Chances and Challenges of Automation Pyramid Changes by Industrie 4.0

Masterarbeit

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You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete. - Richard Buckminster Fuller

1 Introduction and Motivation

The Automation Pyramid (AP) is a model of corporate architecture of manufacturing companies that is widely used in science and practice (cf. Walzer et al. 2008;1). Depending on the perspective, the data flows of the technical systems of the entire company are depicted. This ranges from the highest management level to monitoring units, to the executing shop floor and the production processes. With the advent of Industrie 4.0 (I4.0) technologies, such as cloud computing or Artificial Intelligence (AI), this whole design is undergoing change today and in future, for which new perspectives are needed.

Not only the rough planning of the production and lot sizes by means of an Enterprise Resource Planning System (ERP) takes place in the scope of the AP, but also the detailed planning and the creation of concrete instructions and set-up times by the Manufacturing Execution System (MES) are part of this model. The functions of the AP include the control, data collection, monitoring, troubleshooting and process adjustments of production, as well as all involved software (SW) and hardware (HW) components (cf. Siepmann 2016;47ff). The AP forms a comprehensive reference model of manufacturing. It is a representative and application-oriented structure and process model, which is characterized by both business administration and engineering facets. Therefore, the studies on the AP are considered dual according to these facets. Due to the fact that the AP existed for a long time only as a best practice, detailed and comprehensive descriptions or procedural models are missing. In the existing literature, there are either the simplest schematic constructions of the AP (cf. Siepmann 2016, Kellner & Fiege 2009, Haenisch 2017), or detailed descriptions of the individual systems at the respective level, without reference to the AP or the adjacent levels (cf. Finger et al. 2012, Louis 2009, Wellenreuther & Zastrow 2005). The lack of a general concept and corresponding research is the motivation for the first part of this thesis. Therefore, the first goal is to define a comprehensive description of the systems and the data flow at and between the individual levels. It also outlines their relationships and interfaces with adjacent areas (within the AP) in order to extend the AP into a model of information management and business computing. Based on this, the respectively associated technological components are integrated into the model and the data flow between these components is visualized holistically.

Building on these basic insights, the corresponding developments of I4.0 (from technology and business) that affect the AP are identified and described. Based on these investigations, the chances and challenges that arise for the AP are defined, validated and elaborated. These investigations constitute the second research gap to be closed in this thesis. The resulting changes are included in the overall concept of the AP. The third research gap is the extent to which the AP continues to be applicable as a model for production, or another (existing or new) model is more appropriate. Therefore, the following construct of research questions (see Figure 1) results from these investigations and research gaps and serves as a guide for the thesis:

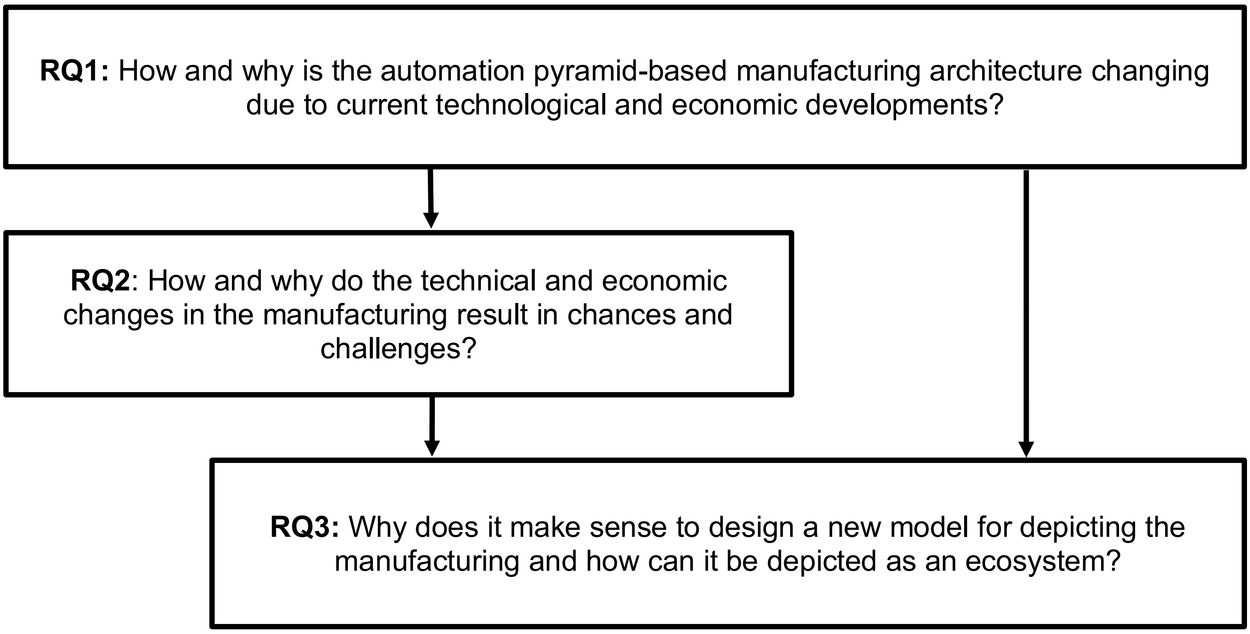

Figure 1: Research Questions.

Source: Own Representation.

These research questions serve to derive the change in production. In this thesis, as a scientific method on the one hand, the literature analysis according to “Webster and Watson” shall be used to obtain the necessary information. For this purpose, 67 subject-related papers and publications were considered. On the other hand, the reference model reconstruction according to “vom Brocke” is carried out in order to create a new reference model of manufacturing from existing models. As a third scientific method, qualitative expert interviews are conducted according to “Mayring” to validate the results and, if necessary, to adapt them to practical impressions. For this purpose, 13 experts from different AP-related companies were interviewed.

These scientific methods are first presented in Chapter 2 and the related procedure is explained. The choice of methods falls on the literature analysis, reference model reconstruction and expert interviews, in order to incorporate both scientific findings and own ideas, as well as consider assessments from practice in the thesis. In Chapter 3, a comprehensive specification of the AP (as it exists prior to I4.0) is depicted, which will be used as basis for further research. Subsequently, Chapter 4 presents the relevant changes brought by the fourth industrial revolution. This not only concerns the technological aspects, but also the requirements of the value generation chain as well as their transformation into a value generation network (cf. Diemer 2017;177). Consumer needs have also changed as a result of the opportunities offered by I4.0. Another important aspect is the global real-time availability of data as well as goods, which puts production into far-reaching change. Each of these changes has an individual impact on the individual levels of the AP, which should be comprehensively considered and described in Chapter 5. Following this, Chapter 6 looks at what models are already available to replace the AP, what functions they offer, and whether they fulfill the purpose of information management previously developed for the AP. In the same chapter, the conclusion of the research part of this thesis forms the draft of a new model.

9 Conclusion and Outlook

Through the intensive analysis of the corresponding literature, the general reference model of the AP could be transformed into a detailed and suitable reference model of information management. This detailed model includes the technological components of production from ERP down to the production processes on the shop floor, as well as the top-down stream of planning data and the bottom-up flow of production data. This model was validated by 13 independent experts from practice as a production image before I4.0. Based on this, the main technology influencing the AP was identified as wireless networks, AI, BDA, CPS, mobile devices and the internet of things and services.

By combining the aspects of the AP and of I4.0, the first research question has been answered by the fact that the new technologies entail a decentralization of production and that, above all, the hierarchical mapping of the AP is neither necessary nor reasonable. But also, the architecture regarding the individual systems in the AP changes due to the above-mentioned technologies and the economic effects. These economic challenges include, for example, globalization, changing consumer demands and ecological awareness of energy and resources. Overall, production can then be described as more independent, autonomous, flexible, decentralized, individual, precise, service-oriented and efficient. This results in various opportunities for products, production and entire companies, as well as the supply chain. These opportunities are accompanied by challenges regarding the interfaces in and between HW and SW, man and machine, as well as virtual and physical processes, and the handling and avoidance of media disruptions. Apart from the interfaces and their bridging, there are also general technological challenges, such as the standardization of HW and SW, the generation and handling of data, the construction of wireless networks and the enabling of total predictive maintenance. All these challenges must be overcome before the opportunities and benefits of technological change can be generated. Finally, the changes, chances, and challenges in this area can fully answer the second research question.

The step-by-step processing of research question 1 and research question 2 showed that the systems and architecture of the AP are subject to change. In the course of the expert interviews it became increasingly obvious that there is not only a technological challenge with a change in production and implementation of I4.0. Particularly in management and among employees, there are challenges before this implementation regarding the recognition, the willingness to invest and implement and the acceptance of new technologies from I4.0. For this reason, the third research question was to investigate to what extent a new model for mapping the data flow in a Smart Factory can be created on the basis of the AP. This model should be explicitly tailored to the lack of affinity of employees in the non-technical sector in order to raise awareness of the importance and extent of the changes and opportunities. This should go hand in hand with teaching the basic functioning and interrelationships of the systems in a production environment. Therefore, the AP was used as a starting point and specified by aspects of the reference models IIRA, RAMI 4.0 and IoT-A.

Furthermore, the technological and economic requirements identified in the course of the thesis were integrated into the model.

In summary, the changes in the AP influence the manufacturing and production as a whole is becoming a construct of increasing complexity. As a result, manufacturing companies have to deal with increasing complexity of the production process. Furthermore, companies carry out the activities from the AP to external specialized service providers as services (e.g. SW services via clouds), thus reducing the perceived complexity for the single company. This achieves a high degree of specialization and avoids inefficiencies as far as possible. The services are paid for according to the pay-per-use principle and thus minimize the TCO of the entire technology, especially with regard to provision, implementation, maintenance and servicing. In addition, this significantly reduces the (above-mentioned) increasing complexity for the individual company without having to accept losses in productivity increase. In order for such cooperation between different specialists to work, there must be a comprehensive, transparent and consistent availability of data regarding all processes and procedures in production. This data also have to be geographically independent, real-time, valid and accurate. This is the foundation on which all the chances of I4.0 are built and therefore a consistent understanding and application of information management in manufacturing companies and all adjacent areas of the AP is essential. The ATRM is a successful, albeit complex and abstract representation of the structure and sequence of this information management, which is both correct for the technical areas and understandable from a business point of view. It includes all systems involved in production and the flow of data between them. In addition, reference is made to internal cloud applications and external service providers, as well as products, consumers and (parts of) the supply chain. Their participation in production processes and planning processes is also taken into account. Therefore, the model can help to increase the understanding of the possibilities of production and I4.0 and to sensitize people with other focal points to the topic.

Because a comprehensive sensitization of the management and employees is the first step for the future conversion of technologies from I4.0 and the associated realization of all possible potentials.