Mid-sized companies in Virtual Factories

A strategy for growth?

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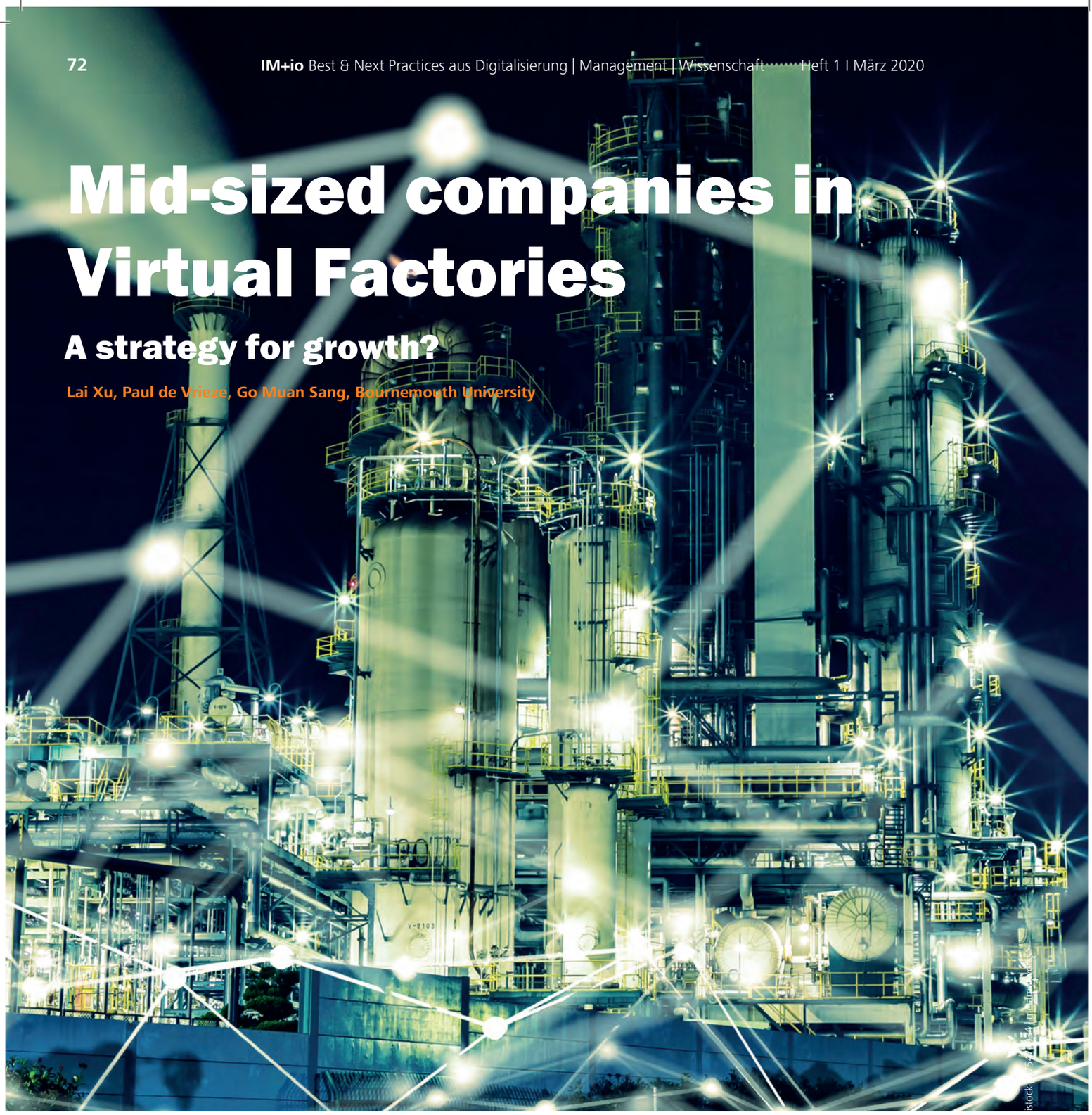

Virtual factories as a foundational concept to future manufacturing allow the flexible amalgamation of manufacturing resources in multiple organisations. Industry 4.0 initiatives introduced by Germany provide the realization of how a future factory will transform enterprise businesses using cloud, Internet of Things, Cyber Physical Systems, Virtual Reality, big data, and the opportunities and challenges that will pose enterprises including SMEs. The article first reviews relevant concepts and relationships among the concepts. The challenges and opportunities for SMEs are discussed for participating in virtual factories.

Virtual factories as a foundational concept to future manufacturing.

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In the context of Industry 4.0, the manufacturing related processes have shifted from conventional processes within one organization to collaborative processes such as product design processes, manufacturing processes, maintenance processes across different factories and enterprises including Small and Medium-sized Enterprises (SMEs). Virtual factories as a foundational concept to future manufacturing allow the flexible amalgamation of manufacturing resources in multiple organisations [1,2]. Industry 4.0 initiatives introduced by Germany provide the realization of how a future factory will transform enterprise businesses [3] using cloud, Internet of Things (IoT), Cyber Physical Systems (CPS), Virtual Reality (VR), big data, and the opportunities and challenges that will pose enterprises including SMEs. There are different concepts related to virtual factories. The article first reviews relevant concepts and relationships among the concepts. The challenges and opportunities for SMEs are discussed for participating in virtual factories.

Smart Factory

Smart factories concern with interconnected systems including sensor enabled devices or equipment which are integrated and communicated via IoT technologies to adapt and react to changes that occur inside or outside the production process [4], assisting users and machines in executing tasks based on context-aware [5]. The core asset of smart factory is the value-creating network which exists at different levels, enabling the value-added integration to occur horizontally and vertically in the manufacturing process [6].

Digital Factory

A digital factory can be described as an integration platform for design, engineering, planning, simulation, communication, and control on all planning and manufacturing levels [7]. A digital factory essentially operates with big data which are typically collected from several sources in the smart factory level for decision-making processes as well as creating simulations of designed prototypes for speeding up time-to-market, etc. [8], enabling better understanding of the manufacturing industry at different levels, and consequently improving the product lifecycle management.

Virtual Factory

The concept of virtual factories derives from the expansion of virtual enterprises in the context of manufacturing. Virtual factory allows the flexible amalgamation of manufacturing resources in multiple organisations to model, simulate, and test factory layouts and processes in a virtual environment with the support of emerging technologies such as IoT, CPS, etc. This enables the simulation of a desired factory before committing to investment and creating the actual factory in shorter time with demand-driven product lines [1, 2]. The former concept of virtual factory focuses on integrating collaborative business processes from different enterprises to simulate, model and test different design options to evaluate performance, thus saving time-to-production [1, 2]. For instance, in the context of a virtual shoe making network community shown in Figure 1, multiple partners such as designers, suppliers, manufacturers, and customer involve in the virtual collaboration. Throughout the shoe making process, multiple partners with various business processes are essentially integrated, and data is exchanged, collected and used for optimising processes e.g. enhancing customer experience and decision-making e.g. optimized supplier process or production process by nearest location of the customer and eco-friendly delivery, etc.

Digital twin

The latter concept focuses on the seamless integration of virtual and physical environments as the entire production system, commonly known as digital twin [9]. In this context, the virtual environment is a virtual representation of a production system that can replicate the whole physical factory as a unit in real time, providing an advanced decision support capability utilising technology like virtual reality. In the context of digital twin, the virtual shoe

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making from Figure 1, will have the shop floor with the capability i.e. a virtual/digital representation of the product manufacturing, offering the customer a selection of various options such as shoe designs, materials, sizes, technology such as ortholife, cushion, etc., before committing the entire shoe making process. The shoe production will then be dealt in the actual physical manufacturing. Throughout the shoe product lifecycle, it offers both the manufacturing chain and the customer several benefits such as better customer experience, improved performance and productivity, increased reliability of equipment and production lines.

Relationship between Smart, Digital and Virtual Factory

Virtual factory aims to support the integration and exchange of data and physical assets through global networked operations, enabling and supporting effective decision-making process [1, 2]. In this aspect, the virtual factory deals with the collaboration of design, production, maintenance process, and the extended supply chain. Smart factories typically associate with the interconnected systems which are integrated and communicated via IoT, implying the hardware layer of a factory floor [4]. On the other hand, digital factories focus on operating with big data collected from the smart factory for decision-making processes [8]. In a smart and digital enabled factory, the smart factory level enables the collection of data which is then utilised at the digital factory level, enhancing the virtual models created within the digital factory with real time data to improve decision making. Overall, a virtual factory provides collaborative business processes with different partners whereas a digital and smart factory can provide collaborative asset management with different partners. SMEs are the driving force of many manufacturing economies [10]. As such, the impact of SMEs on the emerging Virtual Factory can be significantly, however, they often face different challenges and barriers to larger companies.

Challenges

Unlike large organizations, SMEs often associate with limited resources, lower productivity, higher costs and less on-time delivery performance [14]. This restricts SMEs to perform business operations in different ways. Industry 4.0 tools, for instance, would require huge investment and a high level of expertise. And Industry 4.0 focus can typically be global markets and networks, associating with large companies who have considerably significant resources and different working partners [15]. This can be a daunting prospect for SMEs due to its limited resources. SMEs are generally driven by short-term strategy for their business operations and activities. Though, this provides the flexibility and adaptability to changes and demands, it may hamper significant longer-term investments [16] such as Industry 4.0 capabilities, machine tools and processes. The organisational structure of SMEs is typically characterised by proximity management in which managers involves in all company's decisions [17]. This inherently results in lack of domain experts as well as expert support functions, subsequently may hinder adopting Industry 4.0 enabled solutions in a complex and competitive environment like virtual factory. The adoption of Industry 4.0, enabling better control and operations to adapt in real time and in response to constant demands, is promising [18]. However, it requires clear understanding of technologies, processes and practices and of the increasing complex and competitive manufacturing [19].

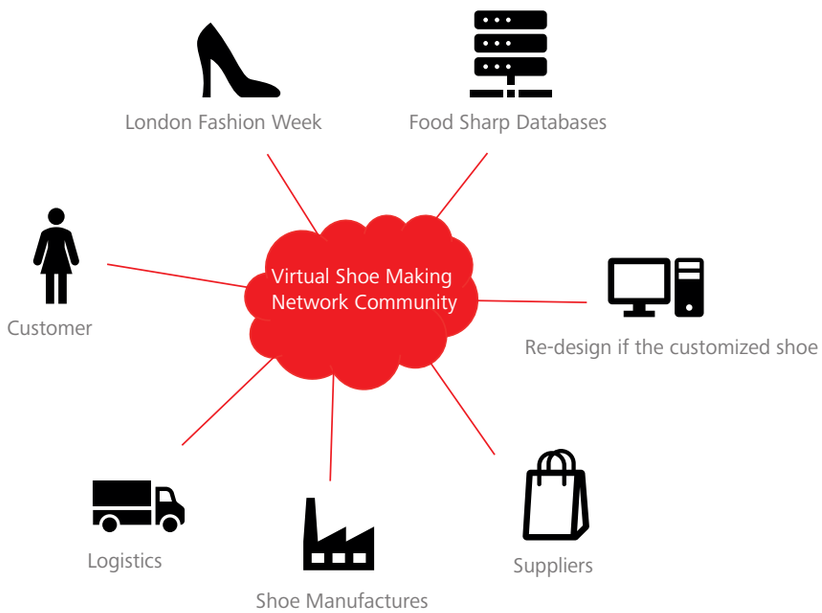

Figure 1: Virtual shoe making

Such challenges including security, transparency pose major concerns for both SME and large enterprises. Collaborative virtual factories are not restricted by the physical co-location or long-term collaborations [1]. The variability of different solutions/virtual factory models and how to adapt the potential solutions/virtual factory models, as well as to upkeep and maintenance of various models and tools are challenging for both SMEs and large enterprises wishing to form or join a virtual factory environment [11]. In addition, interoperability is essential to collaboration, and it can be problematic for SMEs as they still rely on traditional software like MS Excel [20].

Opportunities

As the business strategy of SMEs is often based on flexibility, reactivity and customer proximity, the concept of Industry 4.0 has the potential in providing a more streamlined flow of information, enabling better planning and control processes [18, 22]. Industry 4.0 capabilities enabled by cloud computing offers SMEs a flexible and viable option to compensate their limited resources and capability [21, 23]. Collaborative virtual factories allow a variety of models, processes, tools, competencies to be integrated, and are ultimately not constrained by the physical co-location or longer-term collaboration [1, 11]. Large enterprises may reduce costs i.e. replace direct investment in global locations by cooperating with local SMEs for a specific business interest and skills. In turn, outsourcing SMEs can obtain accessing global markets and pooling of experts through the large global collaboration. This may subsequently lead SMEs to further developing new opportunities such as expansion of collaborations i.e. exploit the virtual communities utilizing their specialized knowledge and skills [12], maintaining low cost and increasing value. The physical manufacturing equipment and systems of virtual factories are expensive [13] and often beyond the reach of SMEs. However, SMEs can take advantage by identifying and focusing on the most critical but viable options in the collaborative chain. For instance, the penetration of CPS in SMEs is expensive, complex and limited however SMEs can target the most critical machines to be upgraded and thus limit investment costs. Data exchange is essential to the operation of a virtual factory [18]. With increasing number of data sources, data is generated throughout the production process at different levels and is critical for decision-making process and optimizations [22]. SMEs can take advantage of these data by optimising their business/production processes at low cost, and ultimately, by exploiting the data sharing economy with its own produced data such as customer feedback or a product/process data in the manufacturing industry, obtaining new value.

Conclusion

Virtual factories allow flexible collaborations among multiple organizations who have different competencies including SMEs. This offers a more streamlined flow of information, enabling better planning and control processes. For SMEs, as being often recognized for their flexibility, proximity to customers, their low investment capacity and short-term strategy, Industry 4.0 production tools require intensive investment, while collaboration and optimization tools seem less expensive. And this offers potential for adapting optimization tools, exploiting the available big data to improve operational performance as well as exploring data economy to create new value and maintain low cost. Research and case studies are still required to demonstrate the impact and substantial benefits SMEs can obtain from virtual factories. ■

Kurz und Bündig

Industry 4.0 manufacturing related processes have shifted from conventional processes within one organization to collaborative processes across different factories and enterprises. Virtual factories as a foundational concept to future manufacturing allow the flexible amalgamation of manufacturing resources in multiple organisations using emerging technologies such as Internet of Things (IoT), sensors, etc. The article provides relevant concepts as well as the challenges and opportunities of virtual factories for Small and Medium Sized Enterprises (SMEs).

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