-active coordination of engineering and data management processes for collaborative engineering projects, on the other hand supporting the capture and the systematic organization of knowledge in the form of manufacturing templates. Within the Know4Car we develop faster, easier, error-free user interfaces for data visualization in the shop floor, this is achieved by taking advantage of recent augmented reality techniques together with real-time tracking of machines, parts and activities at the shop-floor.

CONTEXT

Production line design and development can be regarded as one of the most challenging decision-making processes, since it is affected by numerous design factors and criteria. It involves collaborative work carried out by several design engineers such as process engineers, industrial engineers, and manufacturing equipment engineers. Different models, methods, techniques and technologies have been researched and developed to aid engineers in managing the complexity of production line design and development. Within different departments and organizations these different models, methods and techniques also come in different concrete software and data implementations.

The efforts to capture, integrate and reuse the knowledge pertaining to the diverse stages across the entire product lifecycle, from product development to manufacturing to ongoing service and after-sales support are at their peak. Enterprises involved in the engineering supply chain have tried to improve the efficiency in which they can collaborate both with their suppliers (e.g., integrators, designers of tooling etc.), as well as with their customers (e.g. the OEMs) in order to reduce effort and accelerate production. Similarly, enterprises want to manage the knowledge of the product development processes in order to increase sales, achieve faster time to market and close communication with customers and employees, depending on the accuracy and accessibility of the corporate information. Without it, companies risk alienating customers and business partners, losing valuable market share to competitors.

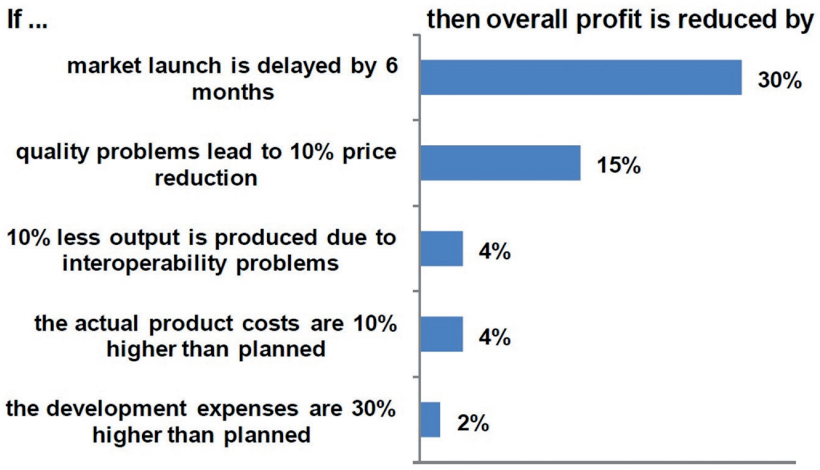


Figure 1 Effects on product profit.

Key Features

• Time required for identifying existing relevant knowledge, decreased by 60%.

• Enable faster process design by 20%.

Project website

www.know4car.eu

Community contribution to the project

6.155.000 Euro

Project start date

01 09 2011

Duration

48 months

Contract number

2011.7.4- 284602

Engineering design is one of the most critical R&D activities. Estimates suggest that more than 75% of the engineering design activity comprises reuse of previous design knowledge to address a new design problem. Specifically, in the domain of manufacturing, the design and development of a new production line constitute a very critical part of the tasks related to the product development in terms of product lead-time, cost and quality. Taking a closer look at the automotive industry, in particular, a delay of the market launch of a new car by 6 months may result in a decrease of the overall profit by 30% (Figure 1).

Being able to effectively reuse design knowledge has, therefore, great potential to dramatically improve product quality, shorten lead-time, and reduce cost.

Current digital manufacturing platforms have provided a series of tools, including CAx, PDM and PLM systems, to support engineers in their specific activities.

However, there is still a long way to go for effectively addressing collaboration support and engineering knowledge management issues:

•Today'senvironmentsarelimitedintheintegration between collaboration on process and collaboration on data, and typically focus on either process or data collaboration.

• When collaboration around data is supported, the management processes around the shared data are mostly manual and therefore laborious, such as the uploading of data to be shared, the version and access rights management.

• Process-based collaboration support is often relatively limited, for example, it does not support multiple work-items across multiple organizations.

• When extensive process-based collaboration support is provided, it typically does not encompass the management processes around the shared data as mentioned above.

• When extensive process-based collaboration support is provided, it is often decoupled from the needs of project management, such as the tracking of the execution status of the project, and the execution of measures.

• Today's PDM/PLM systems are supposed to host significant amounts of technical / engineering information, however there is often no link with actual key performance indicators, such as cost, time, and quality parameters (often residing as raw data within ERP systems): for instance, a good technical solution may sometimes be too expensive or practically impossible to implement due to quality or time constraints related to the available suppliers.

• Current UIs (User Interfaces) are often too complex and require much effort to follow and use effectively either in the shop floor or in the engineering office.

• Knowledge is often dispersed over many stakeholders and many IT systems.

• There is still a significant absence of robust tools for automatic knowledge capturing as well as for systematic reuse of knowledge, especially in the area of engineering.

• A large part of the revisions and the process iterations during the product and process development could be avoided with the use of new IT tools, focusing on taking advantage of existing knowledge and experience.

OBJECTIVES

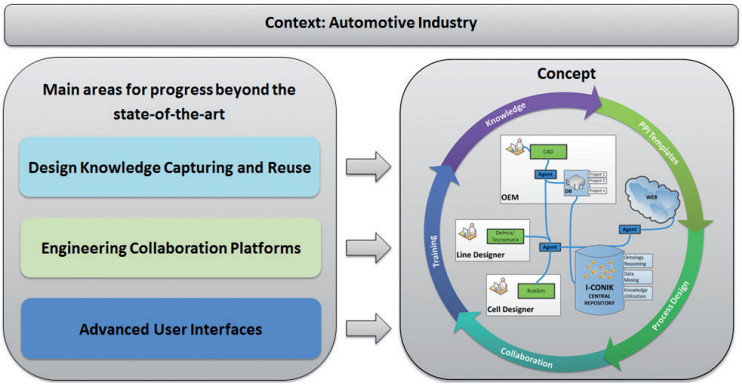


Figure 2 Know4Car main areas for progress beyond the current state-of-the-art in the area of production system design

The Know4Car platform will integrate four components that will be developed separately (Figure 2):

Manufacturing Process Knowledge

The first component of the Know4Car platform is an ontology-based database through which knowledge related to process design may be structured and organized, so that it may be managed more efficiently.

Agent-based Engineering

In various processes, engineers need autonomous agents that plan and simulate possible solutions on basis of and extending the manufacturing process knowledge. An agent-based platform will provide the infrastructure for realizing such agents, and interacting with the extended engineering component.

Extended Engineering

The Know4Car platform will support efficient collaboration across organizations. This encompasses two main aspects:
1) data sharing: enabling organizations to share relevant data over a data repository
2) process sharing: pro-active coordination of engineering and data management processes for projects across the engineering supply chain. The approach bridges project management and workflow as projects are subdivided until the level of work-items. Work-items can include data management aspects, such as uploading and downloading data to and from a repository of shared data.

Advanced UI and Training

The introduction of advanced User Interfaces and Training options within the Know4Car platform aims at streamlining the interaction and eventually the performance of the engineering teams and the available IT tools. Different types of interfaces will be available for addressing the needs originating from different groups of technical personnel. In addition, a set of Augmented-Reality (AR) techniques and tools will be employed for providing faster training and feedback options to operators and technicians.

Scientific, Economic and societal Impact

Through the Know4Car platform, the process of capturing, organizing and distributing the manufacturing knowledge will become more efficient, and will reinforce the European leadership in knowledge-driven platforms, tools, methodologies, product development and manufacturing. Furthermore, the autonomous software agents of the platform will be capable of undertaking a series of everyday activities towards accelerating the product design and manufacturing process, enabling new products to be realized with a considerably shorter time-to-production and time-to-market.

PROJECT STRUCTURE

The project work has been divided into a series of Sub-Projects (Figure 3), with each sub-project organized into work packages. The work includes the specifications and requirements (SP1), the modeling, development, integration and refinement (SP2, SP3, SP4, SP5) and the realization of all project developments (SP6). SP7 includes all dissemination and exploitation activities of the project. The management of the project is allocated in SP8. The major objective of the research work packages is to address the collaborative design and manufacturing challenges, while the focus of the realization work package is to integrate the Know4Car platform into a real environment and validate its performance. Due to the fact that the specifications and requirements, elaborated in the sub-project SP1, deliver the requirements and use cases that need to be validated at the end of the project, the approach is considered a two-way approach. The continuous communication between research and application is reflected throughout the entire project and the continuous involvement of the partners will guarantee that the scientific and technological outcomes are focused on improving manufacturing at a European level.

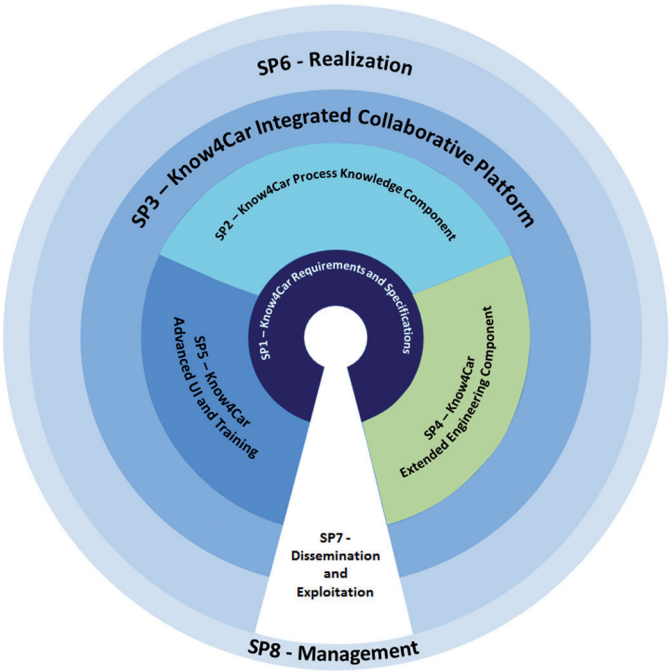


Figure 3 Work plan and work package relations.

CONSORTIUM

Know4Car involves 11 partners from 5 EU countries (Germany, Greece, Italy, Spain and Sweden), see Figure 4. Four partners represent the manufacturing and engineering world (CRF, VOLVO, IAM, EDAG), 2 are ICT providers (SAP, PDTEC), 1 is an SME Manufacturer/Supplier (BAZIGOS), while 4 partners are research institutes and universities (TECNALIA, LMS-UOP, KIT, CHALMERS). The consortium consists of well-known European industrial companies competing in the global manufacturing environment and academic partners, which have demonstrated high intellectual properties. Some of the partners have cooperated well together in past projects achieving significant success especially concerning the exploitation of the results and their application to real industrial practice. Two of the companies are SMEs (PDTEC and BAZIGOS) that are developing products of breakthrough technology. Their participation in Know-4Car provides an opportunity to promote high-tech software and develop a robust technology portfolio that will help them to become key players in the EU market. Across the EU, there are around 23 million SMEs: that is 99% of all enterprises. And SMEs account for about 100 million jobs. These SMEs have the opportunity to start a strict collaboration with the 4 research organizations with high motivation and participation in Industrial research (TECNALIA, LMS-UOP, KIT, CHALMERS), operating in different areas of Europe (West, Centre, South and North Europe).

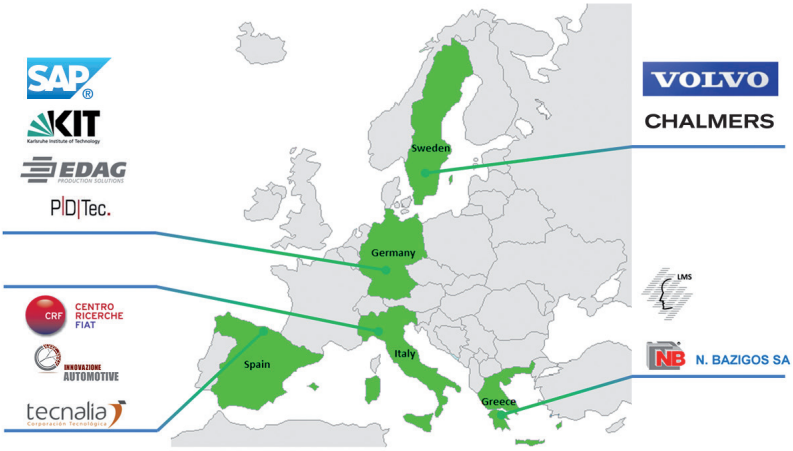


Figure 4 Know4Car involved countries (Germany, Greece, Italy, Spain and Sweden)

Know4Car brings together a team of high-level experts with very extensive experience in all the areas that it is going to address (Figure 5):

• KIT and VOLVO will contribute to the specifications and requirements for the Know4Car platform in SP1.

• SAP and LMS-UOP lead the group to design, develop and refine the Integrated Collaborative Platform in SP3.

• LMS-UOP and EDAG lead the group to design, develop and integrate the Process Knowledge Platform.

• TECNALIA, LMS-UOP, CHALMERS, CRF, PDTEC and KIT are all experts in their fields and will work together to design and develop the Advanced User Interfaces and Training framework in SP5.

• PDTEC, SAP, LMS-UOP, IAM and BAZIGOS work jointly, for the design and development of the Extended Engineering Platform in SP4.

• VOLVO, CRF, IAM, TECNALIA, EDAG, BAZIGOS and CHALMERS worked jointly together for the realization and exploitation of the technology developed in Know4Car, through SP6 and SP7.

• VOLVO, LMS-UOP, CRF and SAP are the the core partners. They represent each one industrial sector and steer the project to achieve both breakthrough innovation as well as industrial exploitable results.

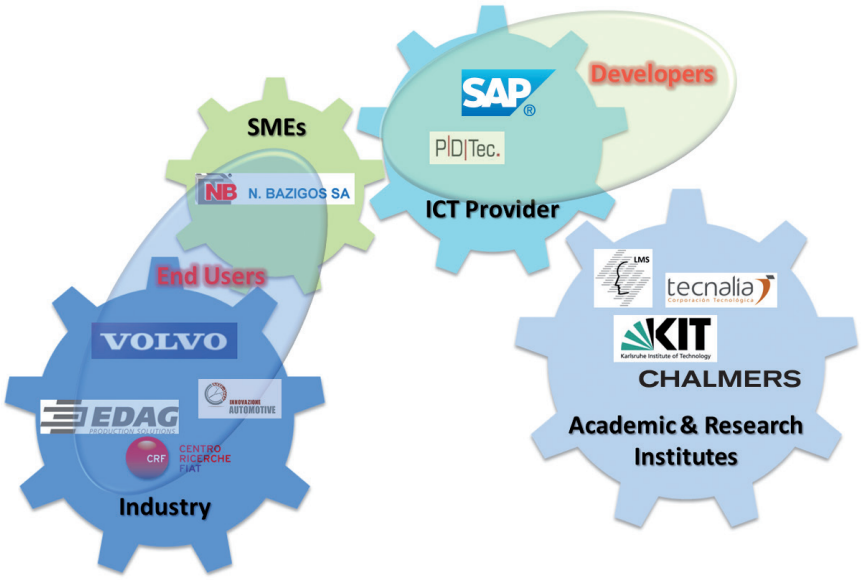


Figure 5 Know4Car structure.

USE CASES

The different use cases that was used for validation of the development of the Know-4Car platform are summarised below

Use Case 1 – Cab development

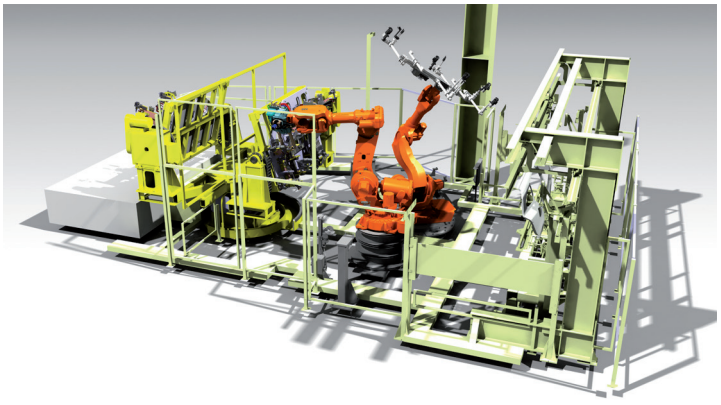
In the cab development use case a change request on the cab triggers a new project were current cab will be updated to a new version also including customized software. The use case is started in the late phase of the product development and ends with an updated production process specification. The cab update adds electronic hardware to the cab together with some design changes and software features added to the cab. This update requires an update on current production process, e.g. adding software download and software verification step. In the use case the engineering phases was demonstrated by collaboration between internal and external resources.

The use case demonstrates collaboration between two project partners using the Know4Car platform and the external Variability Agent. The chosen use case can exemplify in a down scaled complexity how the Know4Car platform can provide additional support from a management perspective providing guidance to the work and handling project data and resources in an efficient manner. Additionally, the Know4Car platform will enable effective collaboration along the project's phases.

Use Case 2 – Axle outsourcing

In the axle outsourcing use case, outsourcing request triggers a new project were a new production process will be created at a supplier. The use case is started in the phase of industrialization (production development) and ends at start of production. The use case demonstrates possible phases in the production development process where an assembly sequence is generated an assembly line balancing is performed. The use case demonstrates collaboration between four project partners using the Know4Car platform and external tools linked to the Know4Car platform e.g. assembly line balancing algorithm and the assembly sequence generation plug-in to the CAD-environment. The chosen use case exemplifies in a down scaled complexity how the Know4Car platform can provide additional support from a management perspective providing guidance to the work and handling project data and resources in an efficient manner. Additionally, the Know4Car platform will enable effective collaboration along the project's phases.

Project partners	Country
Volvo Technology AB	SE
SAP SE	DE
University of Patras	GR
Centro Ricerche Fiat SCPA	IT
Karlsruher Institut für Technologie	DE
Fundacion Tecnalia Research and Innovation	ES
PDTEC AG	DE
Innovazione Automotive e Metalmeccanica SCRL	IT
Chalmers Tekniska Högskola AB	SE
EDAG Production Solutions GmBH & Co KG	DE
N. Bazgios ABEE	GR



IMPACT

The impact of Know4Car, in respect to the work-programme, can be seen in the table below. The Know4Car integrated project apply its innovative research to the automotive industry sector, focused on automotive production/assembly and extended engineering collaboration.

Expected income from Work-programme	Know4Car contribution	Quantified impact
Reinforced European leadership in knowledge-driven platforms, tools, methodologies, product development and manufacturing.	Through the components designed in Know4Car, the capturing, organizing and distribution of manufacturing knowledge will become more efficient. Engineers will be aided towards utilizing existing knowledge in a faster and collaborative manner.	Time required for identifying existing relevant knowledge, decreased by 50%.
Accelerated product design and manufacturing, enabling new products to be realized with a considerably shorter time-to-production and time-to-market.	Know4Car deliver an advanced IT platform based on autonomous software agents that is capable of undertaking a series of everyday activities, including data search, knowledge capturing and reuse for supporting the data / knowledge exchange throughout the extended enterprise, based on the organizations' policies and rules. The platform is largely web-based and thus platform-independent, which will dramatically improve data management among users of different platforms.	Enable faster process design by 20%. Reduce the Time to Market and the associated costs by up to 20%; Reduce number of process changes by 15%.

CONTRIBUTIONS

The development of the Know4Car Platform has impact on both the European Industry and Academic Research. The projcet has resulted in both tools than can be used by the industrial partners and scientific publications. The development and evaluation, through anlysis and simulations, shows that the timed saved by using the Know4Car platform in different phases of product development can be up to 20%. Thus the Know4Car platform will support an accelerated manufacturing design process where improved collaboration and more efficient engineering tools will result in reduced time-to-production and improved reliability of the manufacturing processes.

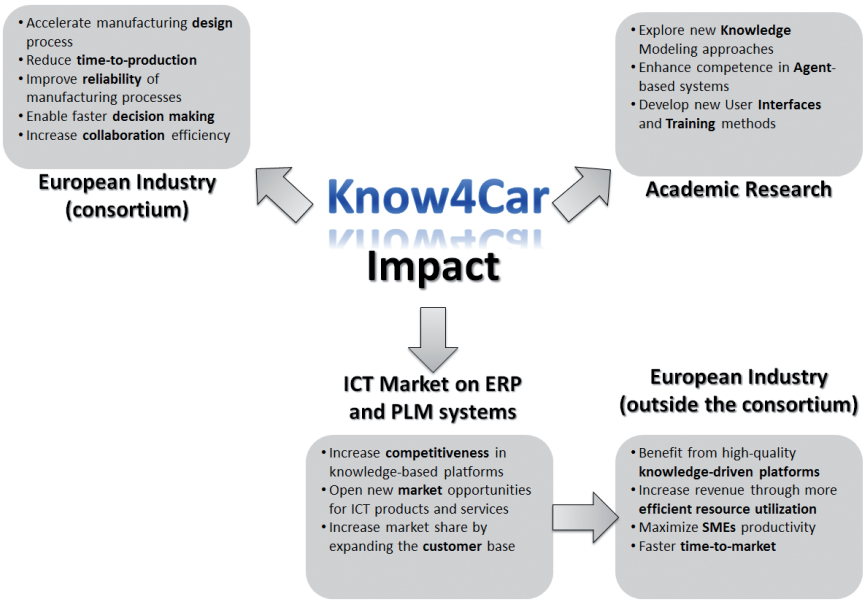


Figure 6 Contribution of Know4Car
in the European leadership in the areas of Industry, ICT market and Academic research.

KNOW4CAR PLATFORM

The Know4Car platform is mainly composed by four principal components. The four componets are (i) Agent Component with Extended Engineering Collaboration; (ii) Extended Engineering Components; (iii) Advanced User Interfaces and Training; and (iv) Knowledge base component.

In the area of agent component and extended engineering collaboration:

- PACE: PlAtform for cross-supply Chain Engineering.
- Project Execution.
- Product Cost Calculation.

In the area of extended engineering components:

- SQL bridge: Intelligent data management for seamless and robust data availability.
- Cloud-based collaboration platform: cloud-based platform for data sharing and exchange.

In the area of Augmented reality:

- AR Module for Registration.
- AR Module for Remote Assistance.
- AR Module for Visualization.
- Full AR system (3 integrated modules).
- Module for tracking of human operations for training purposes including the ability to compute key performance indicators.

In the area of the Process Knowledge Component and engineering + execution support:

- Lines Balancing and Optimization: Assembly Lines Balancing (ALB) algorithm and Discrete Event simulation (DES) agent.
- Assembly Precedence Diagram Generation tool.
- Information Extraction Agent.
- Special AR tools for training and guidance of assembly operations.
- Manufacturing Knowledge Management infrastructure including knowledge model regarding:
- Product, Process, Resource and relevant parameters (PPRE).

In Figure 7, a list of the tools developed within Know4Car is presented together with the responsible partner.

Together these tools contribute significantly to the ICT manufacturing platform by supporting collaborative development of product and manufacturing systems and by represning manufacturing related knowledge in a structured also enable the use of engineering agents that assist in the the development of new or updated manufacturing systems.

Know4Car Component	Tool	Responsible Partner
Agent component / Extended Engineering Collaboration	• PACE – PlAtform for cross-supply Chain Engineering • Project Execution • Product cost calculation	SAP
Extended Engineering Component	• SQL Bridge – Intelligent data management for a seamless and robust data availability • Cloud-based collaboration platform • Variability Management tool	PDTEC PDTEC CHALMERS
AR subsystem	• Full AR system: three integrated modules for Registration, Remote Assistance and Visualization • System for training of human operations by tracking. Computation of performance indicators of human operators	TECNALIA CHALMERS
Process Knowledge Component and engineering + execution support	• Lines Balancing and Optimization: Assembly Lines Balancing (ALB) algorithm and Discrete Event simulation (DES) agent • Assembly Precedence Diagram Generation tool • Information Extraction Agent • Special AR tools for training and guidance of assembly operations • Manufacturing Knowledge Management infrastructure including knowledge model regarding: • Product, Process, Resource and relevant parameters (PPRE)	LMS-UOP

Figure 7 The Know4Car components in the Know4Car Platform together with the responsible partners.

PUBLICATIONS

1. S. Makris, G. Pintzos, L. Rentzos and G. Chryssolouris, *Assembly support using AR technology based on automatic sequence generation*, CIRP Annals - Manufacturing Technology. Volume 62, Issue 1, 2013, Pages 9–12. http://dx.doi.org/10.1016/j.cirp.2013.03.095

2. G. Pintzos, L. Rentzos, K. Efthymiou, N. Papakostas and G. Chryssolouris, *A Knowledge based collaborative platform for the design and deployment of manufacturing systems*, 10th International Conference on Product Lifecycle Management, Nantes, France, July 2013. http://dx.doi.org/10.1007/978-3-642-41501-2_27

3. J. Provost, A.H. Ebrahimi, K. Åkesson, *Online support for shop-floor operators using body movements tracking*, 12th IFAC/IFIP/IFORS/IEA Symposium on Analysis, Design, and Evaluation of Human-Machine Systems. Las Vegas, USA, August 2013. http://dx.doi.org/10.3182/20130811-5-US-2037.00077

4. L. Rentzos, S. Papanastasiou, N. Papakostas, G. Chryssolouris, *Augmented Reality for Human-based Assembly: Using Product and Process Semantics*, 12th IFAC/IFIP/IFORS/IEA Symposium on Analysis, Design, and Evaluation of Human-Machine Systems. Las Vegas, USA, August 2013. http://dx.doi.org/10.3182/20130811-5-US-2037.00053

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6. N. Papakostas, G. Pintzos, C. Giannoulis, N. Nikolakis, G. Chryssolouris, *Multi-Criteria Assembly Line Design under Demand Uncertainty*, (DET 2014), 8th International Conference on Digital Enterprise Technology, 25-28 March, Stuttgart, Germany (2014). Procedia CIRP. Volume 25, 2014, pages 86-92. http://dx.doi.org/10.1016/j.procir.2014.10.015

7. G. Pintzos, L. Rentzos, N. Papakostas, G. Chryssolouris, *A Novel Approach for the Combined Use of AR Goggles and Mobile Devices as Communication Tools on the Shopfloor*, (DET 2014), 8th International Conference on Digital Enterprise Technology, 25-28 March, Stuttgart, Germany (2014). Procedia CIRP, Volume 25, 2014, Pages 132-137. http://dx.doi.org/10.1016/j.procir.2014.10.021

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10. Amir Hossein Ebrahimi, Pierre E.C. Johansson, Knut Åkesson. *Challenges in product family knowledge modeling and analysis: from product design to manufacturing*. Proceedings of the 6th International Workshop on Feature-Oriented Software Development. FOSD '14. Extended abstract. http://dx.doi.org/10.1145/2660190.2662954

11. Nikolaos Papakostas, George Pintzos, Christos Triantafyllou. *Computer-Aided Design Assessment of Products for End of Life Separation and Material*. CIRP Annals – Manufacturing Technology. Volume 64, Issue 1, 2015. Pages 185-188.

12. Nikolaos Papakostas, George Pintzos, Christos Giannoulis, George Chryssolouris. *An Agent-Based Collaborative Platform for the Design of Assembly Lines*. International Journal of Computer Integrated Manufacturing. Accepted. http://dx.doi.org/10.1080/0951192X.2015.1066862

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14. George Pintzos, Markos Matsas, Christos Triantafyllou, Nikolaos Papakostas, Dimitris Mourtzis, George Chryssolouris. *An integrated approach to the planning of manual assembly lines*. ASME IMECE 2015.

15. Amir Hossein Ebrahimi, Knut Åkesson, Pierre E.C. Johansson, Thomas Lezama. *Formal analysis of product variability and the affects on assembly operations*. 2015, 20th IEEE Conference on Emerging Technologies & Factory Automation (ETFA). Pp. 1-4. http://dx.doi.org/10.1109/ETFA.2015.7301619

In addition, three patents have been filed and issued during the project.

1. *Coordination execution of a collaborative business process*. Theo Dirk Meijler, Zbigniew Jerzak. Applicant name SAP, Application authority: United States Patent and Trademark Office. Filed Sep 19, 2011. Issued Mar 21, 2013.

2. *Collaborative Engineering Support*. Theo Dirk Meijler, Benjamin Heilbrunn, Olena Kutsenko. Applicant name SAP, Application number: 120585US02, Application authority: United States Patent and Trademark Office. Filed October 15, 2013. Issued April 17, 2014.

3. *Dynamic and adaptable event integration for flexible business processes*. Theo Dirk Meijler, Matthias Winkler. Applicant name SAP, Application number: 120565US01, Application authority: United States Patent and Trademark Office. Filed December 13, 2013. Issued: June 18, 2015.

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The direct beneficiaries, of the development of the platforms and frameworks, from the Know4Car project, are the industrial partners but also the applied research and software development partners. Know-4Car's aim is to design, develop and bring a more sophisticated collaboration concept into industrial practice. Considering the quality of the participants as researchers and as departments of big companies of the automotive and ICT sector, but also considering the experience in the field of manufacturing of all partners, it is forseen that Know4Car's implementations are to be exploited by the industry. The results have been applied in use case scenarios organized mostly by the industrial partners, have created the initial momentum for future exploitation. The fact that important industrial partners are included in the consortium of Know4Car is a proof of how important are the issues that will be addressed in this project and also supports the proposed solutions to these problems.

About EU Framework Programme 7

The Seventh Framework Programme (FP7) bundles all research-related EU initiatives together under a common roof, playing a crucial role in reaching the goals of growth, competitiveness and employment; along with a new Competitiveness and Innovation Framework Programme (CIP), Education and Training programmes, and Structural and Cohesion Funds for regional convergence and competitiveness. It is also a key pillar for the European Research Area (ERA).

The broad objectives of FP7 have been grouped into four categories: Cooperation, Ideas, People and Capacities. For each type of objective, there is a specific programme corresponding to the main areas of EU research policy. All specific programmes work together to promote and encourage the creation of European poles of (scientific) excellence.

EU FP7 website:
http://cordis.europa.eu/fp7

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