Industry 4.0 – The Fourth Industrial Revolution

Digital Transformation

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ABSTRACT

Digital transformation in the manufacturing industry, termed Industry 4.0 has become of strategic importance in a highly competitive space. This paper talks about the digital transformation of Volvo Construction Equipment (VCE) and how it brought about a seamless physical-digital integration of humans, processes, systems and machines across geographies.

The scope was to have a common blueprint for digitalization of the production flow for 10 VCE plants spread across APAC, Europe and Americas. This was a high visibility, high impact initiative and agile methodology was the cornerstone of the program. This implementation resulted in huge improvements in the production flow in terms of cost, time and visibility.

The paper highlights the business value the program created for the organisation by leveraging the power of Industrial Internet of Things (IIOT) integrated with SAP Manufacturing Integration and Intelligence (MII). Having a robust integrated end-to-end system led to the reduction in the "Manufacturing Execution Systems" maintenance cost by more than 50%. One of the key challenges of a Just-in-Time/Just-in-Sequence production line is the dynamic nature of the shop-floor layout. This program achieved a shortened lead time for adaptation to shop-floor layout changes from 4 weeks to 3 days. Implementation of shop floor visualisation and data analytics led to improved operational efficiency.

We were one of the early adopters to implement an integrated Industrial IOT with an ERP system. In addition, a holistic approach was taken towards providing value to the Business by developing a Business Continuity Plan for all the Volvo CE plants.

INTRODUCTION

In order to be a proactive, lean and cost efficient manufacturing organisation, there are a few key objectives to be met, like having the right information available for the shop floor operations at the right time, using automation and production equipment integration for swift and smooth data flow, real-time information sharing across plant operations such as production, quality, material supply and plant maintenance. The improved visibility and traceability of manufacturing process data ensures that right decisions are made resulting in operational efficiency.

These key objectives are formalised into the six design principles of Industry 4.0 which are Interoperability, Virtualisation, Decentralisation, Real-Time Capability, Service Orientation and Modularity. [3]

While the Internet of Things (IOT) had been around for over a decade, large organisations could not exploit its potential to a substantial level as it did not address all the six design principles. This changed with the introduction of "Enterprise Manufacturing Intelligence" products in the market by the major enterprise software providers. These products served as enablers for the manufacturing organizations in their transition towards Industry 4.0 readiness, by offering integration of machines with the backend business systems coupled with real-time analytics.

This paper will take you through the journey of Volvo Construction Equipment (VCE) towards reaching the goal of being a highly adaptive manufacturer by leveraging the power of Industrial Internet of Things (IIOT) integrated with SAP Manufacturing Integration and Intelligence (MII).

DETAILS OF THE PAPER

Dawn of the Industrial era

Towards the end of the 18th century the advent of mechanization and mechanical power generation brought about the transition from manual work to the first manufacturing processes. This led to the first Industrial Revolution. By the end of the 19th century the second industrial revolution was heralded with the use of electrification which enabled mass production. The advances in computers and technology towards the end of the 20th century triggered the third revolution. This is also termed as the digital revolution. Programmable machines gave flexibility to the assembly lines. We are now in the fourth industrial revolution which encompasses cyber-physical systems, with advanced connectivity and cognitive computing. The figure 1 depicts the different stages of the industrial revolution.

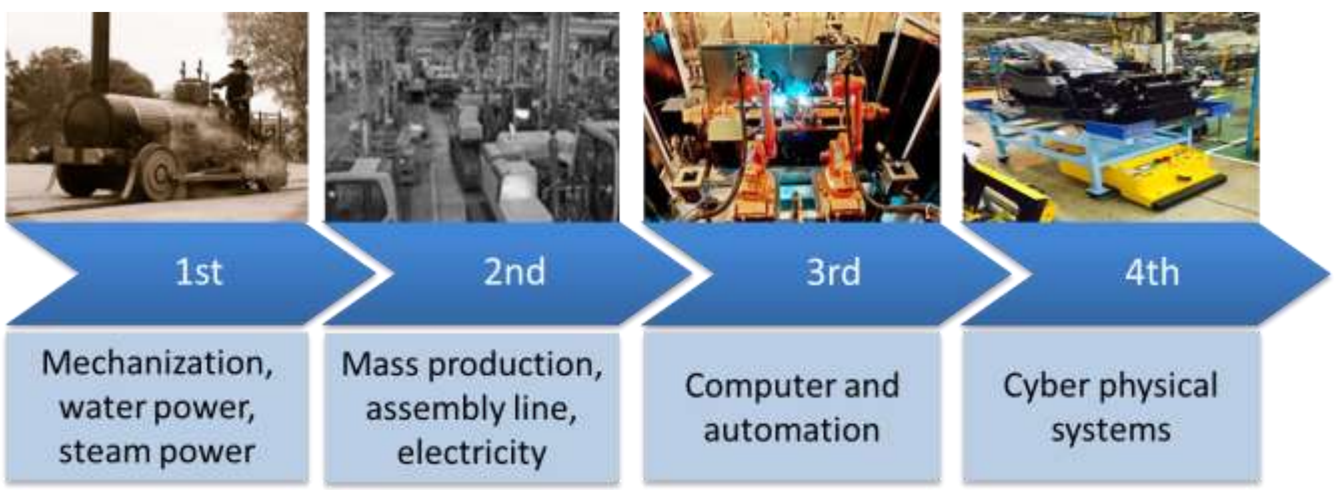

Figure 1: Industrial Revolutions 1st to 4th [2]

Throughout history Volvo Construction Equipment (VCE) has been a front runner in the industrial revolutions. VCE has sixteen plants across the world with a wide product range. With the advent of the fourth industrial revolution there was an assessment done in 2014 to check the digital manufacturing maturity of the VCE operations. It was found that there was lack of vertical integration between the shop floor operations and production equipment data. In addition, the processes were not harmonized across the plants. This resulted in low visibility and a lot of manual work which had an impact on production efficiency.

Solution Approach

We chose a two pronged approach to embark on the transformation to Industry 4.0. The first step was to harmonize the processes and ways of working across the plants. A common blueprint was established and this was set as the future way of working. The next step was to have a digital transformation of the existing systems. For this, an analysis was done on the existing enterprise manufacturing intelligence solutions. The key criteria for selection were to have a scalable and out of the box solution which could tightly integrate the manufacturing processes with business operations. SAP Manufacturing Integration and Intelligence (MII) was the solution of choice.

Change management was critical as this program would impact the existing ways of working. To ensure good buy-in from the stakeholders, a proof of concept was developed and a road show was held for the key users from all the plants. After receiving positive feedback and a go ahead, the solution implementation program was formally setup.

Implementation Methodology

Agile methodology was the cornerstone of the implementation. Depending on the size and complexity of implementation in each plant, different levels of agility were adapted as depicted in figure 2.

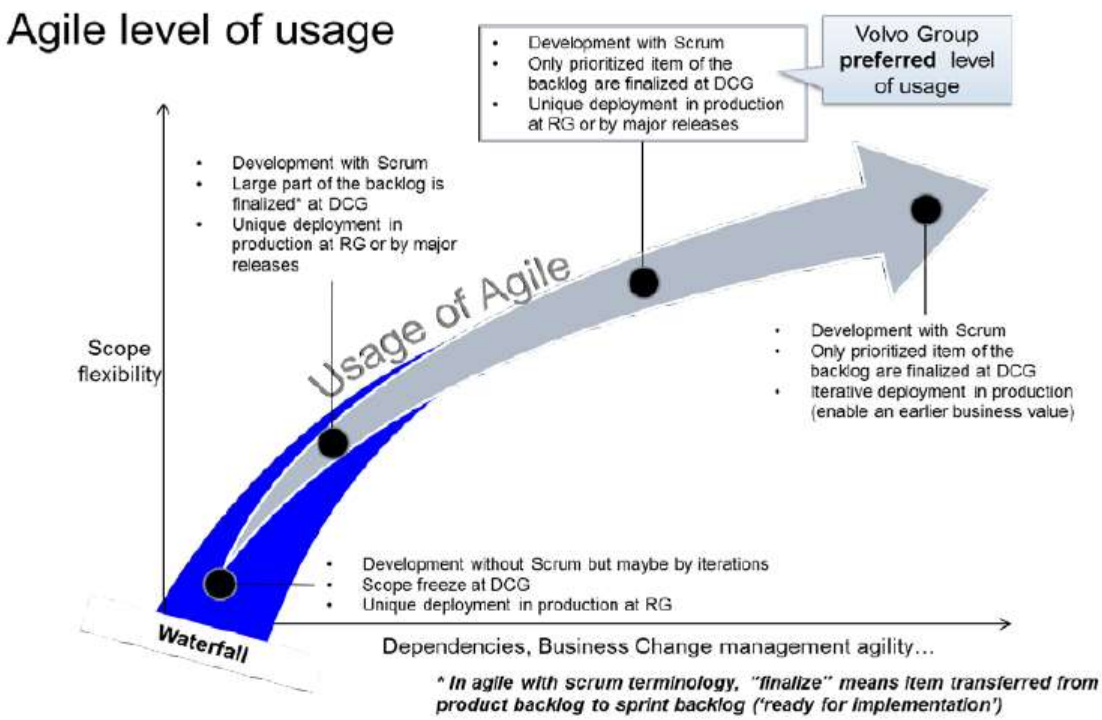

Figure 2: Gives guidance on which project execution model to use. The scope flexibility is the vertical arrow and dependencies and business change management agility is on the horizontal arrow. The dark blue area shows when to use Waterfall and the grey area shows when to use Agile. (DCG: Design Commitment Gate is the stage where the solution sign-off is committed. RG: Release Gate when the organisation is ready to receive the solution for use) [1]

In the Shippensburg (USA) plant, there was a good buy-in from the Business and the scope was fixed. There was an added limitation of a small window for completing the implementation due to dependency on other projects and key user availability. Hence, a low agility approach was chosen.

The Changwon (Korea) implementation required higher agility due to larger scope involving a high amount of machine integration, higher complexity due to process changes and longer timeline. However, there were challenges to be managed, like synchronizing sprint planning with the business key user availability windows, risk of scope creep and the scrum team not being co-located.

The MII Implementation program spanned over four years, with near sequential rollout of the solution from plant to plant. Every new rollout contributed some improvements to the common business blueprint for which impact analysis was regularly done to ensure alignment among the plants.

Solution Implementation

The solution concept was based on the parameters as shown in figure 3.

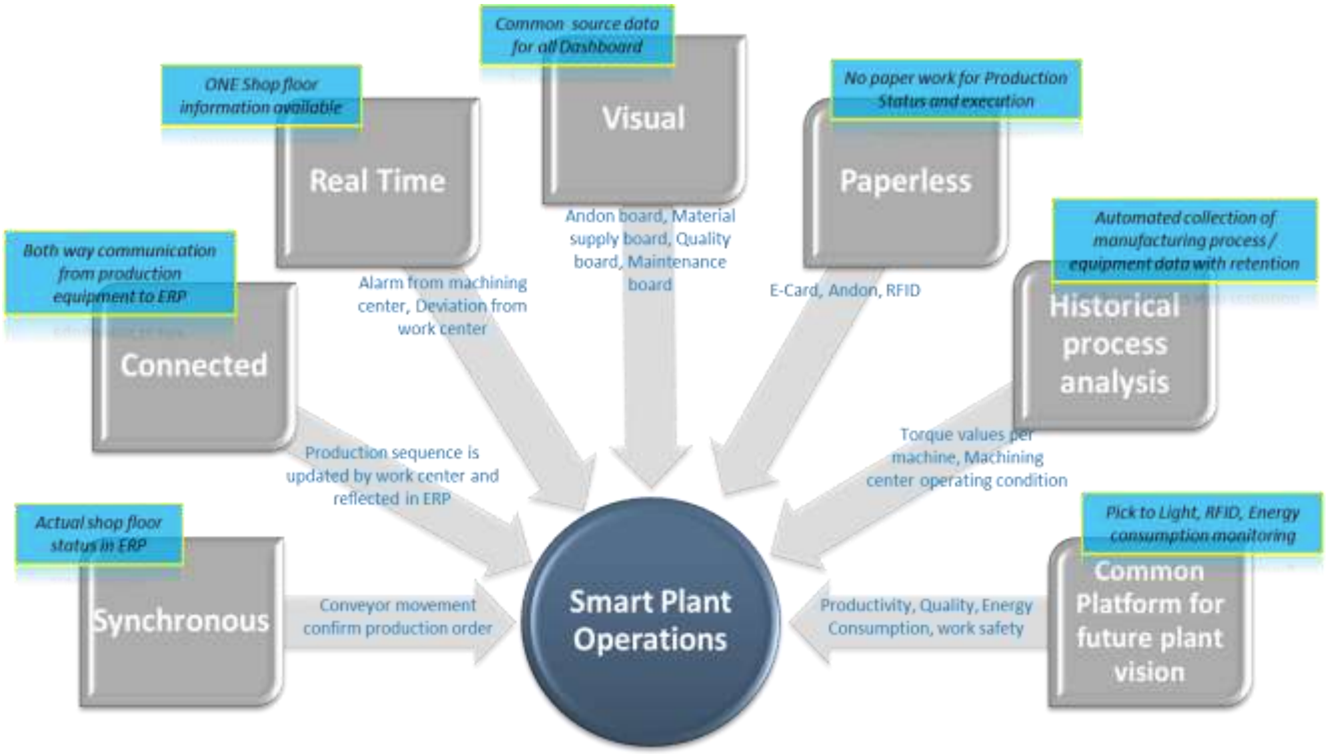

Figure 3: Overview of the solution concept parameters.

Synchronous / Connected: Shop floor operators will not need to manually report operation confirmation in the system. Instead, operation confirmation will be triggered by devices like Andon button, limit-switch or conveyor movement from each work station in real time and updated in the Enterprise Resource Planning (ERP) system.

Real-time: Shop floor operators can report a deviation message with pictures and voice, and route it to the responsible persons through notifications created in the system. This notification message switches on the Andon light. The responsible person can follow up on this deviation, record cause, action and the results. As this kind of reporting and follow-up processes are stored in the ERP, historical information can also be referred to for problem resolution by the person who detected the deviation thus avoiding production stoppage.

Visual: The various dashboard displays give shop floor visibility. For example, Warehouse will get visibility on actual production progress on time for feeding right parts to right location through the material supply board.

Paperless: Paper work is eliminated for production status and execution updates, by the implementation of Andon and Radio Frequency Identification (RFID) devices.

Historical process analysis: The shop floor machines can use the historical data of the previous operations to automatically set machining parameters for the next operation.

Common platform for future plant vision: The program will lay the foundation for end to end connectivity. The platform will continuously be adapted and integrated with new technologies of the future.

Solution Architecture

There are three levels of integration provided by MII as shown in figure 4. The Integration with machines is done using SAP Plant Connectivity (PCo) plugin with third party Open Platform Communications (OPC) Programmable Logic Controller (PLC) software. This integration facilitates bidirectional communication with the machines. The second level of integration is with the backend business system or ERP where the information is processed and stored. Finally, the intelligence layer of integration provides real-time analytics of manufacturing operations, using visualization tools and dashboards to show Key Performance Indicators (KPIs) and alerts.

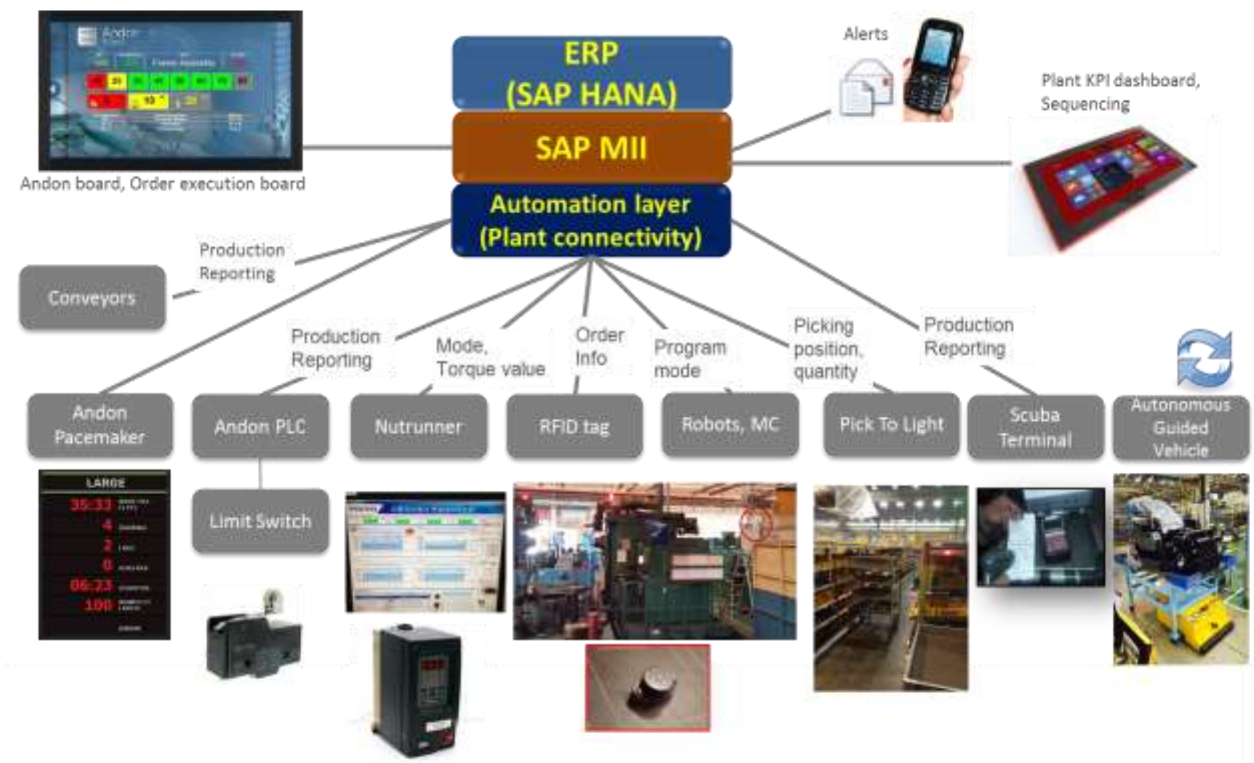

Figure 4: Solution architecture showing the various layers and interfaces. [2]

Alignment of IIOT, MES and MII

The figure 5 gives a view on how the Industrial Internet of Things (IIOT), the Manufacturing Execution System (MES) and the Manufacturing Integration and Intelligence (MII) work together in achieving the solution concept.

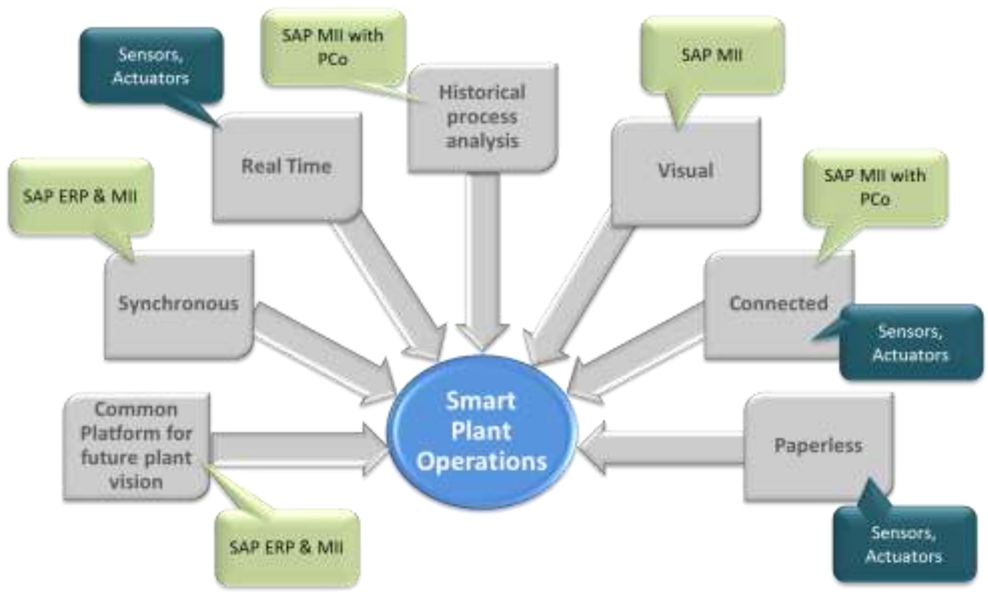

Figure 5: Alignment of the IIOT, MES and MII with the solution concept

Deployment

Once the solution concept and architecture was finalised, the pilot rollout was initiated towards the end of 2014 for three plants in Americas and Europe. The project team comprised of a good balance of Business key users and IT resources. The project execution followed the agile scrum framework. Takt based phased go-live approach was taken starting with the Fabrication lines followed by the Assembly lines. This ensured minimum operational impact during the deployment of the solution. Based on the success of the pilot, the solution was rolled out to the other VCE plants over the next three years, and the program was completed in early 2018.

Business value

The program established the platform for smart manufacturing which can be scaled progressively with the future innovations in manufacturing. One of the key challenges of a Just-in-Time/Just-in-Sequence production line is the dynamic nature of the shop-floor layout. This program achieved a shortened lead time for adaptation to shop-floor layout changes from 4 weeks to 3 days. Another key achievement was the reduction in the time taken to introduce a new product model in the production line from 2 weeks to 7 hours. There was also an improvement in First Time Through yield (FTT) and deviation reporting.

Having a robust integrated end-to-end system led to the reduction in the "Manufacturing Execution Systems" maintenance cost by more than 50%. There was a substantial improvement in the visibility of the production order progress with the implementation of shop floor visualisation and data analytics, which led to improved operational efficiency.

Critical Success Factors

Good diversity in the project team comprising of multiple nationalities, competencies and experience levels contributed to a high performance team. Takt based go-live instead of a big bang approach minimised the risk of production disruptions. Gemba (refers to the place where the value is created) approach to dealing with issues, with the presence of key users and IT users on the shop floor during the rollout bolstered the confidence of the end users. Global weekly meeting with representation from all the VCE plants ensured new changes were in line with the common blueprint expectation. Management trust on the project team and support during the deployment contributed to the smooth rollouts.

With increased automation of the production flow, the single points of failure (SPOF) increased too; hence there was a higher risk of production stoppage due to system unavailability. While most of the SPOFs were addressed individually and failover systems were put in place, the risk of production stoppage could not be eliminated fully. Hence the Business Continuity Plan (BCP) was added to the program scope and incorporated in the rollouts. There have been a few instances of system unavailability, during which the BCP has been successfully invoked to minimise impact on the production flow.

Key challenges and lessons learnt

There was limited availability of key users in some of the plants due to their involvement in other projects. The availability time windows were incorporated in the project planning to best utilise their time. Maintaining the attendance in global weekly meetings was a challenge due to the different time zones. As these meetings were critical to the success of the Solution Framework / Common Blueprint approach, a fixed recurring time slot was reserved for this meeting and maximum attendance was set as an expectation. The go-live timing coincided with high production volume for a few plants. This had to be managed diligently by ensuring the project team presence on the shop floor during the rollout, as any stoppage would have a high impact. Even though the focus was on a common blueprint, there were unique needs to be addressed for each plant. A conscious effort was made to minimise such local developments.

The MII program spanned multiple years with the team spread across time zones. Hence, there was a risk of burnout of the development team. Co-location was the preferred mode of interaction during critical phases of the program. Site level autonomy and trust among the team members was the key to sustaining the energy levels and motivation of the team members.

Business key users and plant management support is important to ensure a successful deployment. Synergy among the plants is highly beneficial for harmonizing the solution and for best practice sharing. Gemba approach during the go-live by the project team is a must to ensure a smooth rollout. Also, the IT team should have a good understanding of the Business to be able to contribute effectively. Having a strong focus on change management is critical as the end user, who is usually the operator on the shop floor, works on tight schedules and would hate disturbances and surprises.

CONCLUSION

This paper has highlighted the key aspects of an Industry 4.0 implementation for a large manufacturing organisation. A wholesome approach of harmonising the production processes along with digitalisation is suggested to maximise the benefits of IIOT with real time analytics in achieving the vision of a smart factory. The good practices shared under critical success factors and lessons learnt will be of value for similar digital transformation programs.

We were one of the early adopters to implement an integrated Industrial IOT with an ERP system. While the platform has been established for smart manufacturing, the pace of innovations in the IIOT and the analytics fields is rapid. The platform will go through continuous improvements to keep pace with the innovations.

The disruptive changes in technology and thinking will create new business models. Organisations should be swift to adapt their business strategies as per the new business models. For an organisation to maintain the competitive edge and be a leader in the industry, a flexible lean mind-set with an innovation culture is paramount.

REFERENCES

[1] Volvo Project Handbook (Figure 20).

[2] Volvo archives.

[3] Hermann, Pentek, Otto, "Design Principles for Industrie 4.0 Scenarios", 2016.