Automotive industry without conveyor belt and cycle – research campus ARENA2036

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1 Abstract

The main driver within the framework of integrated industry (Industrie 4.0) is a holistic and integrated resource efficiency. The production of the future is based on flexible and highly qualified staff which will operate intelligently automated processes. The future of the digital factory is distributed, decentralized and smart – and this complex production will organize itself on the base of real time information and cyber-physical systems (CPS). Complexity in this environment must not only be handled, mastered and administered but downright be operated and actively managed. In the University of Stuttgart’s cooperative research campus ARENA2036 this notion is integrated into an innovative smart research factory for lightweight automotive production.

2 The Fourth Industrial Revolution

Based on cyber-physical systems today changes in production are envisioned, that are investigated within the national German Initiative Industrie 4.0. The platform’s name says it: Industrie 4.0 is the Fourth Industrial Revolution. What will be the changes?

Fig. 1: Industrial Revolutions
(Source: Fraunhofer IPA/Audi/Auto Medienportal DFKI Bahnbilder.de)

The Fourth Industrial Revolution follows the theme „technology instead of abstinence“ and is bound to decouple growth and prosperity from resource consumption. ICT will be the core enabler.

The decentralized, cloud-based, real-time use and processing of information will evolve the factory towards the smart factory. Data will be recorded by sensors and allocated to worldwide services. Analysis results can be played back directly and thus optimize the factory via smart actuators virtually in real-time.

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Networks via digital communication (wireless or wire-bound, local or global) thus can operate the physical world. For this purpose multimodal human-machine-interfaces are being used, among others this can be touch displays, language or gesture control.

The development of cyber-physical systems went from passive RFID via active sensors and actuators as well as network-compatible intelligent components. But only the "systems of systems", the comprehension of cyber-physical systems, that are able to combine their singular capabilities intelligently to generate and offer new skills and features, can fully optimize the factory of the future. Cyber-physical systems (e.g. machines, units, orders) have an identity. They communicate with each other and their environment. They configure themselves and store information. In the end, they organize themselves in cooperation with human operators.

Fig. 2: Machines and workers communicate via internet
(Source: Fraunhofer IPA/IFF University of Stuttgart)
3 Complicatedness versus Complexity

The high diversity of technologies, the lack of dominant designs, along with increasing individualization of products and services will lead to an explosion of complexity.

Increasing external complexity, however, leads to a rising degree of decentralization and autonomy. Only this way enterprise structures can be developed that are able to operate and deal with external complexity successfully.

Complexity does not just mean a high degree of complicatedness. While complicatedness implies a high number and variety of systems, problems, algorithms or data that still can be exactly calculated and predicted, we have to learn to let go when facing complexity. Complex systems cannot be described exactly anymore which means for managers that they will not always have everything under control anymore.

Variability and ambiguity as well as uncertainty and dynamic behavior are the main characteristics of complexity. Because these factors play a major role in enterprises, they have to be managed systematically. This means, that resources – and complexity is itself a resource – have to be used appropriately so that they create value. This kind of advanced complexity management is a core competence of successful enterprises.

If the objects of a production in the future negotiate with each other, to find the best way – for instance to optimize capacity utilization – the producer will have to let go at a certain point. He or she has to hand over responsibility to the decentralized production system. It is similar to a network: Everybody can communicate and thus very robust solutions are created that are able to handle a high level of complexity.

Complexity within an enterprise (e.g. product variety) has to be adapted to the market complexity and cannot be considered independently. Internal complexity is optimal, if it corresponds exactly to external complexity. If internal complexity is too low, external complexity cannot be managed appropriately. Advanced complexity management is not effective. If internal complexity is too high, the enterprise has to make unnecessary efforts and advanced complexity management thus is not efficient.
3.1 Complexity Opens the Market to New Competitors

There is a bivalence of added-value in the automotive branch. This means that on one hand customers and governmental regulations drive the OEMs to offer more and more sustainable solutions and on the other hand personalization of mobility leads OEMs to a highly diversified product and service portfolio. The market expectation is that both offerings should be on the same price basis as traditional cars or even cheaper. So mass sustainability and mass personalization are the main drivers for future mobility concepts and will lead to a higher level of complexity.

Mass sustainability in the automotive branch will be realized through lightweight construction, electrification and smart mobility. The principle of the sharing economy is applicable to many branches and consumer goods, not only cars. The same applies to recycling: The future will be a production with a hundred percent recycling of all materials without any waste.

Mass personalization will bring an ongoing service-orientation (XaaS). Through these services, autonomous driving will be possible. Drivers will evolve to “prosumers” who are fully integrated into the multimodal production process e.g. through digital personalization e.g. via additive manufacturing.
3.2 Developments and Trends in Production and IT

For IT and production controlling in enterprises this means – as mentioned above – an ongoing service-orientation. It also leads to a de-hierarchization, an app-ization and the necessity for open standards. The further service orientation (XaaS) in all areas of life (use it but do not own it) will not stop at the digital factory. Service-oriented IT-architectures will enter in all industrial areas. The hierarchical structure of the various levels will dissolve, because new functions and applications are based on services from different areas and levels.

App-design through process owners in the value creation process, e.g. planners or replenishers will be possible, just like simulation in real-time. The use of open standards is essential here. Only this way all efficiency potential of IT-clouds can be realized.

This entails the intelligent interlinking of peripheral information carriers and information creators. Digital product-lifecycle-management, the digital factory, the digital factory management, including the orientation towards services, data clouds and manufacturing apps are resumed under the idea of Industrie 4.0, the action space of cyber-physical systems.

Future software designs will be fully operational any time soon. They are infinitely scalable and flexibly expendable. They can be functionally integrated with no significant expenditure. Unlike today, in the future they will be distributed use license packages which means leased and not sold any longer.

The smart factory as factory of the future uses these new systems as nodes of a network. Embedded systems will be IP-capable and thus enable a cross-linking between the physical production and production-IT based on web technologies, illustrated in the idea of a worldwide „internet of things, data and services“. This means that smart objects introduces decentralized intelligence to the network. This way, horizontal and hierarchical control architectures are being removed.

New factory planning methods based on digital models allow a personalized and resource efficient production – the core aim of Industrie 4.0.
The University of Stuttgart, together with Fraunhofer IPA and further partners have started the project ARENA2036 (Active Research Environment for the Next Generation of Automobiles). This research campus develops competitive production models for a flexible factory of the future in 2036, the 150th anniversary of the automobile. Lightweight material such as fiber composites can then be handled in serial production as effectively as aluminum and steel today.

Additionally, flexible production will take the place of fixed production lines and thus offer new possibilities for cooperation between robots and humans in the factory.

The BMBF funded research campus is designed as support instrument. It bundles research activities and competences from university and industry in one place. Scientists from universities, non-university research institutions and industry work under one roof. The research campus does middle and long term research on this specific topic with a special focus on application-oriented basic research. The research factory is an integration platform, meant as experimental field for new methods for the manufacturing and assembly of light weight vehicles. It continuously transfers the results also into other industries. The campus is a motor for the promotion of young scientists, further education, equal opportunity, a binding private-public partnership at eye level.
4.1 The Benefit for the Partners

ARENA2036 stands for efficient research in a new type of cooperation which constantly adapts to new developments. It focuses on the next generation of automobiles, designing agile and flexible production and intelligent lightweight construction with functional integration. The cooperative campus yields three main benefits for its partners:

- Creativity: The campus initiates new promising projects and gives access to a new project area of more than 7000 m², including an innovative office concept. Highly complex and interconnected problems can be solved here.
- Cooperation: Competitors work together on a neutral ground and carry out long-term-oriented research programs. There will be an early integration into automotive industry's technological development. Intellectual property processes will be regulated through cooperation contracts. There will be possibilities for additional public funding as well as good publicity through a condensed brand message.
- Transfer of skills: Our industry gains access to a unique scientific think tank. Mutual learning processes and information exchange under one roof and a positive public feedback will attract excellent students and scientists to work on the campus of ARENA2036.

4.2 Starting Project Research Factory

Fraunhofer IPA and the IFF and IFT of the University of Stuttgart in cooperation with Daimler, Bosch and Bär, carry out one of three starting projects: The research factory for the production of the future. It sets up a revolutionary hybrid concept for an adaptive production of lightweight automobiles using innovative robots as base.

Fig. 5: Research Factory ARENA2036 (Source: Fraunhofer IPA/Storz Medienfabrik)
Whereas today the manufacturing of automobiles is clocked and synchronized at the conveyer belt, tomorrow there will be decoupled, fully flexible and highly integrated production systems (Fig. 6 and 7).

In such a hall, assembly stations are not interlinked and can – in addition to just assembling – carry out e.g. coating tasks. Therefore, we use the term process module for defined manufacturing and assembly operations. Since many of such process modules work side by side all necessary technologies for vehicle production can be provided. The car body is early put on its wheels and equipped with the respective control and communication technology. Without needing any handling technology or main computer, such a rolling car body moves to the required stations and gives the impulse for the respective further buildup. Thus we gain a decentralized, very robust system which can quickly adapt to alterations.

Fig. 6: Today: Synchronized production of the automobile at a conveyer belt (Source: PSA)

Thus, the vehicle drives autonomously as CPS through the production modules in the assembly hall. The modules work in different cycles. This way, individualized manufacturing steps with scalable tasks can be integrated into the assembly. The vision of the fenceless factory will be reality soon, because the safe man-machine-collaboration is being pushed intensely, for instance at Fraunhofer IPA.
Fig. 7: Tomorrow: Decoupled, fully flexible and highly integrated production systems (Source Fraunhofer IPA)

5 The Industrial Revolution Goes on – a Summary

As far as production is concerned, the fourth industrial revolution focuses on the smart factory. Here, tools and methods from information and communication technology and machinery, equipment and plant engineering are combined. In Germany we are top in variant rich serial production. With the concept of integrated industry (Industrie 4.0) we provide the base for value-creating processes aiming at decoupling growth and prosperity from resource consumption. Here we also take the next step towards even more variety in coincidence with extreme productivity and even smaller lot sizes as well as the customers’ integration into the production process. The industrial revolution goes on and will change markets, technologies, branches and society.