informatics

MDPI

Article

The Development of an Information Technology Architecture for Automated, Agile and Versatile Companies with Ecological and Ethical Guidelines

Klaus Kuehnel [1] and Manuel Au-Yong-Oliveira [2,3,4,*]

[1] DBI Program, University of Aveiro, 3810-193 Aveiro, Portugal; klaus.kuehnel@hotmail.com
[2] INESC TEC—Institute for Systems and Computer Engineering, Technology and Science, 4200-465 Porto, Portugal
[3] GOVCOPP—The Research Unit on Governance, Competitiveness and Public Policies, 3810-193 Aveiro, Portugal
[4] Department of Economics, Management, Industrial Engineering and Tourism, University of Aveiro, 3810-193 Aveiro, Portugal
* Correspondence: mao@ua.pt

Abstract: Based on many years of experience as a management consultant in different industries and corporate structures and cultures, the motivation to use digital transformation in connection with variable corporate goals—such as fluctuating workloads, agile response to customer inquiries, and ecological and economic sustainability—results in a process or a product to be developed that intelligently adapts to market requirements and requires forward-looking leadership. Using an AI-based methodical analysis and synthesis approach, the high consumption of economic and human resources is to be continuously monitored and optimization measures initiated at an early stage. The necessary information technology with its infrastructure and architecture is the starting point to accompany the agility and changeability of corporate goals. Researching the relevant documents begins with writing the panorama or the state of knowledge on the topic. This article is about the IT infrastructure based on the requirements for an architecture and behavior that a versatile, agile company needs to accompany the constantly changing framework conditions of the market. The technology used and the available resources, including the human resources, need to be adapted as early as possible. Data now represent the most valuable asset on Earth and future industrial manufacturing systems must maximize the opportunity of data usage. Low-level data must be transformed to make them useful in supporting intelligent decision-making, for example. Furthermore, future manufacturing systems must be highly productive, adaptable, absent of error, and kind to the environment and to local communities. The all-important design should minimize the waste of material, capital, energy, and media. Herein, we discuss the fulfilling of agile customer requirements involving adaptable and modulated production processes (related to the 'agile manufacturing' and 'digital transformation' perspectives).

Keywords: agile manufacturing; manufacturing information systems; digital transformation; modulated production processes; VOSviewer

Citation: Kuehnel, K.; Au-Yong-Oliveira, M. The Development of an Information Technology Architecture for Automated, Agile and Versatile Companies with Ecological and Ethical Guidelines. *Informatics* **2022**, *9*, 37. https://doi.org/10.3390/informatics9020037

Academic Editor: Antony Bryant

Received: 15 February 2022
Accepted: 21 April 2022
Published: 24 April 2022

1. Introduction

In many companies that are currently looking for an efficient implementation of digital change, it has turned out that market developments in the course of digitization were recognized too late and that the internal structure is deficient both regarding the organization and in the "hardwired" production units. Since market developments are easy to predict in a first approximation and are mostly dictated by political currents, but also by trendsetters in business (Google, Microsoft, Amazon, Tesla, . . .), firms aiming for success should analyze these tendencies, convert them into the inherent system building blocks, and provide instructions for restructuring and adaptation [1]. Events such as the pandemic or the Ukraine war are so-called "disruptive variables" that influence the control behavior of the entire corporate organism. The significance of this research study lies in how it is possible to simulate interactions and currents in the market and, in the sense of the continuous cost-benefit ratio, the predefined, easy-to-implement measures are evaluated and quickly implemented. In a second step, this "adaptation" should be done semi-automatically. Leading research institutes, but also objective data from neutral government reports, provide very good information about the current market economy situation. A continuous analysis of the funding programs and changes in the law provide a second forward-looking input. The modularized building block typology, on the other hand, represents an economy that is reflected in the actual module parameters. The agility of the basic modules in terms of their changeability is the basic requirement. Based on the algorithms of artificial intelligence, this research study develops the set of rules that is necessary to carry out a "restructuring" without having to interrupt production [2] (which should never stop). The technology required for this, including the services required to maintain functionality, is provided in advance and is, therefore, not visible as such, but is an integral part of the concept. Self-adjustment to changing market conditions is, therefore, an integral part of daily production. Continuous market adjustment and a company that can be permanently fully utilized are the non-material and monetary advantages of this concept.

Adjusting production lines in anticipation of market growth without wasted investment requires key knowledge. In a modular system, you can change specific processes without having to change the whole system. It is more doable and does not overwhelm or overpower the company all at once. A major problem is that the customer often does not know what they want, so a design thinking approach is necessary to achieve the set goals, in so far as research and additional knowledge of the customers' problems will lead to an effective solution.

Based on many company analyses of different sizes and the first experiences in subareas of large companies in connection with the new possibilities of digital transformation (and as the recent pandemic has shown, these possibilities are also immense in society), there is a new spectrum of modern corporate management [3] based on technology, the flexibility of customer requirements, and artificial intelligence based functionality. Indeed, "the sky is the limit" in terms of penetrating enterprise digital transformation, including images and real-time comparisons of real-world situations. Maintenance has become particularly flexible in agile manufacturing operations.

Initial studies show that the control mechanisms established so far only make suboptimal use of the limited resources available [3]. Agility regarding customer inquiries and internal company structures, as well as the currently required ecological and economic sustainability measures, set the stage for the intelligent and forward-looking management of a company [3]. A quasi-autonomous management tool can be generated using AI-based methodical analyses and synthesis approaches thanks to a high level of transparency of the current value stream of the company. Crippling top-down principles are being replaced by worker-specific work instructions based on the principle of timely, online-adapted recording of current needs and the company's performance [3].

This article describes the literature review of all currently established control mechanisms for the necessary IT infrastructure, the existent problems, and barriers in the organizational implementation in the culture and hierarchy of the transformed, resource-optimized companies of the future. The ethics of automation and employee appreciation take on a constant reflective framework [4].

This article represents the consequent derivation of the requirements of the market on the adaptability and mutability inherent to the manufacturing industry.

The theoretical approach is based on the current technical possibilities within a holistic, holographic production process. Starting with the decentralized, intelligent sensors and actuators using IoT (Internet of Things) in connection with very high-performance fieldbus systems, the processing of large amounts of data with very powerful algorithms of artificial intelligence requires collaboration and dashboard systems, an agile and modular information system using a generic equipment model approach being ideal [2]. The interface definition and the current software and hardware architectures should represent a framework in terms of their flexibility, which makes functions available on distributed systems at runtime. The derivation of the internal business roles and their factory planning design represents one of the greatest innovations within this study.

The practical contribution of this article is the modularity, which allows any hardware and software components to be integrated into the framework using open-source interfaces.

The article proceeds with a background section, followed by a methodology section, and a discussion of the results, followed by the conclusions, limitations of the study, and suggestions for future research.

2. Setting the Scene

2.1. Historical Example

One of the most famous examples of the above comes from the video game industry [5]. In 2009, Nintendo was ranked fifth in BusinessWeek's list of the world's most innovative companies. This validates Nintendo's significant transformation into an innovative design powerhouse that redefined the dominant business value drivers of the video game industry [6]. However, a few years ago no analyst would have expected that Nintendo would develop in its current direction. Until the mid-1990s, the global home video game console industry was dominated by Nintendo, a Japanese manufacturer of video game hardware and software. Rivalry was marginal in this industry. This changed when another Japanese firm Sony entered the market in 1994. By offering a technologically superior console, Sony surpassed the Nintendo console of the time. This presented new challenges for Nintendo. Nintendo lost its longstanding market leadership to the newcomer. Despite several attempts to regain market leadership in the late 1990s, Nintendo remained stuck in second place. Instead of regaining market share, the opposite happened when Microsoft entered the market in 2001. Nintendo's market share plummeted dramatically because they were unable to keep up with the technological advances of their competitors [7]. The former market leader fell to third place in the industry. Video game entertainment industry analysts even recommended that Nintendo pull out of the highly competitive console market entirely to focus on software development. However, Nintendo refused to give up, but they desperately needed to regain market share. Nintendo's approach to strategy was very different from Sony's or Microsoft's. Instead of competing for core gamers, Nintendo tried to expand the market and attract new customers. For Satoru Iwata, Nintendo's president, the industry was on the wrong track to only focus on core gamers because the overall user base was shrinking, and their spending patterns were declining. How did Nintendo manage to recapture market share in the video game entertainment industry [8]? In this context, the article examines strategies for creating competitive advantages, unique selling propositions, and customer benefits. With the help of the Blue Ocean Theory, which serves as a strategy for identifying and creating new undisputed market space and new, unprecedented demand, the new product development process examines the aspect of how the selected strategic approach can be incorporated into a "state of the art" IT technology [9].

Since its inception in the early 1970's, the video game industry has evolved from a niche to a mainstream market. At the end of 2002, the US video game market was valued at approximately US $6.9 billion and the global industry at approximately US $21.2 billion. It is growing fast, at a compound annual rate in the double-digit percentage range. New consoles come in generations: The normal lifespan of a console generation is four to six years. After that time, it will be replaced by the next generation of consoles. According to demographic studies, the median age of players in 2003 averaged 29 years and the majority of players were male standing at 61 percent. This is the market the Wii faced. To Nintendo's detriment, Sony's PlayStation was an instant hit. It turned out to be a huge threat to Nintendo's market share, since in those early days Sony was already able, with a flexible competitive way of working, to change the competitive landscape with an agile console overall and uproot the established name of Nintendo.

If these examples from the past are analyzed more closely, based on the respective technological level, market leadership can be prepared at an early stage while the competition rests on the laurels of past success.

2.2. Derivation of the Knowledge for the Research Work

The motivation for this topic comes from many years of experience as an internal management consultant in a large corporation in the chemical industry and having also served as a freelance management consultant for small and medium-sized companies. If you take a closer look at companies, many of them have the same problems over and over again in different forms. All companies lag behind the demands of the market and take too long to adapt [10]. Furthermore, internal structures are not flexible enough to react in a resource-optimized manner. This creates unnecessary pressure and losses in the effective implementation of the new requirements [11].

With the new process, the result is that the market is continuously observed, the consequences are simulated using business games, and the necessary conclusions are drawn from this with regard to the most important parameters of the company such as agility, capacity, internal organizational structures, and so on.

Figure 1 shows the schematic representation of a market-oriented control system for the entire production line of a company, which is able to process the challenges of adaptable production in a timely and continuously adapted manner [3]. The market must be scanned, in the beginning, including where the competition stands, as well as customer demand (normally determined via market research efforts). Customer feedback must be sought, at the end of the cycle, and duly incorporated in the process. Key performance indicators (KPIs) will indicate the way forward, regarding business roles. The system will be modelled on company size and business culture.

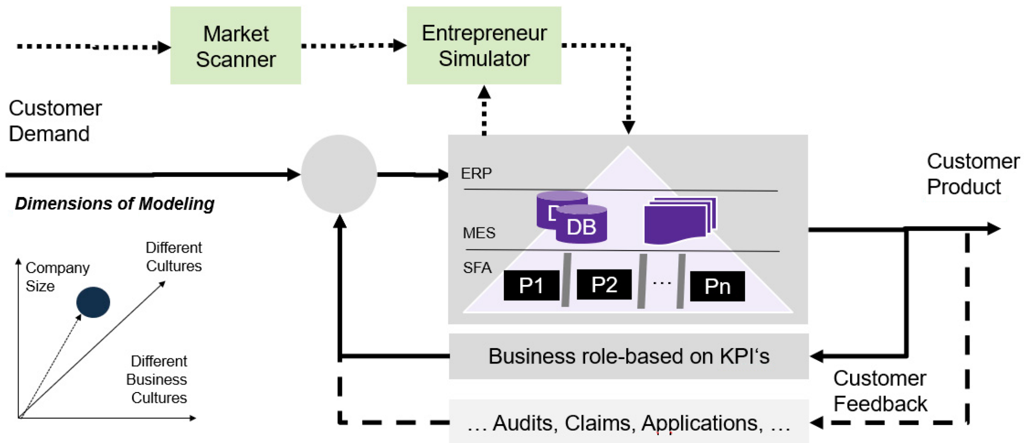

Figure 1. Model of agile, future-orientated Entrepreneur-Structure (own elaboration).

On the one hand, the current customer orders are produced and the classic key figure-based measured values of production as well as customer feedback are included in the control loop [3]. The real challenge, however, is the continuous observation of the customer-specific market. The classic methods of marketing are the first approach for looking into the future. Observing the competition (current and future) is also necessary, albeit not necessarily an indicator of change. The internal structures of the company must be set up in such a modular way that a needs-driven adjustment without significant conversion measures is necessary [12]. It is important to have the central properties of the individual modules well documented. The description of the interfaces and decoupling is of tremendous importance. The adaptability that can be achieved in this way represents the basic requirement for a quickly adaptable corporate structure [13].

3. Methodology

This article is based on observation in the field: "Seeing, hearing or sensing data relevant to the research. An observation is the identification of an occurrence of the subject being researched." [14], p. 149. Our research question regards the fulfilling of agile customer requirements in the best and most cost-effective way, including for the environment and for local communities.

We follow an earlier approach herein, namely that of early anthropology, which "treated those among whom they lived and conducted their fieldwork as subjects and approached their ethnography in a detached way, believing that they were using a scientific approach, reminiscent of a positivism" [15], p. 200. Furthermore, "Ethnographers study people in groups, who interact with one another and share the same space, whether this is at street level, within a work group, in an organisation or within a society . . . The realist ethnographer believes in objectivity, factual reporting and identifying 'true' meanings. She or he will report the situation observed through 'facts' or data about structures and processes" [15], p. 200.

The objectives of the information technology-based project described in this study were to:

(1) Increase productivity;
(2) Reduce costs with personnel, hence saving precious financial resources;
(3) Enlarge the capacity of this production area (to around double the current capacity, based on the current situation of the semiconductor industry, where there is high demand);
(4) Respond to customer requirements more efficiently;
(5) Have fewer "headaches" due to continuous change in the plant;
(6) Improve our quality to reduce waste and re-work (a great effort to further reduce costs).

The firm is already successfully using this type of forward-looking production control in the area of cleaning ultra-pure silicon base material. They were able to increase our productivity by 8% within one year, which with 270 people and a personnel cost factor of EUR 80 k/worker corresponds to a saving of almost EUR 2 million/annum.

The lead author of this research study was in charge of managing and implementing the project. Hence, the lead author acted as intrapreneur, leading innovation as product champion. Previous experience alerted the team to implementation problems, such as those involving resistance to change. There was a need to establish an urgency for change, communicating the project vision effectively and quickly establishing short-term wins to keep the motivation high. The corporate culture was seen to be ready for the challenge, also due to a powerful guiding leadership coalition, as stated by Kotter [16].

The greatest challenge at the beginning of a research project was finding and selecting the relevant articles and information in general [14,17], to support the communication of the relevant concepts. The literature review performed relied on keywords and perspectives intuitively identified by the research team as being relevant. Intuition plays an important role in qualitative research which relies on images and words rather than on numbers [14,18]. The philosophical position is interpretivist, using active reflexivity (critical self-scrutiny) [18]. A series of novel figures explaining the approach were created and are set forth. In this case regarding the fulfilling of agile customer requirements involves adaptable and modulated production processes (related, for example, to the keywords 'agile AND transformation AND manufacturing'; or related to the 'agile manufacturing transformation' perspective).

The methods and tools from the areas of creativity and innovation are very helpful here. The dynamic balance of divergent and convergent thinking can contribute to the systematic research of the literature with the help of different tools [15,19]. Thinking tools in their actual structure can be used in a targeted manner by means of visionary, diagnostic and strategic thinking, and the large field of articles found using nominated keywords. A good basis for the keyword search is created by thinking about ideas with context-oriented and/or tactical approaches with a structured approach such as COCD box, 2 × 2 matrix, SCRUM matrix, or the pairwise comparison. If tools for the divergent development of solutions, such as the prototype, proto-case, Zen-Statements, Crazy 8, PPCO, NABS, or Business Testing Canvas, are then used, you get a relatively good overview of the essential content. If the diversity is still too great, tools for convergence, such as the telescope or cluster method or classic mind mapping, are used.

The research so far has been as follows:

- Get an initial general overview with the help of the central keywords;
- Analyze the statistics in SCOPUS and use them for further filtering;
- After the second step, use the VOSviewer to sound out the direction for further areas through the significant nodes [20];
- This results in very good hits when selecting interesting and target-oriented articles;
- Read and categorize the article content for further references and continuations to confirm the research study purpose.

4. Results

Figure 2 summarizes the results of a search on Scopus using the keywords "agile AND transformation AND manufacturing." As you can see, the number of publications has grown very significantly over time. Figure 3 shows the emphasis of publications being directed towards international conferences and academic journals. Meanwhile, Figure 4 shows the most active scientific areas for the above-mentioned Scopus search. Figure 5, on the other hand, shows the countries which are leading for this particular keyword search—"agile AND transformation AND manufacturing."

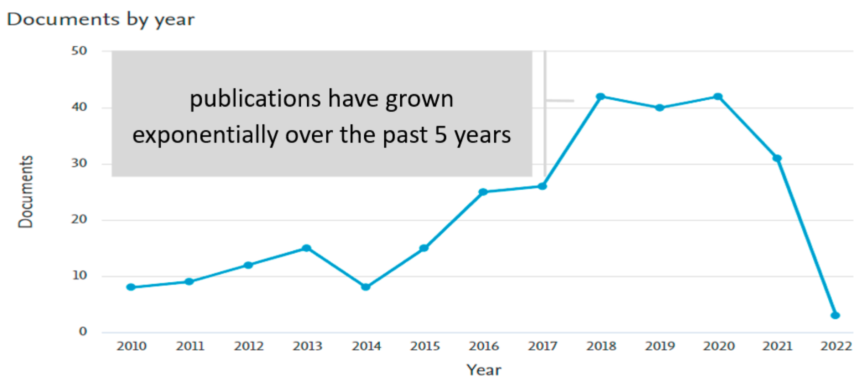

Figure 2. Agile AND transformation AND manufacturing—Documents by year.

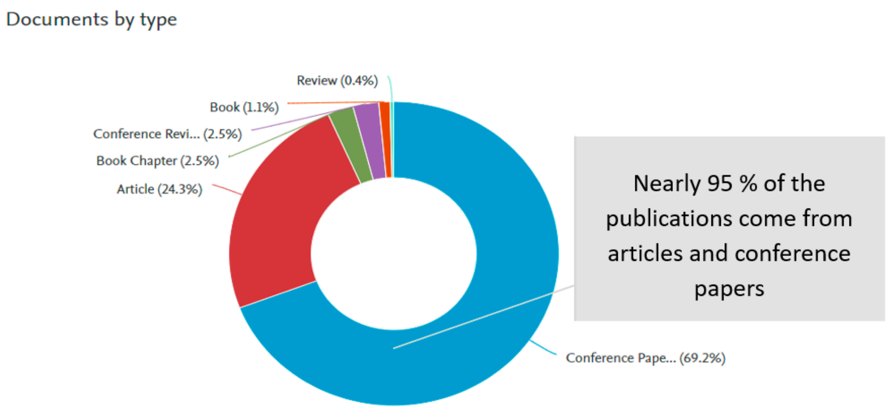

Figure 3. Agile AND transformation AND manufacturing—Documents by Type.

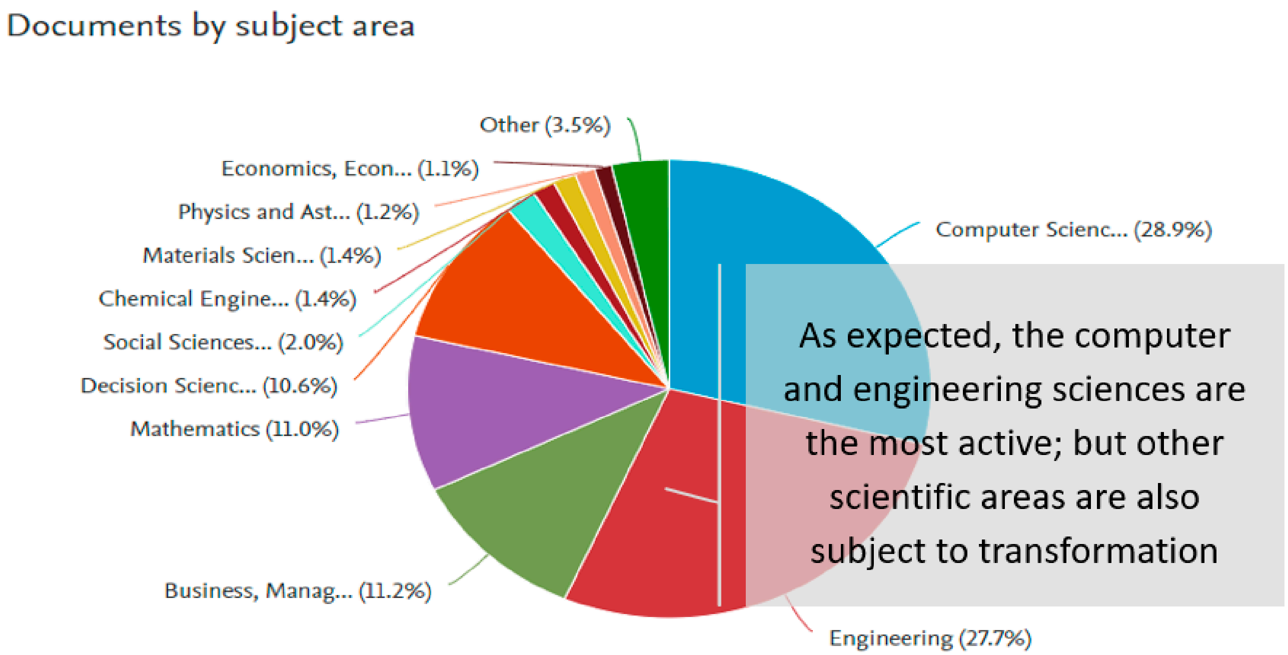

Figure 4. Agile AND transformation AND manufacturing—Documents by Subject area.

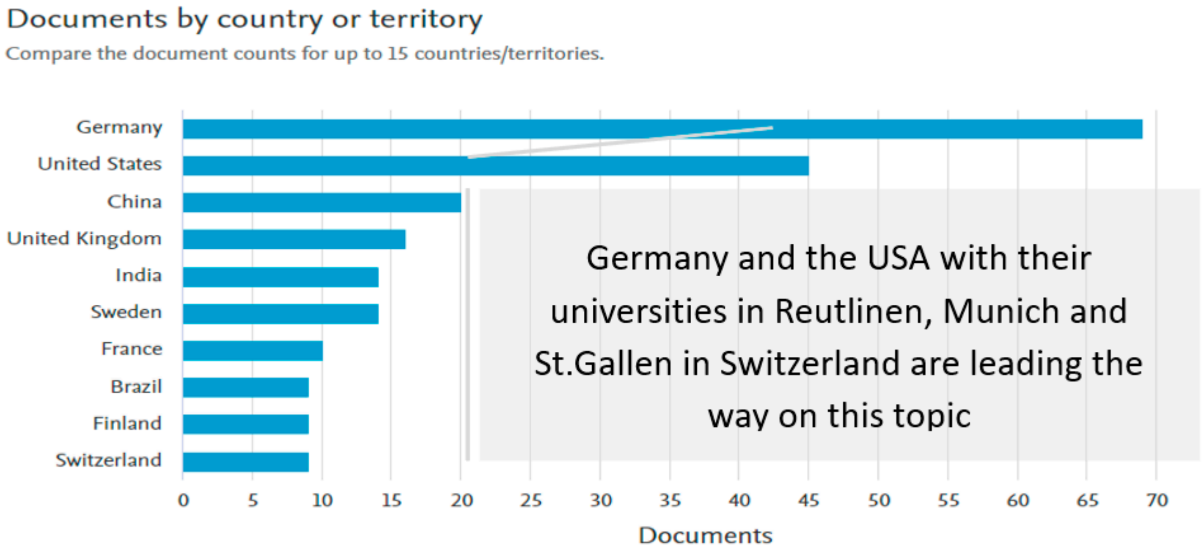

Figure 5. Agile AND transformation AND manufacturing—Documents by Country.

For example, if you take a search result from the SCOPUS database with the same keywords 'Agile' AND 'Transformation' AND 'Manufacturing' and transfer the data with the dedicated RTS filters to the visualization tool VOSviewer.exe, you get a very good quantitative overview of the existing literature. The size of the circles corresponds to the frequency of the respective key term (Figure 6). Note how the bigger circles are information systems, software design, and digital transformation which seem to be linked to lean manufacturing, lean production, and manufacturing in general, for example. Industry 4.0 also has a large circle possibly indicating that the Internet is pervasive and can be found everywhere in the firm, including on the shopfloor and in main machinery and subsequent applications.

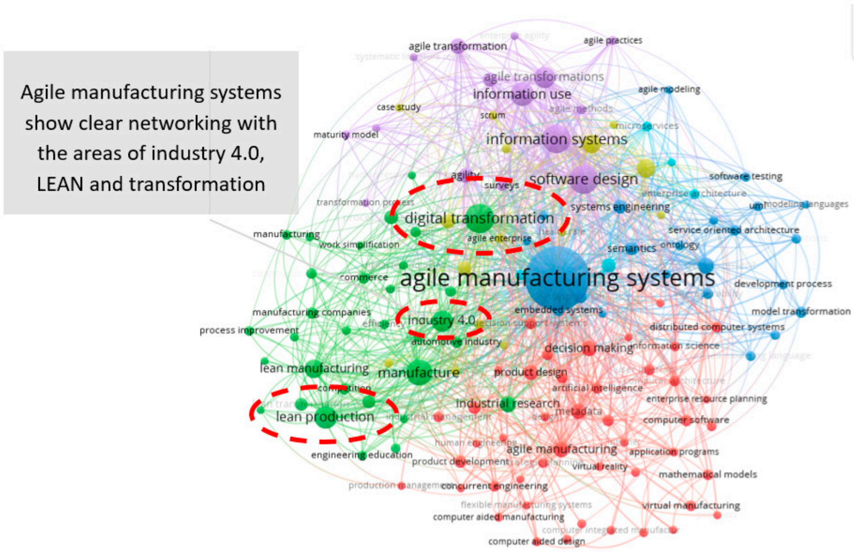

Figure 6. VOSviewer: Result—agile manufacturing transformation.

If you focus on the next larger 'galaxies' in the "orbit" of the VOSviewer, an interesting path through the next refinement levels results. With a bit of practice, one arrives relatively quickly at a convergence that describes a targeted, iterative search strategy. After two to three iteration loops, with possibly varying attributes of the graphic focus representation, the hit rate of the relevant articles and treatises increases significantly.

The different combinations of the three key terms (Agile AND transformation AND manufacturing) result in focal points that make it possible to reduce the number of relevant documents for the next iteration level and to prioritize the research articles (Figure 7). Notice that the larger circles remain unchanged, as in Figure 6. This gives us confidence that we are focusing on the right topics and areas. The "digital transformation" node creates a link to "information systems" and "software design" (Figure 8).

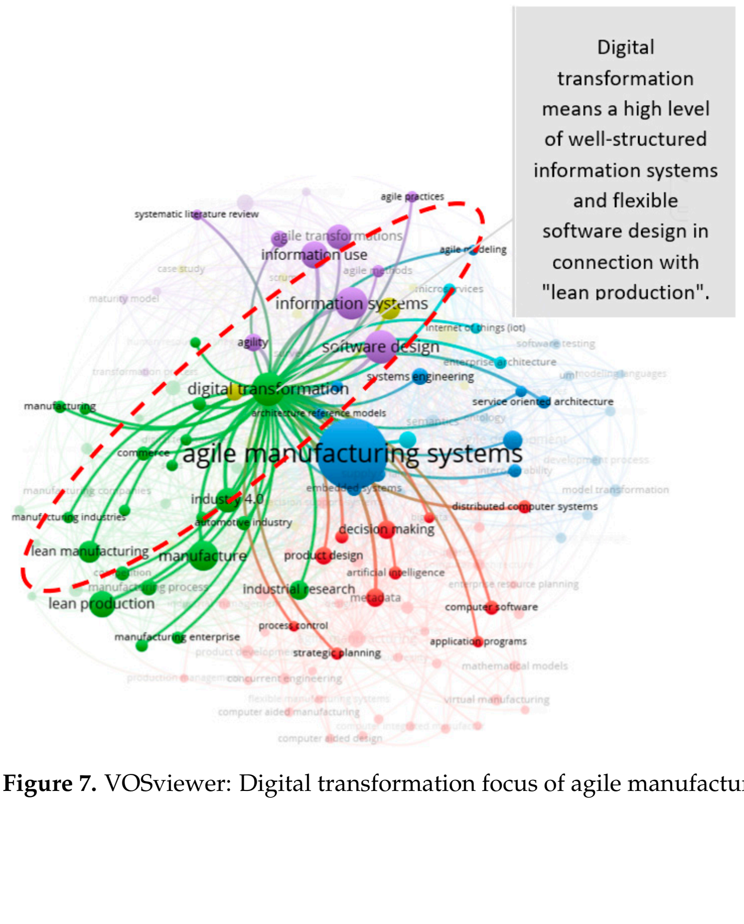

Figure 7. VOSviewer: Digital transformation focus of agile manufacturing systems.

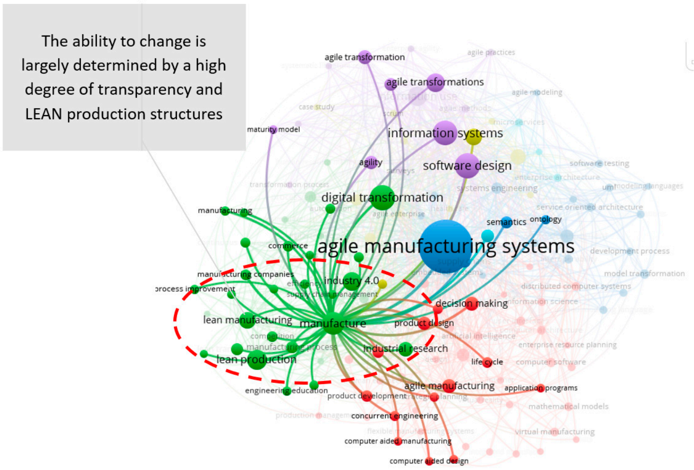

Figure 8. VOSviewer: One focus of agile manufacturing systems is digital transformation.

A systematic evaluation of the large bubbles creates a holistic picture around the central search terms. With the VOSviewer tool, an interesting structuring can be achieved by cleverly arranging the data files transferred from Scopus. In principle, the customization options of the VOS Viewer are not very numerous, but the classification of the related keywords can be converted into a color classification by this data structure. In this way, different "galaxies" are formed and visualized in a quasi-3-dimensional "keyword space" with the continuous awareness that this structuring was stopped in the background. Furthermore, by just touching key entities, the focus can be turned to the current focal point by graying out the rest of the entities and routings.

Hence, the research study is given a comprehensible history, which is of great importance for the reflexive course and creation of documents for the research process in a comprehensible manner. The subsequent assessment of the usefulness of the articles largely confirmed this approach. It should be noted here that this approach is just one of many possibilities for targeted research.

As you can easily see from Figures 9 and 10, the neighboring areas, such as the development of systems and the associated software, are related to the agility and flexibility issues.

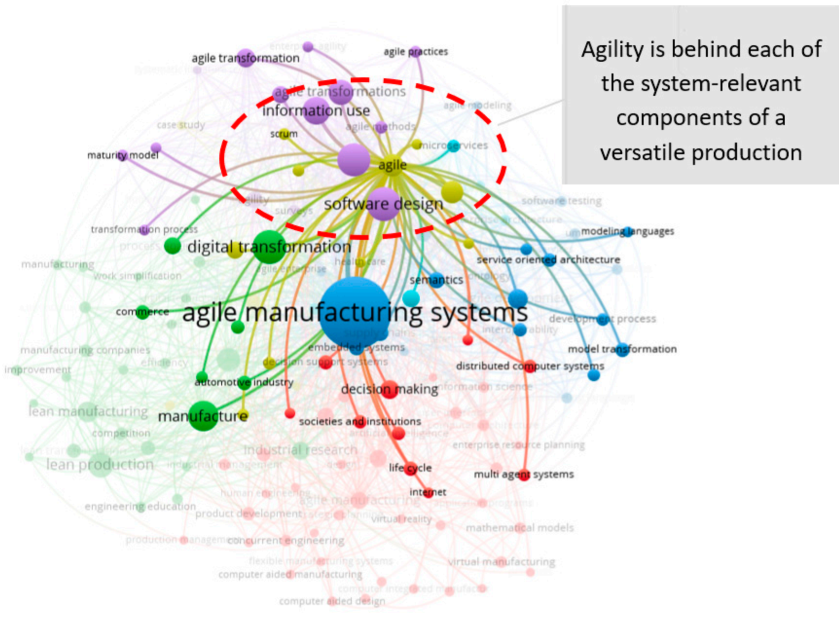

Figure 9. Focus-oriented evaluation results in 'agile hardware and software design'.

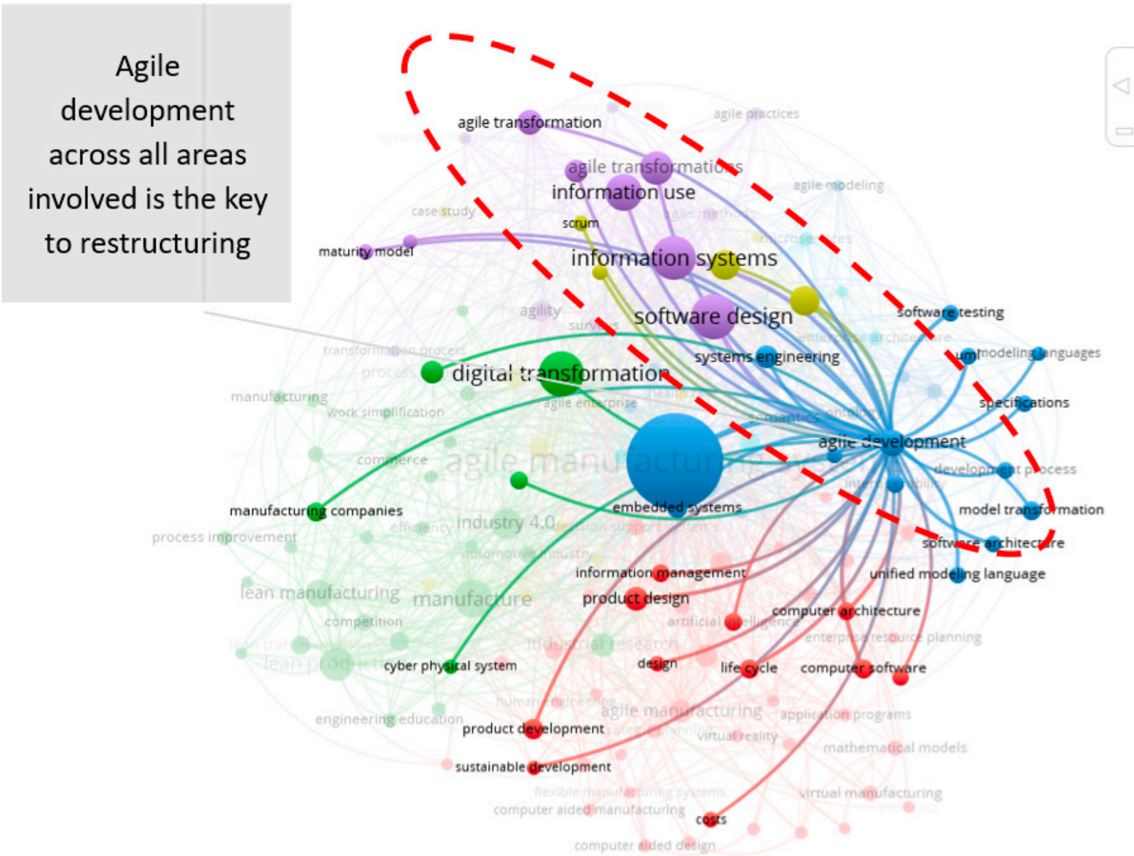

Figure 10. Focus keywords in most articles are agility in development and software design.

If you now change the search in the direction of "Advanced Production Control", very interesting "folding topics" arise with regard to the neighboring areas "Human" and "Quality", which have a significant influence on the targeted properties of production areas in terms of agility and the necessary adaptability.

Iteration Level of the Systematic Research Process

If you now take the results of the first focus search to the next Scopus search and the other key terms (advanced AND production AND control), then there is a further diversification to the very broad coverage of neighboring scientific areas. The current status and development of this topic is very clear from the Scopus overview diagrams. Figure 11 shows that an upward trend was already visible before the year 2000 and that the search has experienced rapid development in the last 5 years. The two Figures 12 and 13 show the type of distribution for the SCOPUS search: advanced AND production AND control (documents by type and by subject area). Regarding the distribution in the fields of engineering and computer science, a high technological presence prevails here (Figure 13). Figure 14 shows some leading authors and Figure 15 shows how the USA has taken the lead, followed by China and Germany.

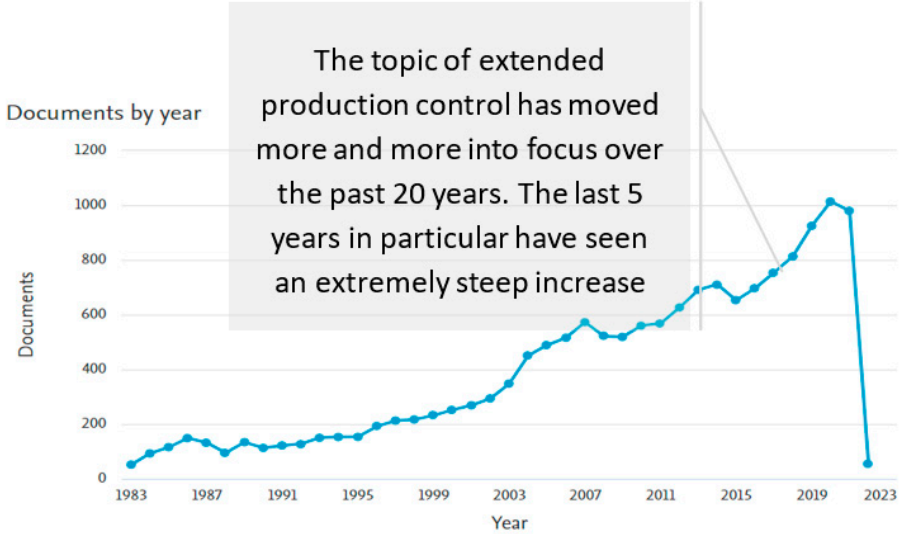

Figure 11. SCOPUS: advanced AND production AND control—Documents by year.

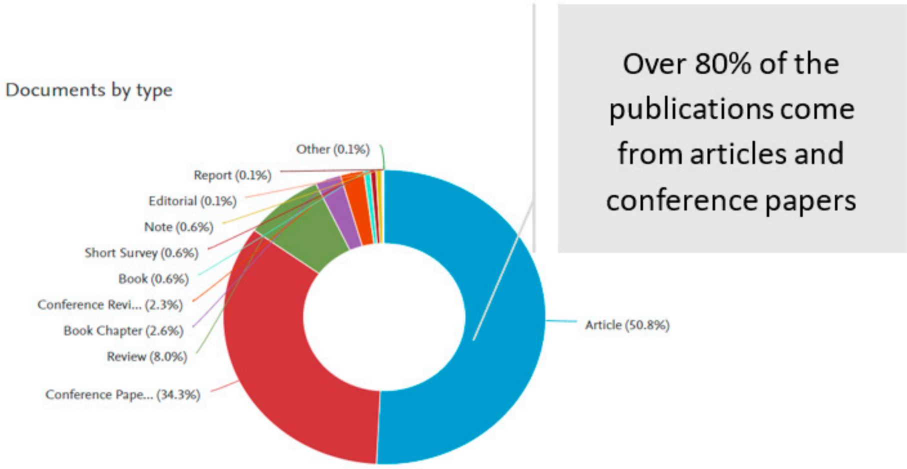

Figure 12. SCOPUS: advanced AND production AND control—Documents by Type.

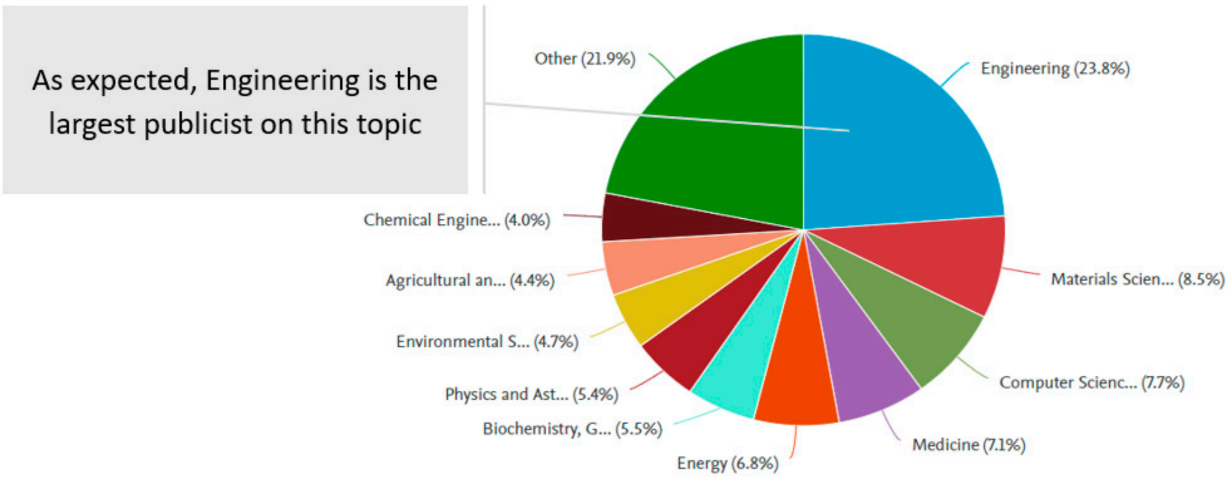

Figure 13. SCOPUS: advanced AND production AND control—Documents by subject area.

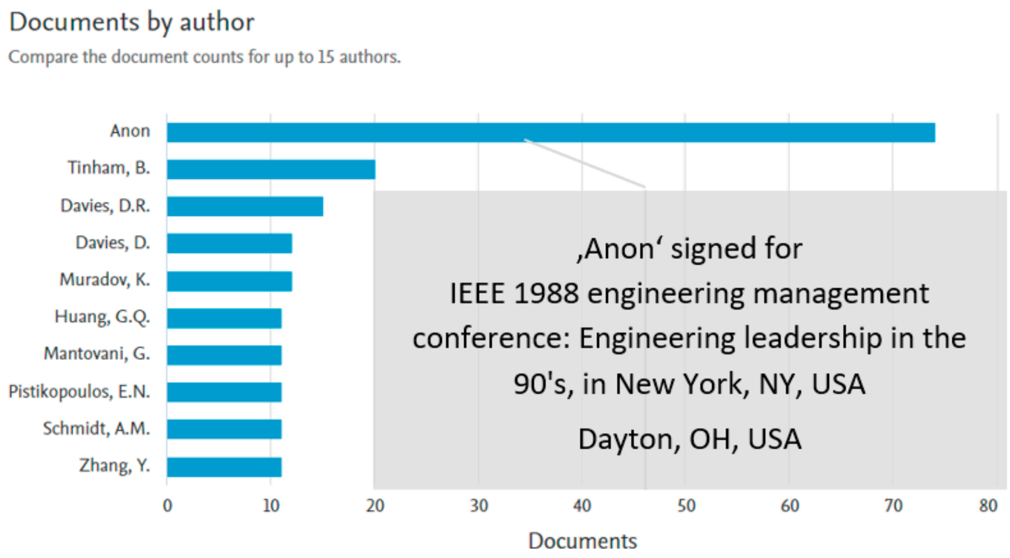

Figure 14. SCOPUS Search: advanced AND production AND control—Documents by Author.

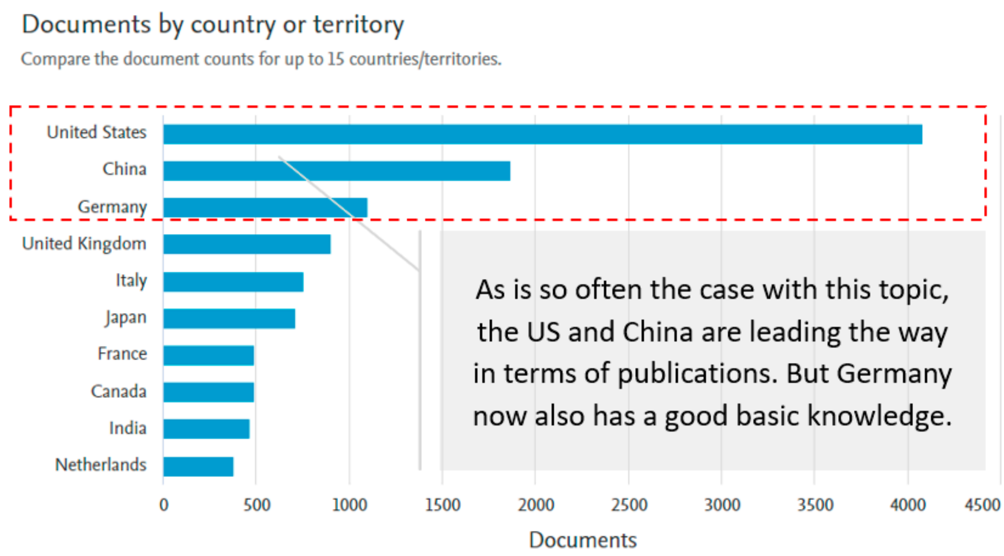

Figure 15. SCOPUS Search: advanced AND production AND control—Documents by Country.

If you take over the SCOPUS results again in the VOSviewer and proceed in a similar, empirical way when evaluating the attributes (citations, number, author evaluation, . . .), a fact-based search with high efficiency results in a very broad basis. However, this approach also harbors the risk of losing focus on entire areas. However, since each iteration step is very efficient, these can be carried out in different directions with a focus on the center of gravity and thus reducing this error well.

We then proceeded with the keyword-related search 'Advances Production Control'. This subject area must always be considered in context.

The VOSviewer overview image (Figure 16) shows that this approach is in the immediate vicinity of the much-cited Industry 4.0 subject areas (Figure 17) which clarifies this even more and brings key terms such as the IoT and the area of controlling processes and production into the context.

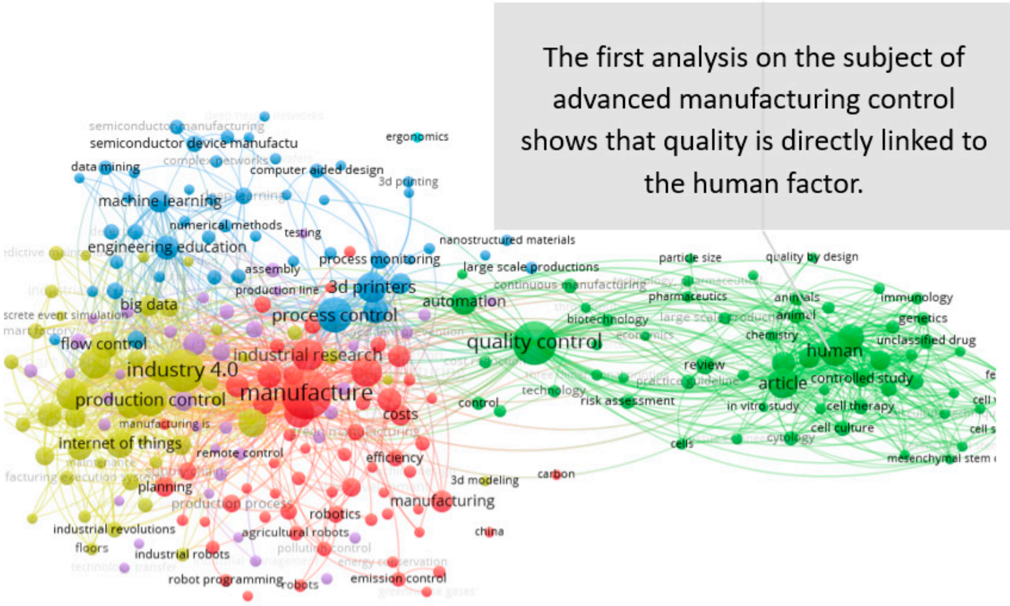

Figure 16. VOSviewer Result—advanced manufacturing control.

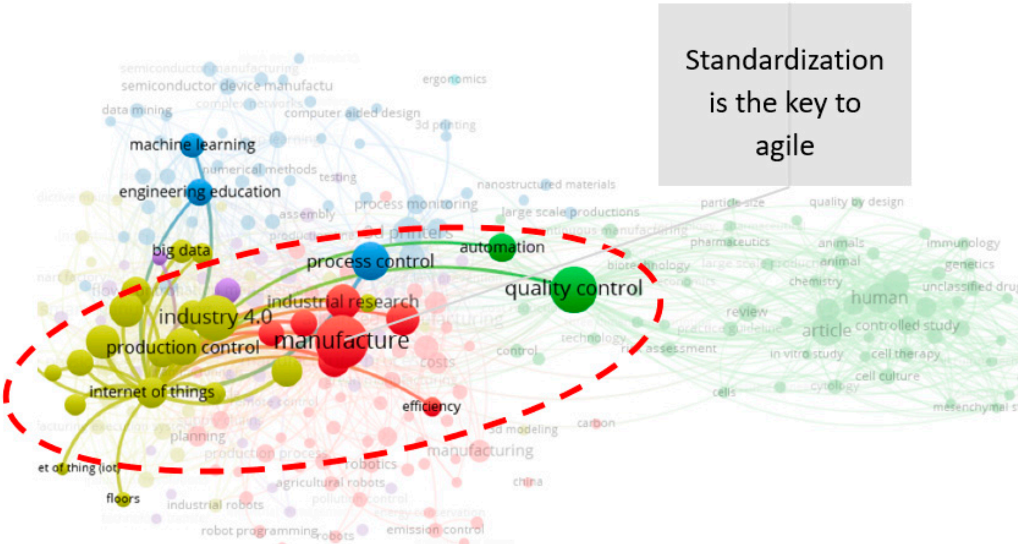

Figure 17. VOSviewer: The first look at the STANDARDIZED world of the INDUSTRY 4.0 landscape.

It is very interesting that statements such as "Human" (Figure 18) have a significant impact on the success of research via the size of the bubbles. The continuous monitoring and regulation of quality (Figure 19) also has an immense influence on the set goals of agility and flexibility.

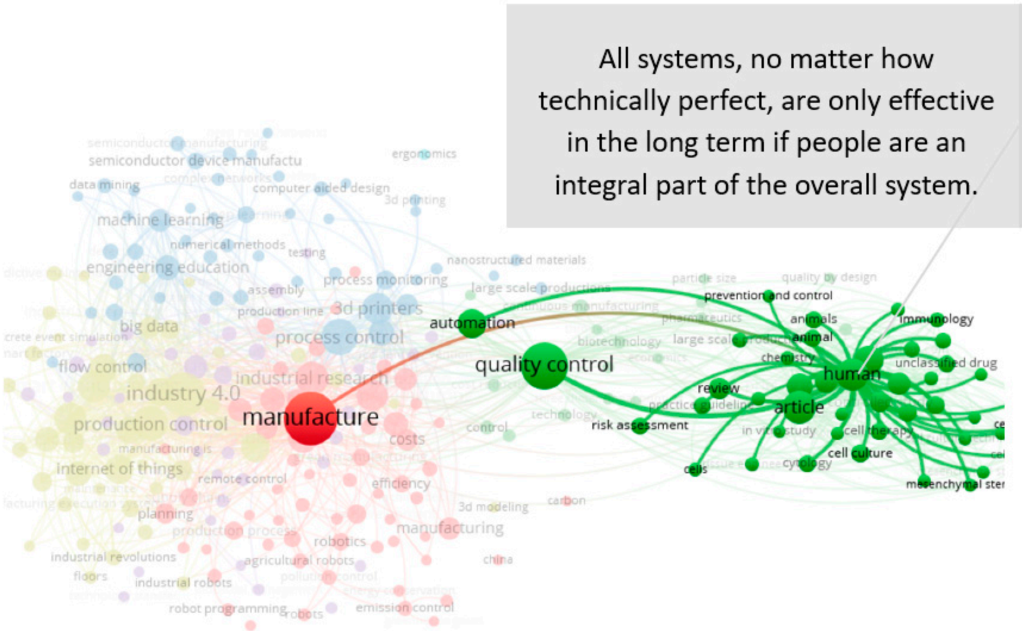

Figure 18. VOSviewer: The HUMAN focus in the context of extended production control.

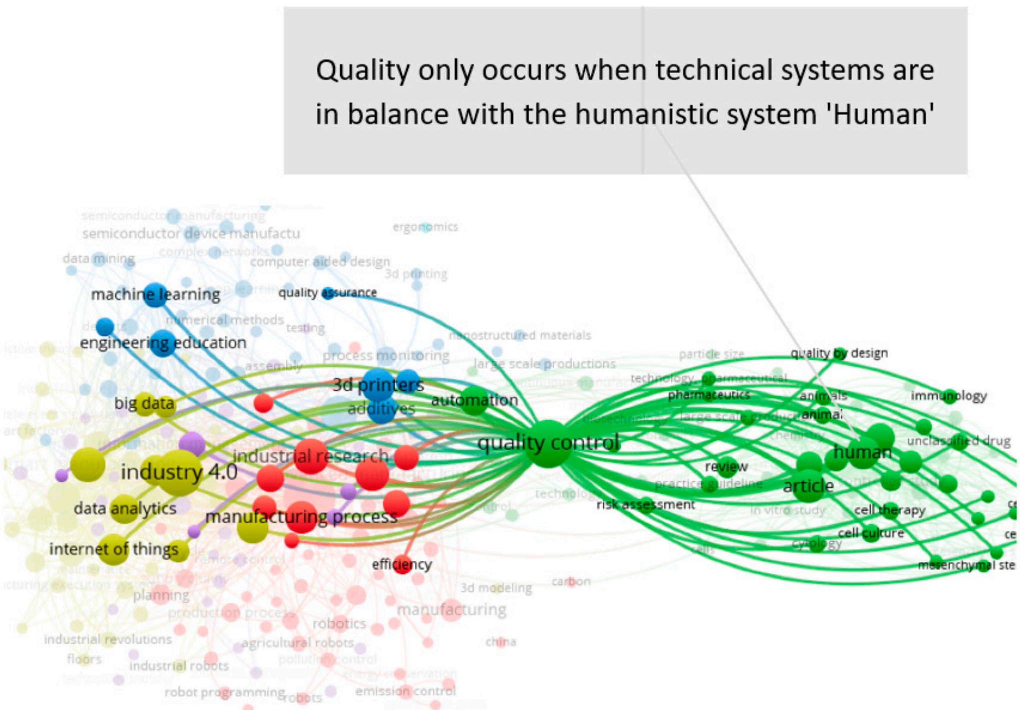

Figure 19. VOSviewer: The QUALITY focus in the context of extended production control.

If you now take out the three most heavily weighted keywords ‘digital transformation’, ‘agile development’ and ‘manufacturing technologies’ and combine them, the result shows an interesting novel combination of circles and concepts. Quality control has now gained importance (Figure 19). One is tempted to confirm the literature whereby products without quality just will not sell—there is just no room for them—hence the significance of quality control.

After working through the documents and a structured documentation of the essential statements and content of the articles, an initial assessment resulted as follows:

To facilitate competitiveness through informed and timely decisions, future manufacturing systems [21] must consider being:

- As flexible as possible in highly technological and turbulent times and able to adapt to rigorous and unpredictable market demands;
- Improve the use of overall opportunities regarding system data;
- Data from the most basic levels of the enterprise can serve as an important input to decision-makers using real-time information [22,23].

From this, for example, the idea of "*Agile Information System Architecture (AISA)*" developed.

Modern architectures are increasingly event-driven, namely, with:

- Loose coupling [23,24];
- Prototype-based information model and system [23,25];
- Services with the capability to transform structures formally [23,26].

Maintain present that the emphasis will be on:

- Integration at the factory level in a flexible way and based on data usage [27];
- Integrating devices as well as services from the top to the bottom of the enterprise [23] via hardware made to be as accessible as possible;
- Integrating novel intelligent services [10,23];
- Supporting Kaizen-type continuous change and improvement [3,10] where visualization systems and information control are paramount.

Real industrial data and industrial demonstrators are the basis for the architecture [23], collected from consultant experience and interactions gained at a prominent multinational chemical company. A first prototype based on the Microsoft Office product world already showed in a small production area how flexibly and purposefully such a system can work.

5. Discussion

5.1. Event-Driven Manufacturing Information System

Data now represent the most valuable asset on Earth and future industrial manufacturing systems must maximize the opportunity of data usage [23,28,29]. Low-level data must be transformed to make them useful to support intelligent decision-making, for example [23,30]. Furthermore, future manufacturing systems must be highly productive, adaptable, absent of error, and kind to the environment [25] and to local communities. The all-important design should minimize waste, in all its forms.

One needs to be able to easily control, reconfigure, and optimize the system, and additionally, all human intervention in manufacturing plant processes is relevant, within established limits and requirements, with a vision for the manufacturing of the future, at all levels. The need to manage data and transform them into knowledge, facilitating intelligent automated decisions, has been an important focus of late [23]. Interactions such as Industry 4.0, IoT, and cloud robotics and automation [10] are essential to the new architecture [23], however disruptive and uncomfortable they may be. As with all technological innovation [10], the benefits are not clear to all of the stakeholders involved, including device manufacturers [23]. Integrating a wide variety of devices and new services into existing systems can, therefore, be an important driver for adaptation. For example, many automotive firms have already adopted state-of the-art technology and information systems. However, significant aspects remain absent to make integration easier. Manufacturing sites often use a number of devices based on various technologies from different moments in time. Some devices originate from the time of classic plant construction and were then added as part of a continuous improvement effort, in a Kaizen-type fashion of positive and evolutionary change [10,23]. The retrofitting of legacy devices is therefore a particularly important aspect and must therefore be capable of being integrated, regardless of their capabilities or technologies. A possible and very transparent approach is the 'Agile Information System Architecture', or AISA for short. This is an innovative yet simple architecture and design pattern for the quick and easy integration of intelligent services into current factory infrastructures and processes [3,23]. AISA is based on events and services to be utilized by the information system architecture so as to integrate both such devices and services [23]. This has led to the denomination "Tweeting Factory". Simple messages (tweets) are sent from all kinds of devices and converted into knowledge recognizably at a higher level [23]. Parts of this AISA architecture are already being used in the automotive industry (one of the industries which adopts innovations the fastest), where numerous devices, such as PLCs, robots, and scanners, are brought together. The architecture was also evaluated using past and existing data. In addition, AISA simplifies changes and updates in the calculation of Key Performance Indicators (KPIs) for novel, as well as for historical, records. New services may be add-ons, such as those involving robots and the improvement of energy usage.

5.2. Agile Architectures and Point-to-Point Integration

Information and communication architectures exist in various areas of manufacturing. For example, in planning, holonic production, in quality control, or also service-oriented and cloud-based architectures [31,32].

Information is required by these architectures on the real-time performance and reactions of the manufacturing system. Albeit, not many focus on how to connect the diverse selection of devices and how to deal with change over time. Many companies have partially developed proprietary solutions based, for example, on ISA95 (ISA 2009) [23]. The solutions found are normally reliant on integrating on a point-to-point basis.

As novel functions and systems become part of the whole, they must be rapidly integrated into what already exists [23,33]. As a consultant, this is an important part of the job.

Figure 20 shows how SFA (shop floor automation) is at the lowest level of the digital transformation and how ERP (enterprise resource planning) is more high-level (ERP really transformed how customers may visualize the firm, and they are thankful for that). The Actual Production Process is again low level and senior management will be more interested in looking at Company Management KPIs (key performance indicators) which are of value to them.

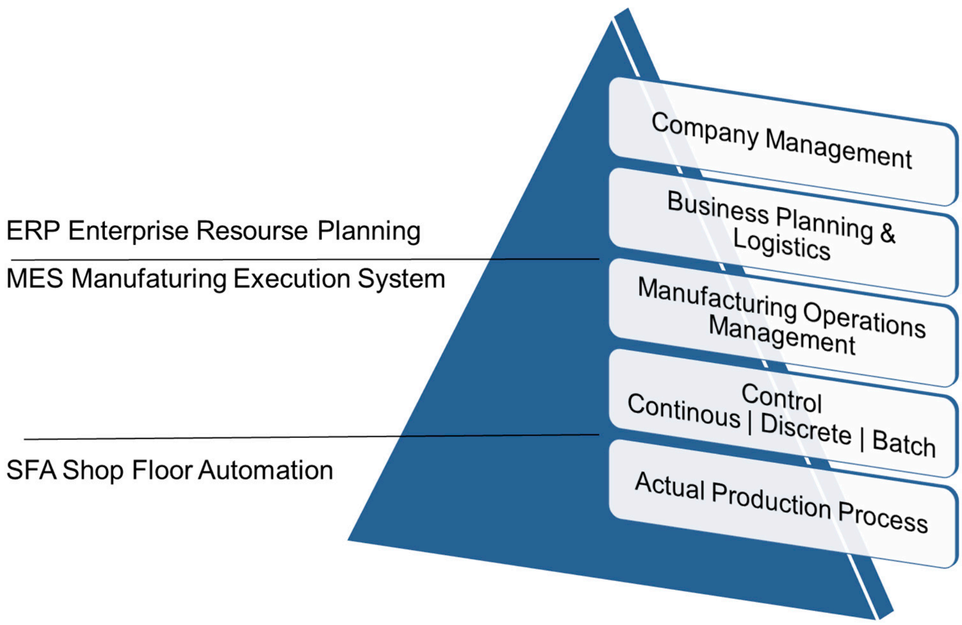

Figure 20. Functional hierarchy according to ISA95 (own elaboration).

The pattern requires the server and client to mutually recognize their existence. In a fully operational network, the increase in requests means an increase (quadratically) in the number of connections—known as the "spaghetti integration" [23]. Such complexity implies rigidity in the system, which will be difficult to upkeep. Further difficulties arise with the different layers of the ISA95 protocol—this process is called vertical integration [23]. Hence, the PLC variable structure needs to be known throughout [34]. Migration has benefitted to a large extent as service-oriented architectures (SOAs) have appeared [23,35].

5.3. Service-Oriented Architectures (SOAs)

SOA, an IT initiative, is a distributed software architecture in which standalone applications and services can be linked to other applications. For full benefits, SOA applications must be self-explanatory, and platform- and language-independent [23]. This results in a loose clutch and high flexibility. SOA has recently received a lot of attention from academia as well as industry. Advanced optimized use for business purposes can revolutionize manufacturing [36].

The further down in the hierarchy in Figure 20 that we go (from company management to the actual production process; or from Enterprise Resource Planning to Shop Floor Automation), means that there will be less time to react. Regarding the most basic level, job requirements will be in the order of milliseconds, versus at the highest level where managers will have more time, possibly days or weeks to take more strategic decisions. The devices running at the most basic level often have severely limited processing power, meaning possible complications in terms of the much desired and sought-after flexibility [23].

5.4. Architecture of the Agile Information System

With AISA, a flexible message structure for integration is used. Core components of AISA include the message bus as well as the AISA message format and their communication and service endpoints [23]. They enable creation to capture and transform events in a loosely coupled manner and turn them into actionable information.

5.5. AISA Events

A common approach to information systems is an object-oriented structure for event types, which is the new modern tendency of late. AISA, however, uses a prototype-based perspective. In contrast to object-oriented inheritance, prototypical inheritance is achieved by cloning and refining an object, as here with the events. There is no strict class hierarchy enforcing class relationships, therefore, event creation, identification, and filtering are reduced.

Thus, in the event of occurrences such as a machine status change changing its status, an event is sent with information about the change.

5.6. AISA Message Bus System

AISA uses an Enterprise Service Bus (ESB). Unnecessary Peer-to-Peer connections should be avoided. Note that messages use a message bus and that messaging is event-based [36]. Additionally:

- Publish-subscribe channel: a copy of the message is delivered to each channel subscriber [23,37];
- Message filter: requirement—move towards satisfying the demands of the message filter, or it will be discarded. Incoming messages will be filtered [23,38].

Apache ActiveMQ is used in the AISA prototype [12], but it could be replaced with any ESB-supporting data server.

Figure 21 shows a perspective of the communication architecture. Application actions (devices involved, services rendered, and external applications linked to) are connected to the ESB via the endpoints responsible for them:

- Alteration of occurrences and data/knowledge to the AISA message vision [23];
- Publishing AISA news on the adequate channels regarding the ESB [23];
- Ensuring incoming AISA messages from the ESB are filtered [23].

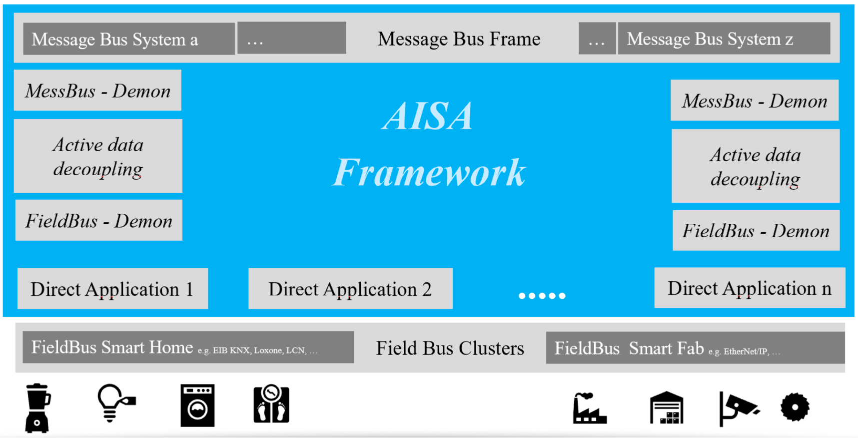

Figure 21. Overview of the AISA communication architecture (own elaboration).

In the event of an application being altered, endpoints need to be changed too, but no further changes are necessary. Additionally, the AISA message format is designed to work easily, in terms of its structure, consisting of a header and a body, or key-value map.

5.7. Business Control Systems

Now that the basic requirements for the SFA shop floor automation in terms of agility and changeability have been examined and provided with solution approaches, the next two levels of the MES manufacturing execution system and ERP enterprise resource planning are to be focused on in relevant articles. While the MES level is used for compression, storage, and processing, the order, storage, and global control functions are located in the ERP layer [39]. The concept of extended production control now represents the first approach in this research area.

Using the example of reporting, the dimensions and responsibilities of the different levels of information become very clear. Figure 22 shows how data may trigger alarms, visible in the control room, leading to the checking of lists and the sending of messages, if necessary, and ultimately leading to dashboard changes when the priority exists. Especially relevant are shift changes, which occur several times per day. Note how there is a pyramid which exemplifies the different hierarchical levels in the firm.

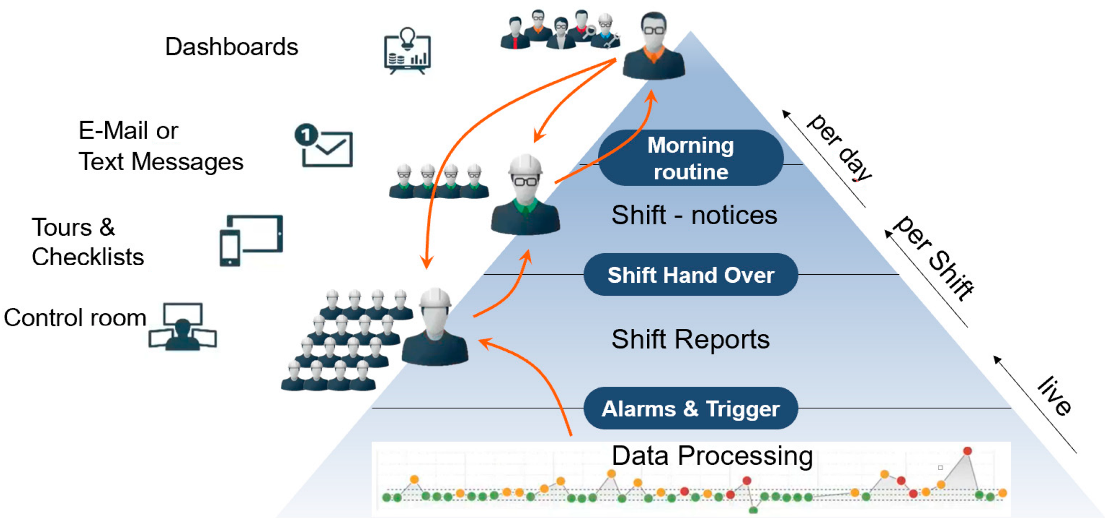

Figure 22. Significance of the automation levels using the example of reporting (own elaboration).

On the shop floor level, the data in real time of the essential basic data are necessary in order to guarantee the flawless functioning of the production process by means of direct control. Properties such as real-time capability, data quality, reliability, etc. are absolutely necessary and must also be designed to be stable in terms of data security.

The manufacturing execution systems condense, calculate, and visualize the next more abstract level. This cockpit controls the interaction of the production units and coordinates the lines with their active production cells and the passive decoupling buffers. The respective corporate rules are based on the optimized consumption of resources and the respective requirement. A smart control strategy guarantees the continuous coordination of the essential KPI's key performance indicators. The so-called ERP enterprise resource planning level is responsible for the global and strategic planning of orders with the available resources as well as the economic monitoring of the entire company.

Methods and strategies for the digital transformation of manufacturing enterprises (Figure 23):

A. Strengthen government's policy support and the introduction of external digital technology.

B. Enterprise's digital planning and implementation:

   (a) Evaluation of the foundation of enterprise digitalization Strengthen exchanges with high-quality companies in digital-related technologies; learn about new market dynamics/new management concepts and management models by overall planning and step-by-step implementation—specific requirements of lean production—analyze the value stream.

   (b) Informatization, digital planning and integration: The construction of the information architecture is the core content—value chain as the penetration line, in order to complete the enterprise informatization and digital planning including: Implementation enterprise digitalization route.

C. Intelligent manufacturing strategies through . . .

- Interoperation, integration, and the merging of the physical world and the cyber world of manufacturing. IoT: Acquisition of data from the physical world;
- Cloud computing, big data, mobile Internet: Processing and transferring to the Internet;
- Cyber-Physical Systems (CPS): Integration of the physical world and the cyber world of manufacturing. The "Manufacturing-as-a-Service" concept provides manufacturing as a service for users on the basis of interoperability and platform independence;
- The "Service-oriented smart manufacturing (SoSM)" combines new IT and services and proposes a framework for manufacturing through the full use of new IT and services.

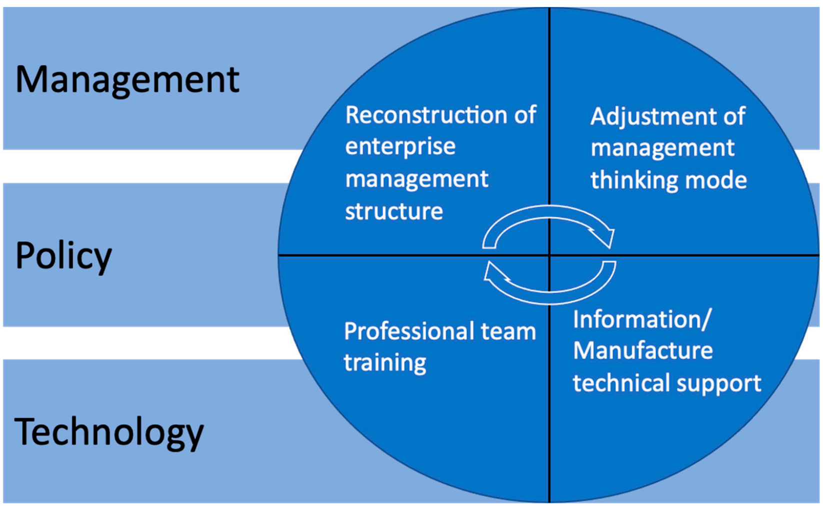

Figure 23. Factors influencing digital transformation of manufacturing enterprises (own elaboration).

6. Conclusions

What value is being wasted and what costs, due to inefficient processes in our firm, are being passed on to the customer, making us more vulnerable to the competition?

What green opportunities, to benefit the environment, are being overlooked because we are distracted by daily "fires" in the enterprise which require our attention, currently focused on the essential, but which is not of strategic importance to the firm?

Are we adhering to strict ethical principles when we "juggle" around our human resources to fit into roles which the firm needs performing but for which no prior training was given?

With our research and the experience of the research team we have sought to provide answers to the above with this article.

The basic requirements for a resource-optimized [40], agile, and adaptable company resulted from the literature research of a very large number of currently established IT infrastructures in different companies and their control mechanisms. Through modularization and a concrete description of the interfaces between the processes, a modular system is created. This allows the organic structure of the processes and the associated information technology to be structured in such a way that, in the sense of a value-added handling of the business processes based on the respective customer requirements, an optimum according to the set economic and ethical points of view can be acted upon [41]. We, hence, answer our research question regarding the fulfilling of agile customer requirements.

In order to focus this research work specifically on information technology issues, the associated organizational structure adjustment under the company's applicable guidelines and the associated ethics [42] were excluded and will be dealt with in subsequent articles [43].

Based on the theoretical approaches of an agile and versatile information system of the future, which has already passed the basic practical test in the form of a prototype, the claim of a value-added contribution to the cost-optimized adaptation of the existing processes of a production system—to the requirements of the market—was taken into account.

The current dynamics of the individual basic components of information processing in the field of decentralized, intelligent sensors and actuators (IoT, fieldbus), and the information processing of large amounts of data in connection with the visualization and reverse integration through production and resource planning tools in the control loop of production control, have been focused upon. A subsequent dynamic framework, consisting of standard components from the market, based on state-of-the-art technology, is not yet available. The test in a production area of the large chemical industry has already been tested positively and is in the evaluation phase.

Getting all the processes "on board" and in motion is a true challenge. Though it is very possible, as we have proven with our implementation to date.

We are already successfully using this type of forward-looking production control in the area of cleaning ultra-pure silicon base material. We were able to increase our productivity by 8% within one year, which, with 270 people and a personnel cost factor of EUR 80 k/worker, corresponds to a saving of almost EUR 2 million/annum (so far, and as mentioned above, but the savings are expected to increase significantly). It was an easy process to transfer to this approach as the algorithm proved to be very useful and everyone came on board very quickly. This was in Germany in the main plant (development and production plant—Bgh). This project is still in a pilot phase and will soon spread to other business units.

The savings were due to a better usage of resources and by quickly re-dimensioning the plant to reduce losses. The more people and business units involved, in the future, the greater the benefits and savings to be achieved.

6.1. Limitations of the Research

The study herein and its results still need to be tested in various other environments namely in other countries outside Germany, China, and the USA. In medium to large firms and in their production lines. The passage of time will show the adaptability of the model proposed and how it maintains its relevance, or not, as an agile solution for the flexible workplace.

6.2. Suggestions for Future Research

We suggest that case studies of the implementations of the type described in the study be undertaken and the results shared in the academic and practitioner communities. At a time when the pressure to perform is high and when there is a true battle for competitive advantage our model needs to be tested further and the results communicated.

If you take a deeper view of companies, as mentioned above, in similar geographies or in similarly developed economies, many of them have the same problems over and over again, in different forms. All companies tend to lag too far behind the market demands and take too long to adapt their processes, including in manufacturing. Consequently, internal structures are not flexible enough to react in a resource-optimized manner, minimizing costs for the firm and for the environment. Unnecessary pressure is, hence, created, resulting in losses in the effective implementation of the new requirements, regarding what should be the path to a more sustainable enterprise. Our research calls attention to the above and sectoral studies or studies of clusters of firms would be most welcome and useful to the ongoing debate—for both theory/academic scholars and practitioners alike.

Author Contributions: Conceptualization, K.K. and M.A.-Y.-O.; Formal analysis, K.K.; Funding acquisition, M.A.-Y.-O.; Investigation, K.K. and M.A.-Y.-O.; Methodology, K.K. and M.A.-Y.-O.; Project administration, M.A.-Y.-O.; Resources, M.A.-Y.-O.; Software, K.K.; Supervision, M.A.-Y.-O.; Writing—original draft, K.K. and M.A.-Y.-O.; Writing—review & editing, M.A.-Y.-O. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Please contact the first author for more data on the project described herein, which is part of a doctoral effort at the University of Aveiro, in Portugal.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Moore, G.C.; Benbasat, I. Development of an instrument to measure the perceptions of adopting an information technology innovation. *Inf. Syst. Res.* **1991**, *2*, 192–222. [CrossRef]
2. El-Gayar, O.F.; Ambati, L.S.; Nawar, N. Wearables, artificial intelligence, and the future of healthcare. In *AI and Big Data's Potential for Disruptive Innovation*; IGI Global: Hershey, PA, USA, 2019; pp. 104–129.
3. Lindvall, M.; Muthig, D.; Dagnino, A.; Wallin, C.; Stupperich, M.; Kiefer, D.; May, J.; Kahkonen, T. Agile software development in large organizations. *Computer* **2004**, *37*, 26–34. [CrossRef]
4. Klebanov, B.B.; Madnani, N. Synthesis Lectures on Human Language Technologies. In *Synthesis Lectures on Human Language Technologies*; Morgan and Claypool Publishers: San Rafael, CA, USA, 2022; pp. 1–314.
5. Aurégan, P.; Tellier, A. Nintendo in the pursuit of the blue ocean. In *Innovation in the Cultural and Creative Industries*; Wiley: Hoboken, NJ, USA, 2019; pp. 1–28.
6. Lantano, F.; Petruzzelli, A.M.; Panniello, U. Business model innovation in video-game consoles to face the threats of mobile gaming: Evidence from the case of Sony PlayStation. *Technol. Forecast. Soc. Chang.* **2022**, *174*, 121210. [CrossRef]
7. Negrini, S.; Bissolotti, L.; Ferraris, A.; Noro, F.; Bishop, M.D.; Villafañe, J.H. Nintendo Wii Fit for balance rehabilitation in patients with Parkinson's disease: A comparative study. *J. Bodyw. Mov. Ther.* **2017**, *21*, 117–123. [CrossRef]
8. Schön, S.; Schön, R.; Kröger, K.; Creutzburg, R. Overview and forensic investigation approaches of the gaming console sony playstation portable. In *Multimedia Content and Mobile Devices*; SPIE: Burlingame, CA, USA, 2013.
9. Madhavan, S.; Pradhan, S. Relationship between Nintendo's Wii balance board derived variables and clinical balance scores in individuals with stroke. *Gait Posture* **2020**, *79*, 170–174. [CrossRef]
10. Gašpar, T.; Deniša, M.; Radanovič, P.; Ridge, B.; Savarimuthu, T.R.; Kramberger, A.; Priggemeyer, M.; Roßmann, J.; Wörgötter, F.; Ivanovska, T.; et al. Smart hardware integration with advanced robot programming technologies for efficient reconfiguration of robot workcells. *Robot. Comput.-Integr. Manuf.* **2020**, *66*, 101979. [CrossRef]

11. Gallo-Molina, J.P.; Cogoni, G.; Peeters, E.; Ambati, S.R.; Nopens, I. A hybrid model for multipoint real time potency observation in continuous direct compression manufacturing operations. *Int. J. Pharm.* **2022**, *613*, 121385. [CrossRef]
12. Cerquitelli, T.; Pagliari, D.J.; Calimera, A.; Bottaccioli, L.; Patti, E.; Acquaviva, A.; Poncino, M. Manufacturing as a Data-Driven Practice: Methodologies, Technologies, and Tools. *Proc. IEEE* **2021**, *109*, 399–422. [CrossRef]
13. De Modesti, P.H.; Carvalhar Fernandes, E.; Borsato, M. Production Planning and Scheduling Using Machine Learning and Data Science Processes. In Proceedings of the 9th Swedish Production Symposium, SPS 2020, Jönköping, Sweden, 21–24 April 2020; IOS Press BV: Amsterdam, The Netherlands, 2020.
14. Remenyi, D. *Dictionary of Research Concepts and Issues*, 2nd ed.; ACPI: Reading, UK, 2017.
15. Saunders, M.N.K.; Lewis, P.; Thornhill, A. *Research Methods for Business Students*, 8th ed.; Pearson Education: Harlow, UK, 2009.
16. Kotter, J.P. *Leading Change*; Harvard Business Review Press: Boston, MA, USA, 2012.
17. Wu, K.J.; Tse, E.C.M.; Shang, C.; Guo, Z. Nucleation and growth in solution synthesis of nanostructures—From fundamentals to advanced applications. *Prog. Mater. Sci.* **2022**, *123*, 100821. [CrossRef]
18. Mason, J. *Qualitative Researching*, 2nd ed.; Sage: London, UK, 2002.
19. Yan, J.; Li, B. Research hotspots and tendency of intelligent manufacturing. *Kexue Tongbao/Chin. Sci. Bull.* **2020**, *65*, 684–694. [CrossRef]
20. Svobodová, L.; Bednarska-Olejniczak, D. SMART City and Economy: Bibliographic Coupling and Co-occurrence. In Proceedings of the 19th IFIP WG 6.11 Conference on e-Business, e-Services, and e-Society, I3E 2020, Skukuza, South Africa, 6–8 April 2020; Hattingh, M., Matthee, M., Smuts, H., Pappas, I., Dwivedi, Y.K., Mäntymäki, M., Eds.; Springer: Berlin/Heidelberg, Germany, 2020; pp. 102–113.
21. Frazzon, E.M.; Agostino, Í.R.S.; Broda, E.; Freitag, M. Manufacturing networks in the era of digital production and operations: A socio-cyber-physical perspective. *Annu. Rev. Control* **2020**, *49*, 288–294. [CrossRef]
22. Brandi, S.; Gallo, A.; Capozzoli, A. A predictive and adaptive control strategy to optimize the management of integrated energy systems in buildings. *Energy Rep.* **2022**, *8*, 1550–1567. [CrossRef]
23. Theorin, A.; Bengtsson, K.; Provost, J.; Lieder, M.; Johnsson, C.; Lundholm, T.; Lennartson, B. An Event-Driven Manufacturing Information System Architecture for Industry 4.0. *Int. J. Prod. Res.* **2017**, *55*, 1297–1311. [CrossRef]
24. Cao, J.; Brinksmeier, E.; Fu, M.; Gao, R.X.; Liang, B.; Merklein, M.; Schmidt, M.; Yanagimoto, J. Manufacturing of advanced smart tooling for metal forming. *CIRP Ann.* **2019**, *68*, 605–628. [CrossRef]
25. Biuki, M.; Kazemi, A.; Alinezhad, A. An integrated location-routing-inventory model for sustainable design of a perishable products supply chain network. *J. Clean. Prod.* **2020**, *260*, 120842. [CrossRef]
26. Fouz-González, J. Using apps for pronunciation training: An empirical evaluation of the English File Pronunciation app. *Lang. Learn. Technol.* **2020**, *24*, 62–85.
27. Cappuccio, P.; Burrafato, S.; Maliardi, A.; Ricci Maccarini, G.; Taccori, D.; Dalla Costa, R.; Raunholt, L.; Larsen, Ø. Full robotic drill floor as advanced rig automation. In Proceedings of the Abu Dhabi International Petroleum Exhibition and Conference 2019, ADIP 2019, Abu Dhabi, United Arab Emirates, 11–14 November 2019; Society of Petroleum Engineers: Richardson, TX, USA, 2019.
28. Chen, W.; Liu, H.; Qi, E. Discrete event-driven model predictive control for real-time work-in-process optimization in serial production systems. *J. Manuf. Syst.* **2020**, *55*, 132–142. [CrossRef]
29. Oluyisola, O.E.; Bhalla, S.; Sgarbossa, F.; Strandhagen, J.O. Designing and developing smart production planning and control systems in the industry 4.0 era: A methodology and case study. *J. Intell. Manuf.* **2022**, *33*, 311–332. [CrossRef]
30. Liu, Y.; Xu, H.; Lau, W.C. Accordia: Adaptive Cloud Configuration Optimization for Recurring Data-Intensive Applications. In Proceedings of the 10th ACM Symposium on Cloud Computing, SoCC 2019, Santa Cruz, CA, USA, 20–23 November 2019; Association for Computing Machinery: New York, NY, USA, 2019.
31. Aileni, R.M.; George, S.; Pasca, S.; Alberto, V.S.C. Data fusion-based AI algorithms in the context of IIoTS. In *EAI/Springer Innovations in Communication and Computing*; Springer Science and Business Media Deutschland GmbH: Berlin, Germany, 2020; pp. 17–38.
32. Christou, I.T.; Kefalakis, N.; Soldatos, J.K.; Despotopoulou, A.-M. End-to-end industrial IoT platform for Quality 4.0 applications. *Comput. Ind.* **2022**, *137*, 103591. [CrossRef]
33. Bentabet, D.; Cloud-Io, T. Platform for Smart Irrigation Solution Based on NodeMCU. In Proceedings of the International Conference in Artificial Intelligence in Renewable Energetic Systems, ICAIRES 2020, Tipaza, Algeria, 22 November–24 November 2020; Hatti, M., Ed.; Springer Science and Business Media Deutschland GmbH: Berlin, Germany, 2021; pp. 689–696.
34. Crawford, B.; Sourki, R.; Khayyam, H.; Milani, A.S. A machine learning framework with dataset-knowledgeability pre-assessment and a local decision-boundary crispness score: An industry 4.0-based case study on composite autoclave manufacturing. *Comput. Ind.* **2021**, *132*, 103510. [CrossRef]
35. Castro-Martin, A.P.; Ahuett-Garza, H.; Guamán-Lozada, D.; Márquez-Alderete, M.F.; Urbina Coronado, P.D.; Orta Castañon, P.A.; Kurfess, T.R.; González de Castilla, E. Connectivity as a design feature for industry 4.0 production equipment: Application for the development of an in-line metrology system. *Appl. Sci.* **2021**, *11*, 1312. [CrossRef]
36. Keserica, H.; Sučić, S.; Capuder, T. Standards-compliant chat-based middleware platform for smart grid management. *Energies* **2019**, *12*, 694. [CrossRef]
37. Maia, R.F.; Bálsamo, Â.J.; Lopes, G.A.W.; Massote, A.A. Evaluation of OPC-UA communication in an autonomous advanced manufacturing cell implementation. *Gest. E Prod.* **2021**, *27*, e5414. [CrossRef]

38. Wang, Y.; Zhang, Y.; Tan, D.; Zhang, Y. Key Technologies and Development Trends in Advanced Intelligent Sawing Equipments. *Chin. J. Mech. Eng.* **2021**, *34*, 30. [CrossRef]
39. Fatorachian, H.; Kazemi, H. Impact of Industry 4.0 on supply chain performance. *Prod. Plan. Control* **2021**, *32*, 63–81. [CrossRef]
40. Fallahpour, A.; Yazdani, M.; Mohammed, A.; Wong, K.Y. Green sourcing in the era of industry 4.0: Towards green and digitalized competitive advantages. *Ind. Manag. Data Syst.* **2021**, *121*, 1997–2025. [CrossRef]
41. Grznár, P.; Gregor, M.; Krajčovič, M.; Mozol, Š.; Schickerle, M.; Vavrík, V.; Ďurica, L.; Marschall, M.; Bielik, T. Modeling and simulation of processes in a factory of the future. *Appl. Sci.* **2020**, *10*, 4503. [CrossRef]
42. Gallo, T.; Santolamazza, A. Industry 4.0 and human factor: How is technology changing the role of the maintenance operator? In Proceedings of the 2nd International Conference on Industry 4.0 and Smart Manufacturing, ISM 2020, Virtual Event, Austria, 23–25 November 2020; Elsevier B.V.: Amsterdam, The Netherlands, 2021.
43. Francisco, A.; Taylor, J.E. Understanding citizen perspectives on open urban energy data through the development and testing of a community energy feedback system. *Appl. Energy* **2019**, *256*, 113804. [CrossRef]