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Smart Manufacturing Execution Systems: An approach for SMEs to conquer industry 4.0

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Abstract

Purpose of the article The transition towards a new production paradigm, industry 4.0, is assumed to have already started. Smart devices provide companies with the potential to use their data in almost real time. Doubts are raised that small and medium-sized enterprises (SMEs) are not able to take this challenge in the same way that large enterprises (LEs) do as they are lacking financial and technical resources.

Methodology/methods The manuscript employs a case study in a Slovakian machining SME. The case study makes use of a smart manufacturing execution system (SMES) architecture developed based on the current system architecture in the company. During the case study, company-chosen indicators are observed and ex-post expert interviews lead to an amended proposal of a SMES architecture.

Scientific aim Studies in the recent years focused mainly on introducing industry 4.0 and describing approaches of LEs and laboratory production facilities to conquer the arising challenges. SMEs however have been found to have a fundamentally different way of working and decision-making with a focus on short-term improvements. Thus, this case study contributes to providing viable insight on the working and obstacles of SMEs in transition towards industry 4.0.

Findings For a simple production with one product and only two further components the low complexity of the system allows for a fast adaption of internet of things (IoT) devices. For a fully free data flow a standardisation module and advanced planning module to substitute hand-made excel sheets are required. As real-time data is needed on all management levels, the amendment of interfaces and the integration of different information systems has to be ensured to support SMES.

Conclusions This paper describes the situation in one machining company in Slovakia. It shows the application of an SMES architecture and the required amendments. As SMEs are differing widely also in their transition activities and targets, research will need to focus on finding patterns on SMEs, industries and the different ways of working in the future.

Keywords: Industry 4.0, smart manufacturing execution system, SMES, IoT, big data, standardisation, advanced planning

JEL Classification: L11, L16, L60, M11

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Introduction

Today's companies are assumed in the transition towards industry 4.0. Industry 4.0 is believed to represent a new paradigm of operating and manufacturing, based on real-time data exchange (Feshina, Konovalova and Sinyavsky, 2018). While the term industry 4.0 was minted by S… in 2011 and officially presented as a German government strategy to conquer the industrial challenges of the next decades (Kagermann, Lukas and Wahlster, 2011), there are several similar initiatives in other countries, such as Nouvelle France Industrielle, Fabbrica Intelligente, Made in China 2025 (Trotta and Garengo, 2018). Conducted researches in various areas (Nascimiento et al., 2019) (Gobakhloo et al., 2019) assume industry 4.0 to fundamentally change the operating of companies and the approach towards business and management (Feshina, Konovalova and Sinyavsky, 2018) (Popkova, Ragulina and Bogoviz, 2018).

While large enterprises (LEs) and corporates are already in transition, facilitating the development of technologies and their implementation in production, small and medium-sized enterprises (SMEs) lag behind. Due to their nature, they are facing resource constraints in the financial, technical, and knowledge area (Mittal et al., 2018). According to previous research, SMEs have difficulties to acquire external financial resources from banks

(Madrid-Guijarro, García-Pérez-de Lema and Van Auken, 2016)) not being as creditworthy as LEs. Further, SMEs are known to lag behind due to their reluctance to bear risks. As SMEs usually engage only in a small area room for error is small so that these companies do not develop themselves more than they need to (Müller, Kiel and Voigt, 2018).

Globally, throughout economies, SMEs represent the vast majority of enterprises. Further, they employ a majority of employees across global economies and have a higher share in the economic value created in the countries. This is due to the fact that this category of companies sum up to more than 90%, e.g. in Germany (Sommer, 2015) and further European countries. Thus, it is crucial for economies and supply chains that SMEs successfully transit towards the new production paradigm.

As industry 4.0 requires engagement in the area where SMEs are known to lack resources, such as a developing spirit, expertise and a financial buffer with room for error. The increased requirements on data acquisition, processing and distribution are assumed to make use of technologies belonging to the internet of things (IoT). These IoT technologies use smart devices and sensors to achieve the objective to provide real time data (also referred to as "right-time" (White, 2004).

Being under the pressure to stay competitive on the market, SMEs need to find a way to make use of their strengths to compensate for their lack in resources. Thus, this paper wants to explore an approach of a smart architecture for SMEs based on already existing components, such as the enterprise resource planning (ERP). This approach should provide SMEs with the potential to stay competitive and the meet the requirements of transition towards industry 4.0 without cost-extensive investments. Based on present literature, the model of a smart manufacturing execution system (SMES) based on the SMEs existing infrastructure is developed prior to a case study. In a case study in a Slovak SME from the machining industry the theoretically-developed a-priori approach is verified and further amended to develop a tailored SMES.

1 Literature Review

This section wants to have a look on the scientific state of the art in order to constitute the research framework. As such, this chapter focuses on reviewing the literature on SMEs, Smart Factories and Smart Manufacturing.

1.1 SMEs

Small and medium-sized enterprises, shortly only SMEs, contribute to the vast majority of economic activities in countries all around the world (Sommer, 2015) (Auzzir, Haigh and Amaratunga, 2018). The definition of SMEs varies depending on the source. Usually, SMEs are understood according to the definition of the European Commission to have less than 250 employees generating a maximum revenue of 50 million euro (European

Commission, 2003). Companies going exceeding these Frontiers are understood to be large enterprises, short only LEs. Another definition was given by Gartner where it was defined that SMEs are companies with a maximum number of employees not exceeding 999 and a maximum revenue of 50 million dollar (Sahaym, Datta and Brooks, 2021). Medium-sized companies are characterised with at least 50 (European Commission, 2003) or with at least 100 (Sahaysm, Datta and Brooks) employees. Data from Germany and the European Union (Sommer, 2015) and

Asia (Auzzir, Haigh and Amaratunga, 2018) show that more than 90% of the employees is employed by SMEs, while more than 60% of the revenues in the country is created in these enterprises.

Due to the various constraints in the areas of financial, technical, and human resources (Mittal et al., 2018)

SMEs are acting differently to LEs on the market (Müller, Kiel and Voigt, 2018). SMEs seem to struggle in acquiring external finances, such as credit from banks, however these companies seem also not to be able to acquire the needed finances internally by creating a financial buffer (Madrid-Guijarro, García-Pérez-de-Lema, and Van Auken, 2016). Thus, an Asian study came to the conclusion that SMEs require financial incentives given by the government in order to invest into new technologies (Doh and Kim, 2014). While a survey among Asian managers brought up that SMEs are usually reluctant to adapting new technologies (Stentoft et al., 2019) (Kumar, Somgj and Dwivedi, 2020), the Organization for Economic Co-Operation and Development (OECD) identified also missing managerial skills as one of crucial lacks of resources in these companies (OECD, 2000). This might be one of the explanations for why SMEs are not able to take an advantage on the market from lower transaction cost due to their lower complexity in their organisation (Doh and Kim, 2014).

Focusing on industry 4.0 and the increased importance of data exchange and information technology (IT), studies also found lacking resources in the IT security for SMEs (Wang et al., 2016c). The horizontal integration of various systems brings IT security into focus for the company internal IT security risk management (Brettel et al., 2014). With industry 4.0 the vertical integration of systems across companies generates further IT security risks, not only for the SME but for all companies being part of the integration (Bandyopadhyay, 2010). Even well equipped companies and LEs may this way fall prey of intruders (Falkner and Hiebl, 2015) as SMEs provide a backdoor to the LEs for those intruders (Heidt, Gerlach and Buxmann, 2019). This might be due to the reason that SMEs are more focused on the operative activities and on the most apparent challenges than on long term production control and planning (Müller, Kiel and Voigt, 2018). Even in integrated interface areas, such as the logistics industry, IT skills were found to be missing within SMEs (Kawa, 20212), even though those, and in particular the IT security, are understood to be crucial for their further development (Chatterjee, 2019).

Due to the actual constraints and the SMEs issues in planning long-term activities with regard to their situation, studies led to the poroposal of a SME-specific strategical framework (Brozzi et al., 2018). Still in 2018, studies showed that articles dealing with smart manufacturing focused solely on LEs, not taking SME requirements into account (Mittal et al., 2018). As SMEs require a downsized and small-scale framework (Brozzi et al., 2018), in the current situation, they do not feel fit for smart manufacturing and industry 4.0 (Moeuf et al., 2017). Even more, managers do not see how they could benefit from the current development (Schumacher, Erol and Sihn, 2016). Further, SMEs lack a crucial understanding for industry 4.0 and smart manufacturing, concerning the importance of data for their operation. According to Omri et al. (2020), SMEs do not understand how to handle data effectively and how to use them for a continuous improvement process. Thus, Mittal et al. proposed an adopted framework for SMEs (figure 1) showing the steps to be taken to bring SMEs nearer to smart manufacturing. Further approaches discussed a three-stage model (Ganzarain and Errasti, 2016) or a nine-stage model of maturity (Mittal, Romero and Wuest, 2018a).

Source: Pfeifer, 2021 according to Mittal et al., 2019

Figure 1 Smart manufacturing adoption for SMEs

In order to stay competitive on the market, SMEs will have to adapt to the circumstance coming with industry 4.0 and smart manufacturing (Rauch, Dallasega and Unterhofer, 2019). Requiring a specific, individual and tailor-made approach, SMEs should take advantage of standard components to be connected through a modular approach (Weyer et al., 2015). Thus, the aim of this research is to develop a smart manufacturing approach for SMEs based on the existing state and further-defined standard components.

1.2 Smart Factories and Smart Manufacturing

Making use of industry 4.0 and smart principles through IoT technologies allow companies to make farther use of data. Smart technologies making use of IoT (Chen et al., 2019) provide companies with the ability to use a wider range of data (Shrouf and Miragliotta, 2015). Making full use of data in production companies may lead to the approach of smart factories (Lin et al., 2016) (Chen et al., 2018), also referred to as digital factories, digital manufacturing, interconnected factories, integrated industry or industry 4.0 (Büchi, Cugno and Castagnoli, 2020).

This is based on integrating smart manufacturing into the company's smart infrastructure, making use of smart principles (Radziwon et al., 2014).

Smart factories are believed to save cost and energy consumption. Due to the increased flexibility these factories are also assumed to work profitably with lower lot sizes (Wang et al., 2016a). In 2020, a study showed that the implementation of smart factories is not yet fully present in reality, as companies of all sizes are struggling with expertise and resources (Shi et al., 2020). Different approaches, such as multi-agent systems (MAS) (Shen et al., 2006) (Fragapane et al., 2020) through discrete manufacturing (Lin, Wu and Song, 2019) have been identified to provide a basis for smart manufacturing. However, while MAS are known to be sophisticated and complex, complexity is reduced by discrete manufacturing in order to build a working system (Chen et al., 2019).

Beside smart objects, also big data analytics is a widely-discussed core component of smart applications (Wang et al., 2016a). Big data does not only allow to collect, proceed and distribute data, but to also use data for diagnostics, optimization and reconfiguration for the whole system (Xu and Hua, 2017). Hence, it is seen as a core component for data-driven manufacturing approaches, in particular for smart factories (Illa and Padhi, 2018). While research found the possibility to explain the architecture of such systems in a four-layer model (Chen et al., 2018) or in a three-layer model (Yang et al., 2011). The layer models should ensure a modular architecture that can be adapted fast. Further, it should be able to provide real-time information with the help of IoT technologies and machine-to-machine (M2M) communication. This adds up to an IoT-based company information system infrastructure (Chen et al., 2019) integrating devices and equipment (Weyrich, Schmidt and Ebert, 2014) where big data technologies represent the feeding technologies (O'Donovan et al., 2015).

In order to achieve smart factories, smart manufacturing has to support the system, being more cost-effective, sustainable and reliable than usual manufacturing processes (Tuptuk and Hailes, 2017). Making use of human-based computer-integrated manufacturing (CIM) principles (Vaidya, Ambad and Bhosle, 2018), cyber-physical networks (CPN) make use of IoT and M2M to facilitate smart manufacturing (Wilkesmann and Wilkesmann, 2018). IoT devices behave as independent agents (Tuptuk and Hailes, 2017). This enables companies to target manufacturing issues with a higher degree of complexity (Davis et al., 2012). Thus, smart manufacturing may not only focus on company-internal systems, but it might be also integrated into digital intercompany communication and data exchange, e.g. in smart manufacturing supply chains (SMSC).

Substituting human-machine communication by M2M puts fiercer requirements on data. Quality and quantity of the data in the system become a vital part of the mart manufacturing approach (Moyne and Iskander, 2017). Big data ensures data volume, data velocity, data variety (Dong, 2013), data value, data veracity (data quality) and data visualisation (Manyika et al., 2011). The development of big data is mostly driven by the even higher requirements of smart manufacturing, such as increased data quantity (volume) and an increased data resolution (veracity) (Maier, Schriegel and Niggemann, 2016).

Based on big data, several authors proposed smart manufacturing reference architectures, such as a reference architecture for automotive industries (Papazoglou, van den Heuvel and Mascolo, 2015). Limits in the knowledge application, being process-bound and product-related, provide issues for companies to make use of specific manufacturing knowledge (Chungoora et al., 2013). Papazoglou et al. propose an interface and query language that should take the interrelations of the special knowledge into account (Papazoglou, van den Heuvel and Mascolo, 2015). A further approach, smart manufacturing systems (SMS), was developed for service industries. It understands system components as services, such as the enterprise resource planning (ERP) and the supply chain management. The link between smart manufacturing and the service components is in the case of the SMS provided through a business intelligence (BI) tool (Lu, Riddick and Ivezic, 2016).

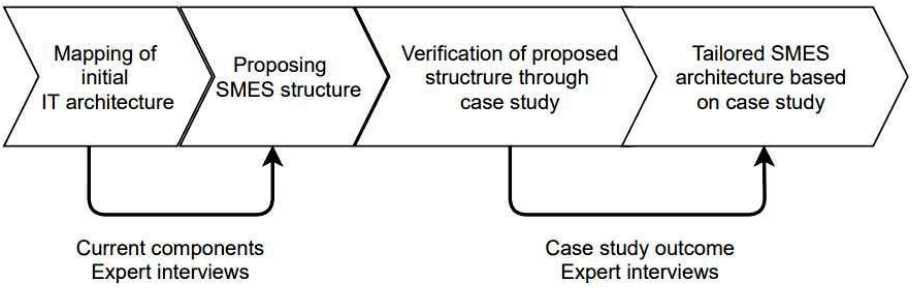
An approach also suitable for SMEs (Menezes, Creado and Zhong, 2018) is the smart manufacturing execution system (SMES). Analoguous to the SMS also this approach wants to make use of existing components, such as the manufacturing executing system (MES) acting in the center of the architecture (Jeon et al., 2016). While SMES architectures use a message broker element that ensure the bilateral communication between the components. Even though this architecture tries to maintain the company architecture as it is without smart technologies (Larreina et al., 2013), SMES has a far wider defined task than MES. While SMES is working with the real-time gathering, processing and distribution of data the MES has its task in the management support (Kim, Jeong and KIM, 2019). The introduction of smart systems also require control systems. Decentralised control systems have been studied (Vogel-Heuser, Lee and Leitão, 2015) based on MAS in combination with MES and ERP systems (Frazzon, Kück and Freitag, 2018). Agents may also include artificial intelligence (AI) agents making use of the capacity of artificial intelligence in order to plan and predict scenarios in production (Leusin et al., 2018). While Papazoglou, van den Heuvel and Mascolo (2015) see the production scheduling as the core of the service-oriented architecture (SOA) with CPN-based production tracking through auto-identification (AutoID) and radio frequency identification (RFID) (Anderl, 2014) (Liao et al., 2017). AI has been applied in laboratory case studies to conduct production scheduling in real-time (Shiue et al., 2018) in logistics (Vlahavas and Refanidis, 2013) and in chemical applications (Segler, Preuss and Waller, 2018). However, a case study on smart product planning and control (smart PPC) showed that even with AI the ERP system is in the center of the smart manufacturing architecture (Haddara and Elragal, 2015; Oluyisola, Sgarbossa and Strandhagen, 2020).

Another approach on production scheduling and control is the self-adaptive collaborative control (SSC) for smart production logistics systems (Guo et al., 2021). In this approach, the system compares data acquired and data from the knowledge base in order to predict scenarios and to enforce planning (Zhang et al., 2018). The control mechanism is working through all layers, vertically, while monitoring is done horizontally in each layer during the manufacturing process (Guo et al., 2021).

Due to their limitations, SMEs are assumed to concentrate on smart products, while LES seem to develop towards smart processes (Oluyisola, Sgarbossa and Strandhagen, 2020). As several approaches seem to be existing in theory, there are only a few approaches for SMEs. As those have to be tailored, this research paper wants to have a look on whether a case study in a Slovakian SME leads to the results found in literature or whether changes in the approach as well as in the components may be found.

2 Methodology

The research was conducted in a Slovakian SME, belonging to the machining and production industry. The research is descriptive is conducted in the company in four steps according to figure 2: a) mapping the initial company IT architecture, b) proposing a SMES structure based on the existing components of the company, c) conduction of the case study, d) proposing a tailored SMES architecture based on the results from the case study.



Source: own proceeding

Figure 2 Smart manufacturing adoption for SMEs

2.1 Company information

The Slovakian company belongs to the category of small and medium-sized companies, according to the classification of the European Commission (2003). With approximately 200 employees, it belongs to the medium-sized companies. The company works has two machining, one assembly and one paint shop. The company distributes its products under their own company brand or through other brands. Depending on the customer, the company provides components or products on the business-to-business (B2B) market.

The case study focuses on one machining shop. This machining shop works with simple products that are done in cooperation for one internal LE. The design and the production specification is likewise determined by the LE. As such, the product is distributed on the market under the name of the customer. The machining shop works with one product that is going through several operations. Depending on the specification on the product, some of these products receive two pieces of an additional component. The assembly is done and is coordinated by the machining line. Beside the machining (workplaces 1, 2 and 3), the production line also includes two non-destructive test equipment (workplace 4 and workplace 6), one assembly workplace for those products that receive additional components (workplace 5) and one workplace for final quality check and measuring (workplace 7). Information on the observed company and its observed machining line may be found in table 1.

Table 1 Information on the case study company

	Dimension	Case study company
General company information	Industry	Machine shop
	Ownership	Private
	Number of employees	197
	Manufacturing location	Slovakia, Europe
	Customer location	Slovakia, Czech Republic
	Yearly turnover	13.5 million Euro
Machining line	Number of workplaces	7
	Number of employees	8
	Shifts	3
	Average hourly output (in pieces)	5.3
	Average no. of components for one unit of output	1.1
	Number of workplaces a unit of product goes through	6.1

Source: own processing, 2021

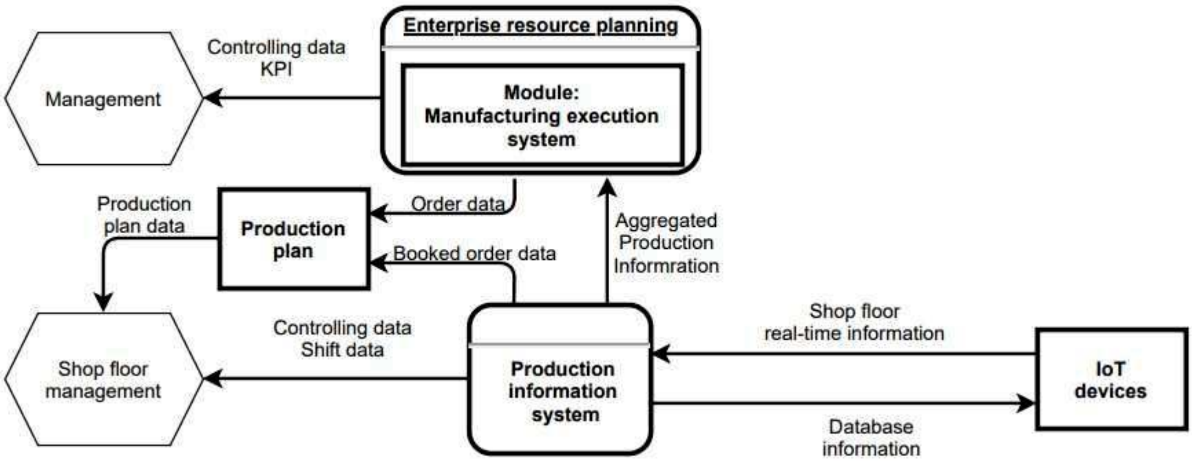
2.2 Mapping of the initial framework

The company makes use of an IT architecture with a tailored ERP system, including a MES module. Further, the company also has a separate production information system (PIS) where all production data is stored. Detailed production data remains in the PIS (e.g. worker name, production label number, shift number, etc.), whereas aggregated and pre-determined data, including serial number and production time, is transferred to the ERP system. Hence, the PIS contains shop floor data. This shop floor data is used in the case of any issue, such as customer claims or internal quality issues and in case of failing internal key-performance indicators (KPIs).

For the PIS, the company makes use of IoT devices in the sense that it is using mobile phones to scan production labels for products, components and machines and equipment, as well as for the storage area. The registration and booking of any product or component to a location (machine, equipment or area) is done through Quick response (QR) codes. The company management implemented these devices instead of planned shop floor terminals as it presented a simple and fast opportunity to book the shop floor orders, being moreover personalised and available in real time. The data from the PIS system may be retrieved either by computer or mobile phone through a browser or through a tailor-made mobile app for the mobile phone. It gives the opportunity to either search for data for a scanned product or component or for a scanned location.

Controlling data is processed in two ways. The data for the top management including the corresponding KPIs is retrieved automatically from the ERP system. This data represents aggregated data for the top management from all area of the company, also from the manufacturing area. As data is provided to the management in the form of an automatically retrieved report on a weekly basis, numbers do not explicitly show particular shift data or any further patterns. Shift data for an operative management level is provided by the PIS system. The report from the PIS is generated with the help of the company's IT department that is retrieving a shift-wise report for all production areas. The fundamental difference between the company's initial IT structure and the company-proposed first SMES architecture for the case study is that all controlling data is initially retrieved manually from the system, while in the SMES these reports are generated in real-time on user (management) request.

The initial company IT structure including the controlling network is shown in figure 3.

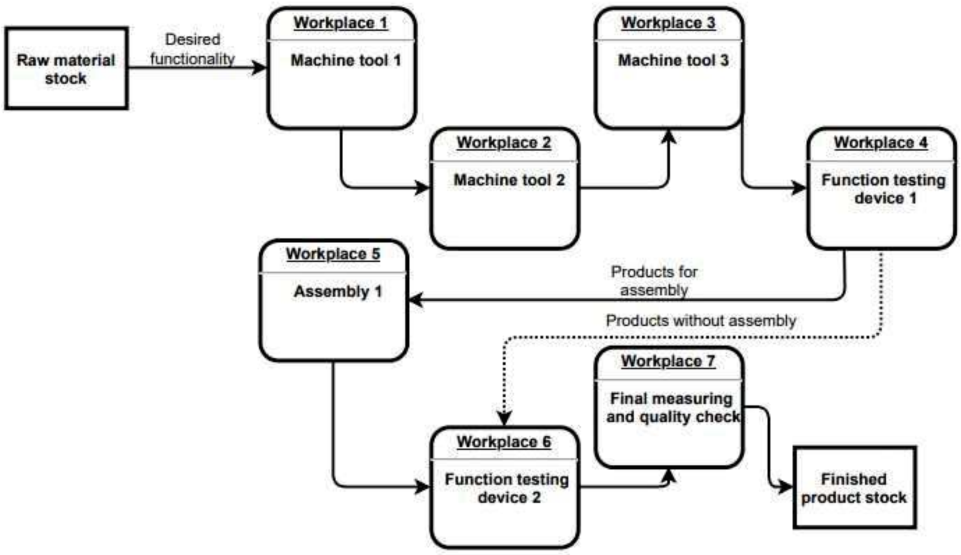


Source: own proceeding

Figure 3 Company IT structure

2.3 Case study design

The case study is conducted in the above-mentioned company as a single case study. The single case study took into consideration one production area, the machining shop (figure 4). This area is characterised by a constant flow of goods with a limited number of seven workplaces. The first four workplaces are connected by an automatic material manipulation system. The further flow of the material is done manually due to the fact that not all products go through workplace 4 and due to the fact that the work pieces need to be turned by 90° for workplace 5.



Source: own proceeding

Figure 4 Case study company's machining shop

The first part of the case study monitors the activities in the machining shop during operation for one week. The data received and the remarks are compared with the PIS report and with the weekly report from the ERP system. Additionally to the differing values for KPIs between plan and reality, the results are reviewed with the company's experts in an open expert interview to determine a first pool of areas for further action to develop an amended production framework.

The second part of the case study made use of the company's internal experts to gather ideas for developing the amended production framework. In order to develop the framework, experts from different area (shop floor leaders, production IT programmers, controlling, company top management) were consulted to develop the new framework based on identified insufficiencies located during the case study conduction. With the support of the experts and based on their recommendation, the new framework is developed trying to take as many components as possible from the initial production framework, making use of the ERP, MES and PIS of the company. The resulting framework may then be characterised as a tailored SMES.

The third part of the case study consists of a weekly employment of the SMES structure. In order to first conduct a study before deciding for an investment into the SMES, the company decided to bridge parts of the existing company structure with fast workarounds. This possibility is available due to the fact that all subsystems are constructed modular with the opportunity to make fast changes with logic operators within the company with the company's IT personnel. The IT system was enlarged by a second IT architecture. Data was transmitted into both systems while the initial structure was working as before. The new structure was working separately in an individual environment.

2.4 Case study results

Based on the company-proposed SMEs architecture, the company was able to achieve differences in several company pre-selected KPIs. These KPIs were picked by the company's top management based on the needs they saw for reporting and controlling. Measurements and logics were applied in both periods in the same way in order to ensure comparability. It may be added that the KPIs were not selected based on a scientific analysis of the situation to understand the different needs of the company. Thus, the results may also show unchanged KPI values were the management of the company assumed changes to happen or where the management wanted changes to happen. The resulting KPIs for the case study and a comparison to the results from a similar one-week production period from one month earlier may be found in table 2.

Table 2 Results of the case

#	KPI	Before value	After value	Percentage of fulfillment
1	Number of pieces produced (per hour)	5.3	5.3	100%
2	Equipment availability	67%	67%	100%
3	Efficiency *	106%	106%	100%
4	Downtime	9%	11%	122%
5	Worker idle time	9%	11%	122%
6	Rework rate	3%	2%	67%
7	Scrap rate	1%	1%	100%
8	Equipment maintenance and repair time	5%	4%	80%
9	Number of equipment breakdowns	9	8	89%

** efficiency basis is the planned standard output of 5 pieces per hour*

Source: own processing, 2021

2.5 Amended SMES framework

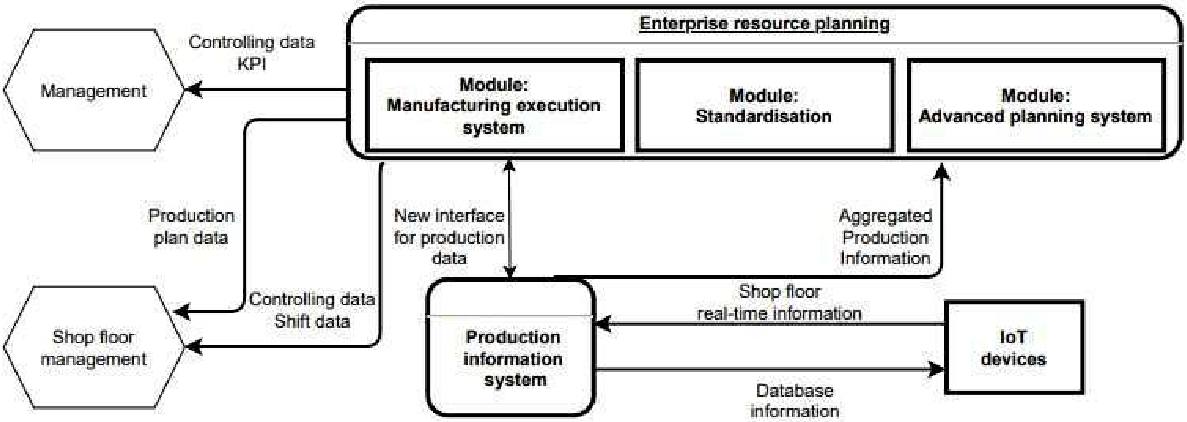
As table 2 shows, the differences between the initial system and the SMES architecture of the company does not show big differences. Due to the small numbers, a small deviation will show off in a 20% or more shift in the KPI. Thus, the case study did not bring significant positive improval for the company and for the management task just by having real-time controlling data available.

Discussing the case study results in expert interviews on all management levels brought the following understanding of issues to be targeted:

- the architecture was meant to only support the real-time reporting,
- the real-time reporting was only available for the management,
- usage of real-time data in production did not exist,
- planned value data is outdated and real-time values available are not used.

In order to target the criticism mentioned by the experts during the interviews, the real-time data availability should be used for planning on an actual basis. Further, the real-time data should also suite to highlight issues in an early stage. Thus, making use of the available data in real-time in the structure requires also PIS data to be assessed frequently and in real-time. In order to assess this data, this also requires a database of standard values to be used. In the case of the company with monotonous and standard work, this may be handled without customised standardisation modules and software. The standardisation module in the company, so far filled but unused, may be suitable for the standard operations.

Taking these requirements into account, a new SMES structure is proposed in figure 5.



Source: own proceeding

Figure 5 Proposal on SMES structure based on case study results

The amended SMES structure focuses even more on the ERP system as the core of the system architecture. The ERP is acting as a central hub for all data processed and distributed. In order to maintain the company's PIS with its tailored functionality, it was decided to establish a new interface between the ERP system and the PIS. It allows users and clients to request and send data in both directions. This ensures the possibility to also transmit data into the PIS system, e.g. for the standards. On the other hand, the ERP system should be enlarged by two modules: the advanced planning system (APS) and the standardisation module. Both modules already exist in the current version of the ERP system, but they are not used in the current production. The standardisation module, however, is filled with most of the data required. The newly-proposed architecture allows the company management of all levels further to check KPIs, machine status and issues with data from the ERP and the PIS. The integration of these systems should provide the company with the possibility to further enlarge the SMES. As machines are not equipped with sensors to provide fully-automatic diagnostics and information. Thus, the company's SMES approach focuses more on a real-time proceeding and distribution of data than on further smart technologies.

3 Discussion

SMEs are known to be constraint in their resources. Lacking expertise and finances (Mittal et al., 2018) SMEs need to find a way to stay competitive during the development towards industry 4.0. The case study of a Slovakian SME shows that a specific SME approach as discussed by some researchers allows companies to adapt in a simple and fast way. Further, this SMES approach make also use of standard components in the company. Thus, the investment into these systems seems to be small. Depending on the level of sophistication and depending on the required data, these systems might also need a higher complexity than in the analysed case study with only one product jumping through several workplaces.

However, the Slovakian SME seemed to have an issue in understanding the potential and the value of data in industry 4.0 and in smart manufacturing. The case study showed that even data filled into a system was not used (standardisation module). This was due to the fact that data was retrieved from the system manually not making use of the possibilities of interfaces providing automatic data exchange. Being under constant pressure to use tailored but cheap solutions, SMEs tend towards excel sheets instead of employing the full potential of the system. The SMES architecture as applied in the case study did not have an effect on the machining line output. But it was a simple and fast way to conduct the case study by making use of existing components. A vital issue of SMEs remains the data processing and the honouring of data. In order to allow for a fast and right-time data exchange, the initial measures are not sufficient. This also provides the chance to understand the logic implications in the whole system. However, an important part of the whole SMES architecture is a bidirectional data interface that allows data to be assessed by different levels in the architecture. In order to achieve the required results, data needs to be used in right time in the right location.

4 Conclusion

The case study in the Slovakian SME shows that alternatives to full industry 4.0 architectures, including big data technologies, may be found with the existing potential of these companies. SMES architectures make use of the existing components and are thus able to minimise the further investments to be done. As those companies face limited finances and skills (Mittal et al., 2018) SMES should be able to help companies to use their potentials. While the research focus on LEs might suggest that SMEs should not have a chance to conquer industry 4.0 due to their limitations, there are still opportunities for these companies to come closer towards the full target (Brozzi et al., 2018; Müller, Kiel and Voigt, 2018).

It must be said that the case study conducted in this case covered only one company belonging to the category of SMEs. The company had its internal obstacles of an insufficient communication between the different management levels that also showed off in the insufficient usage of KPIs that were pre-determined for the case study. It also showed that the first approach for an SMES did not meet the initial targets and did not bring any betterment in the KPIs the company desired to improve. However, company experts were able to propose a revised SMES architecture based on the first case study and its results.

Giving a short outlook into the future, SMEs will need to find a way to adapt to the new circumstances. While Kotler et al. (2016) assume that SMEs may benefit from new technologies, such as 3D printing, by going into new areas of production. However, companies that do not have the finances are reluctant to invest into new technologies. SMEs may for the transition towards industry 4.0 focus on their basis by making use of SMES architectures. The case study in this paper provides one tailored SMES architecture. The additional core components of this architecture identified are the standardisation module and the advanced planning module, as well as the bidirectional data interface between the different information systems. Even though, SMES architectures might be different due to different requirements of companies, this case study proposes the core components mentioned to be a vital part of SMES architectures in production companies of any kind.

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