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2 authors:

Moutaz Haddara
Kristiania University College

Ahmed Elragal
Luleå University of Technology

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The Readiness of ERP Systems for the Factory of the Future

Moutaz Haddara[ab,*], Ahmed Elragal[a]

[a]*Luleå Department of Computer Science, Electrical, and Space Engineering, Univeristy of Technology, Luleå, Sweden.*
[b]*Department of Technology, Westerdals- Oslo School of Arts, Communication, and Technology, Olso, Norway*

Abstract

In 2011, at the Hanover Fair, the term Industry 4.0 was first coined. In October 2012, the Working Group on Industry 4.0, presented a set of implementation recommendations to the German government. The term Industry 4.0 initiates from a project in the high-tech strategy of the German government. Such project advocates the computerization of the manufacturing industry. It is also known as the 4th industrial revolution. Precisely speaking, industry 4.0 is based on the technological concepts of cyber-physical systems, Internet of Things (IoT), which enables the Factory of the Future (FoF). Within the modular structured smart factories of Industry 4.0, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the IoT, Cyber-physical systems communicate and cooperate with each other and with humans in real time. Enterprise resource planning (ERP) systems are considered the backbone for the Industry 4.0. Thus, this paper attempts to answer the research question: "Are today's ERP systems ready for the FoF?". We have conducted interviews with manufacturers, ERP vendors, and partners in order to seek their feedback on the readiness of ERP systems for the FoF. Our results show that ERP systems are ready for the FoF.

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Keywords: ERP; Factory of the future; Industry 4.0; Multiple case study

1. Introduction

The world has witnessed multiple industrial revolutions over history. The 1st industrial revolution was the mechanization of production using water and steam power; the 2nd industrial revolution introduced mass production with the help of electric power; and 3rd industrial revolution use electronics and IT to further automate production. Nowadays, with the modern

* *E-mail address:* moutaz.haddar@ ltu.se

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advancements in machine-to-machine (M2M) and communications technology, the world is just now beginning to experience the next industrial revolution – Industry 4.0. Industry 4.0 allows manufacturers to become connected. This starts from the supplier, manufacturing facility, distributor, to the product itself. This connection lays down the foundation for the factory of the future (FoF), on which the cyber-physical relationships are magnified. This level of integration enables manufacturers to collect and process sheer amounts of information. See below figure.

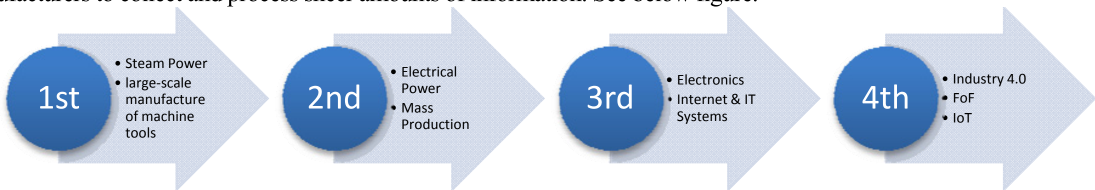

Figure 1. Industry 4.0

Using Internet of Things (IoT) technologies, manufacturers are able to integrate the demand and supply chains, which allow them to engage with end-customers in a very unique, yet unprecedented, way. The core of Industry 4.0 is based on highly intelligent, as well as connected, systems that create a fully digital value chain. Industry 4.0 is also referred to as the Industrial Internet of Things (IIoT). By 2020, connected and intelligent products are predicted to be the biggest "user group" of the Internet, estimated at 24 billion devices. But this is not just a revolution in consumer technology. In the Industrial Internet of Things, connecting smart devices has the potential to transform how factories operate, buildings are managed, and vehicles are maintained and operated - in fact an almost limitless number of new industrial processes, functions and services.

Since ERP systems have been extensively used to manage operations and processes of manufacturers, now the question is, are Enterprise resource planning (ERP) systems ready to tap into the FoF operations and efficiently manage its entire operations?

This paper is organized as follows: next section presents the research background and introduces literature about industry 4.0, which is followed by a section illustrating FoF. Hence, the delta changes required by today's ERP systems are explored. After that comes the methodology part in section 3, where the paper presents the interviewees' details and target cases. The data analysis is provided in section 4, followed by a discussion of the findings in section 5. Finally, conclusions and future research avenues are discussed in section 6.

2. Research background

2.1. Industry 4.0

Nowadays, machines are connected via collaborative community creating the so-called Industry 4.0, whereby machines are connected as a collaborative community [1]. Achieving faultless interaction between surrounding machines and their corresponding systems turns regular machines into self-aware or smart machines, and subsequently improves its performance in the environment where it operates [2]. Internet of Things (IoT) has been an enabler to Industry 4.0. IoT refers to the networked interconnections of objects that are fitted with ubiquitous intelligence. IoT is opening huge opportunities of new applications, which promise better quality of our lives. The connection of physical objects to the Internet makes it conceivable to access distant sensor data and control the physical world from distance. A smart object is a term given to an embedded system, which is connected to the Internet [3]. Experts from industry and research predicts that the upcoming industrial revolution will be triggered by the Internet, which permits communication between humans and machines in Cyber-Physical-Systems (CPS) throughout enormous networks [1].

2.2. The necessity of sensor technology

The problem is that people have inadequate time and imperfect accuracy and therefore they are not very good in capturing data about things in the physical world. The reason behind that is we – humans - are physical and hence our environment is also physical, so collecting and maintaining "digital" information is not our strength! If we had computers that knew everything which needed to be known about things, we would have been able to track and count everything and probably nothing would have gone wrong nor needed fixing. But, reality is that computers rely on humans to enter and maintain data and that creates data quality problems. So, we need computers with their own means of collecting data. Sensor technology enables computers to sense, observe, and understand the physical world – without the limitations of human-entered data [4].

2.3. The factory of the future

The first time the term Factory of the Future (FoF) was mentioned goes back to 1986 where Irwin Welber gave a keynote speech to the 86 international symposium on robot manipulators [5]. Welber explained that the FoF would look like a large-scale intelligent machine, which operates with a highly integrated as well as organized knowledge base. He also highlighted the need for both suppliers and customers to become integral part of the FoF environment. Becoming more and more adaptive is the primary motivation for manufacturing enterprises to adopt the FoF initiative. This becomes necessary due to the new challenges manufacturing enterprises are facing including the need to cut down production costs, making customized products, as well as being able to respond to market changes faster than ever before [6].

2.4. Where are the people?

There are speculations that Industry 4.0 and FoF both carry bad news to people and employment. We strongly advocate the counter argument. That is, people will continue to exist and play major roles in the FoF, but it is a different role with different skillsets. Even the sensory subsystem, a major FoF component, needs people from sales, marketing, production, etc. to keep analyse and understand data and reflect on its implications. People are the supervisors of the robots, the architects of the control subsystem of the FoF. One key, new, role that people play at the FoF is monitoring technology. Failure of technology in the FoF could cause dramatic impact and therefore monitoring and actions are of paramount importance. For instance, sensors are the gateway for FoF (smart) machines to sense its adjacent physical environment. Nevertheless, sensor failure e.g., degradation may pass erroneous readings to analytics' algorithms, which will result in an incorrect decision-making [2]. In the future, people will have to change in content but will still remain irreplaceable. Particularly in view of customization which resulting in an increasing need for coordination. More and more workers will be required to be skilled in decision making in order to do their job in the FoF [1].

2.5. ERP Systems: The delta changes

FoF is based on solid foundation with regards to modularization, mass customization, distributed control, IoT, modelling and forecasting, collaboration, distributed SC, distributed manufacturing, and transparent processes [1]. It is now time to check on readiness of ERP systems to cope with the demands of the FoF. To illustrate, major problem associated with current ERP systems is their ability to predict. In manufacturing enterprises, maintenance is a key activity. Hence, the ability to anticipate machine breakdown and address the root cause of the problems is indeed required at the FoF. As example, SAP has developed a comprehensive framework for predictive maintenance that is able to integrate different diagnostic and prognostic models of equipment wear [6]. The FoF bring rather different type of challenges to enterprise systems. For instance, with the widespread adoption of collaborative manufacturing processes, ERP systems are required to integrate fully with SCM systems in order to protect against counterfeiting and hence ensure that product and raw materials used in the manufacturing process are genuine and are the ones which are supposed to be used. Additionally, one of the FoF foundations is the horizontal integration. That is, manufacturing enterprises and their employees have to communicate with various departments across company boundaries. This communication should be facilitated by open systems and relying on open standards.

Integrated engineering, a FoF requirement, along the value chain is relying on reliable means of communication. That is, all participating entities can be supplied with access to real-time information and control is distributed to the shop-floor level. A central issue of Industry 4.0 is how business processes including engineering workflows and services can be integrated end-to-end in CPSs, using ERP systems. Industry 4.0 and the FoF emphasize on the establishment of intelligent product and processes. Within the FoF, the CPS requires a continuous fault-free two-way communication between machines, humans, processes, and products. With that being said, the question still remains about the potential role of ERP systems to play in order to facilitate such communication. There are some promising applications of Industry 4.0 and the FoF. As mentioned earlier, SAP has developed their predictive maintenance module, which is based on solid integration between robots, machines (to be maintained), and SAP ERP system. The predictive maintenance is based on integration between the ERP data [business data, production, maintenance personnel, spare parts, production shifts, etc.], sensory data, as well as predictive algorithms. More of that time of efforts and integration is to be seen in the near future[†].

As per the ex post literature, and due to its novelty, there is lack of sufficient research exploring the relationship between ERP systems and FoF. In order to envision the ex ante literature of ERP systems we have decided to construct a survey where we get to ask ERP consultants, customer side, vendors, as well as independent consultants our main research question: *Are today's ERP systems ready for the Factory of the Future (FoF)?*

3. Research Methodology and cases

We have conducted a multiple case study [7], with seven face-to-face qualitative semi-structured interviews [8] in Egypt, and three via video conferencing. The interviews were conducted in three manufacturing companies. The participants included a mixture of stakeholders who have been involved in ERP system implementations. Altogether ten interviews gathered information from the different stakeholders. The informants had experience on various local, international, and open source ERP systems. All interviews were digitally recorded, and carried out with employees, which had deep knowledge about the supply chain and manufacturing lifecycles, as well as, the technology (ERP). In the following table, the informants' details from the three target cases and other interviewees are introduced in more detail. The company names are fictitious to preserve anonymity.

Table 1. Overview of informants

Informant	Organization & (Size)	Industry Type	Interview Duration
IT Manager	Company 1 (Medium)	Retailer – food manufacturer	55 Minutes
IT Director	Company 2 (Large)	Home appliances manufacturer	60 Minutes
Applications Section Head	Company 3 (Large)	Retailer- food manufacturer	32 Minutes
IS Manager	Company 3		49 Minutes
Senior ERP Consultant	Implementation Partner	ERP implementation partner	28 Minutes
Junior ERP Consultant	Implementation Partner	ERP implementation partner	25 Minutes
Independent Technology Investment Advisor		Advisor to several organizations	67 Minutes
ERP & EPM Territory Manager	Vendor 1	Leading international ERP vendor	53 Minutes
ERP Sales Development & Strategy Leader	Vendor 1		49 Minutes
Chief Operations Manager	Vendor 2	Leading international ERP vendor	60 Minutes

3.1. Questionnaire and Target Cases

The questionnaire was developed by the authors in order to gather insights about the topic understudy. The questionnaire covered several topics, including: ERP readiness for FoF, future plans for automation, and the perceived opportunities and challenges for the FoF. More information about the target organizations is provided below.

Company 1 is a medium-sized family owned organization that has been founded in 1932. In its industry, the company is currently a leading enterprise in Egypt and the Middle East. The company is specialized in meat processing, dairy, and beverages production. The group employs over 1500 employees. The group produces a range of products including natural pure ghee, natural butter, various processed cheeses, long life juices, long life milk, flavoured milk, and processed meat. Prior to the ERP adoption, the company had several silo systems, which lacked integration and scalability. Thus, the company decided to invest in an ERP. In 2012, the company acquired a SAP ERP system. The company did not have a consultant during the selection process; however, they hired one later on during the implementation. The initial ERP modules implemented in the organization were financial controlling, warehousing, purchasing, fixed assets, order management, manufacturing, and quality management. The company has upgraded the system in 2014 and is now in the process of implementing the human resources module.

[†] SAP IoT Solutions: http://www.sap.com/uk/pc/tech/internet-of-things/software/overview.html

Company 2 is a large Egyptian group of companies that has been established during the 1920s. The Group is mainly operating in the field of domestic electric appliances. They specialize in manufacturing washing machines, refrigerators, electric water heaters and gas cookers. The group owns the licensing rights for some world leading brands in Egypt. The company had several scattered systems prior to the ERP implementation. Oracle JD Edwards was implemented in 2008, with financial, supply chain, sales, manufacturing and MRP scheduling, and quality management modules. In addition an Oracle engineering module was installed, and recently a trade management application have been implemented. The company is now in process of extending the ERP system through implementing an SAP demand planning application to aid in forecasting and analysis of demand.

Company 3 is a retailer that deals with a diverse number of commodities, which are sold directly to customers through two outlets. The company has been established in 2005 in Cairo and is now one of largest Supermarket chains in Egypt. According to the informants, the company falls in the category of large enterprises, and its current workforce consists of more than 2,500 employees. The retailing commodities vary from fresh food, fast moving goods, non-food commodities, textiles, and furniture. The company production mainly focuses on food manufacturing and packaging. Prior to the current ERP adoption, they had a previous local Egyptian ERP system that was implemented in 2006. The system was unstable and had a poor performance,, which dramatically affected the day-to-day routine transactions. Thus the company decided on acquiring a new ERP system. The company had an ERP consultant involved during the whole project. The selected ERP system was Oracle JD Edwards ERP and the implemented modules were FC, Capital Asset Management, Manufacturing, Logistics, Procurement, and Sales & Distribution. The ERP went live in August 2007, and another upgrade was done in 2012.

4. Analysis

Initially, all of our target organizations and the other stakeholders interviewed suggest that the leading ERP packages are "as-is" ready for full automation and supporting the FoF. However, consultants and most of the informants from the target organizations reported that there could be other challenges than operational ones that could hinder the FoF implementations in Egypt. We thus continued the case study by gathering data on what could be the various benefits & hurdles for FoF adoptions in manufacturing companies. The results are organized under three main categories of observations: (1) Technical and operational readiness and challenges of current ERP systems for the FoF, (2) Organizational, professional, and cultural readiness and challenges for the FoF, and (3) Future plans for automation and switching from traditional factories to FoF.

As ERP systems are considered the backbone of the factories of the future, **the ERP's readiness** was a crucial topic for investigation in this study. In general, our informants believe that the established ERP systems are technically ready for automation. *"SAP ERP is 100 % ready for the factory of the future. Also the NetWeaver is ready for interfacing between machines and the system."* (IT manager, company 1). In contrast, other informants have expressed their concerns regarding the integration between machines and the ERP system. *"When it comes to operations and processes, I think our ERP is ready for full automation, but it might need extra modules to serve as middleware or interfaces between the machines and the ERP."* (IS manager, company 3). Likewise, another informant (IT director, company 2) expressed concerns related to the interfacing between the machines and the ERP system. The informant also mentioned that due to the different types of machines on the production lines, which have different standards and purposes, building communication interfaces might be a time consuming and troublesome task. On the contrary, all informants from the vendors' side confirm that the integration technologies, infrastructures, and communication interfaces already exist; however, they need some modifications and customization to accommodate special machines and the special needs of manufacturers. *"I think ERP systems are ready for full automation, and the efforts that have been done by the leading vendors for building integration layers and frameworks between external applications and the ERP system can aid manufacturers in establishing communications between their machines and their ERP systems. Also the SOA (service-oriented architecture) introduction by major vendors to their systems can ease communications between machines and ERPs.*." (ERP sales development & strategy leader, vendor 1). *"Our ERP is fully ready for factories of the future. We also have an integration framework that allows the communication between the ERP and other objects, like machines or software applications."* (Chief operations manager, vendor 2). Also another informant from the manufacturing side suggests that there are some challenges with full automation; however, ERP systems are ready for the FoF. *"The communication protocols and standards themselves needs some work from first, the machines manufacturers, and second from client organizations, and this is costly. But again, when it comes to the readiness of the major ERP systems, they are ready for this automation."* (IT manager, company 1). Correspondingly, other interviewees from case organizations have brought up the issue of communication standards and protocols in the industry, and the lack of a unified sensor-communication standard.

Perceived readiness and challenges for the FoF. An informant (IT Manager, company 1) has stressed that the technology-oriented and up-to-date organizational culture, proper knowledge transfer mechanisms, and employees' awareness of technology could be enablers to the FoF in organizations. However, there are also other issues that could challenge the FOF plans. *"Most of the machines we have on the production lines are old, and they don't have the ability to have the communication tools with the ERP system."* (IT manager, company 1). In addition, some informants have expressed their concerns about intra-organizational issues that could challenge the implementation of full automation infrastructures. *"I don't think that the warehouses in most Egyptian manufacturers are ready for full automation yet. For example, until now when we visit the warehouses, we don't discuss any advanced technologies; however, we discuss ABC organizational warehousing practices. So I don't see any automation in a warehouse that is not well organized nor well ordered. And until now the inventory process at most warehouses is conducted and managed in a chaotic fashion"* (IT director, company 2). While most of the ERP systems have production planning modules, still most factories don't rely on the ERP in this process. "*In most of the factories that I have seen, they don't use the ERP system in production planning. The systems are not used to tell them what to produce or how much to produce, these decision are made based on employees' judgments and later fed to the system." (*Junior ERP consultant, implementation partner)**.** An informant from a manufacturer echoed these concerns. *"We are now working on using the MRP package in a more efficient manner to plan our production. Currently, and on a daily basis, we don't know what we will produce today."* (IT manager, company 1).

We asked our informants about what do they think about the **future of FoF in Egypt.** In addition, if any of the manufacturers they worked with or were involved in implementations at, have any plans for full automation, they responded:

*"Up to my knowledge, no. Their biggest dream is that they get the ERP users and the ERP system to work properly and to be well organized, as it is usually not the case in many organizations." (*Senior ERP consultant, Implementation partner). Other informants have suggested that some industries could be more ready for the FoF technologies than others. *"I think that some industries will have this full automation in the next 20 years. Especially the industries that have high safety risks, like steel factories. Also ceramic tiles manufacturers, they need high precision in manufacturing and the raw materials are very expensive, and these companies can benefit from full automation. In general, I think FoF idea is closer to the heavy type of industries."* (ERP application section head, company 3). A similar view has been shared by several informants from the vendor and partners' sides, *"I think full automation depends on the type of manufacturer, the type of industry, and most important, thy type of product. The more complex the product is, the more the need for automation. Like the car manufacturing industry for example."* (ERP & EPM territory manager, vendor 1).

While most of the informants have expressed their concerns about the economic feasibility of having fully automated smart factories in Egypt in the near future, however, some still see that this could happen but will take time. *"*.....[when asked if FoF will happen in Egypt in the next 20 years], *it must happen, because we are experiencing an increasing manufacturing and manpower costs. Over and above, factories usually have a very high employee turnover, which leads to some sort of drops in their production and additional hiring and training costs. However, salaries in Egypt are still low in comparison to other places in the world. But I think that this will change as well and that the FoF will be more feasible in the near future."* (Chief operations manager, vendor 2). On the other hand, an independent technology investment advisor, has noted that the economic feasibility view alone might be misleading. If the decision to invest in a certain technology or system is solely based on financial measures, it would risk investments in the FoF. *"When company owners or decision-makers are not technology-aware, or if they don't have a consultant, they will mainly care about cost vs. gains from this investment. However, when they understand, they will start to realize that technology is not easily financially justified; it would fail, if your approach is only financial, you will fail, and you will never ever be able to convince anybody to invest, the business value should be clear."* In addition, this informant suggests that the immediate cost of technology is a paramount factor in investment decisions in most Egyptian organizations, regardless the long run or intangible benefits. "*In Egypt and some other regional countries, the employees and workers' salaries are considerably low in several local organizations. So if you would tell owners that you could invest an amount of money in order to automate something in the production process for example, they might say that hiring new workers might be more feasible and cost effective. Similar things happen with ERP systems acquisition. I have seen organizations that have hired more accountants instead of investing in an ERP, as they thought it is less costly. Again, I am stressing on the importance of the top management/owners technology-awareness and education, as it can make a lot of difference in investment decisions."* The issue of low-wages countries and feasibility of the FoF has also been discussed by Brettel et al. [1]. ***Regarding the switch from a traditional factory to a FoF***, several informants mentioned that this switch is very difficult and might not be realistic, as it would require substantial budgets, a lot of business and human changes, and overhauling of current machines and production lines. And some interviewees suggest that idea of FoF might be more feasible and suitable for "to be" constructed factories and companies, rather than changing existing factories. *“In today’s factories in Egypt, the production and manufacturing process heavily rely on human resources. So as a GM to decide to exchange the current people with machines, that would be a difficult decision. But if you have plans for a new factory, the owner in this case could be able to decide on having and investing in automation from day one, if feasible.”* (Senior ERP consultant, implementation partner). *“The decision is based on a simple equation, how much is the cost and how much is the expected revenue. If we find out that the full automation is more economical on the long run, then we should consider what is the degree of business process reengineering (BPR) needed for this change. We should evaluate where we are now “as is”, and where should we go, processes-wise. Some industries’ processes are based on personnel’s own knowledge and experience. In this case, full automation is going to be far fetched, as they have to do extensive BPR before thinking of automation.”* (ERP application section head, company 3). Similarly, some participants expressed their views on the challenges of switching existing factories to cope with the FoF. They suggested that this switch could be a lot harder than building a new FoF “compliant” factory. *“In my opinion, it is a lot easier to build a new factory with full automation on mind, but switching from an existing traditional factory to a FoF might not be feasible”* (IT director, company 2).

Table 2. Summary of results

ERP Readiness & Challenges	Organizational Challenges	FoF's Future
• Technically & operationally ready • Machine to machine and machine to ERP communication and integration challenges	• Economic feasibility of FoF is difficult to justify • BPR & change management • Management/employee awareness & technology transfer • Heavy reliance on HR in the supply chain & manufacturing cycles	• Might be more suitable to some industries than others • The switch from an existing traditional factory to a FoF is difficult • Full automation could be feasible for the "to be established" factories • Could be economically feasible and also dramatically decrease HR and employee turnover costs

5. Discussion

Table 2 provides an overview of our results. All in all, we regard the results as aberrant to the current FoF and industry 4.0. Especially, our results suggest that all the target cases have no clear plans for full automation in the future, as they regard it either as difficult to attain, not suitable to their industry, or might not be economically feasible. Regarding this study’s main research question concerning the ERP readiness for the FoF, there is a general consensus from our informants in the target cases and other stakeholders that ERP systems “as-is” are ready to support smart factories and the full automation process. Our informants also add that most of the day to day manufacturing, production planning, quality control, and supply chain processes are done via the ERP system, but in many cases the data is entered manually. From their point of view, it doesn’t matter with the ERP if the data comes from a human or a machine. Thus ERP systems are ready. While the vendors’ representatives suggest that integration frameworks between their ERP systems and other objects (e.g. machines/sensors) already exist, however, informants from organizations express their concerns about the difficulty of building interfaces that enable the communication between their machines and these integration frameworks. They say that it would consume a lot of time and would be a troublesome task. Thus, there is a need on unifying integration layers from the vendors’ side.

Also, a very important concern has been raised by most of the informants, which is the lack of global communication standards and protocols in the sensor technology. This means that some machines manufacturers have their own communication standards that can easy enable machine-to-machine communication but within the same brand of machines. And usually in production and assembly lines, many types and brands of machines are found, which will require the heavy use of middleware and building customized communication interfaces. Hence, machine manufacturers and proprietary communication protocols and standards might serve as bottlenecks to the future of smart factories. From an organizational view, some of our informants have expressed their opinions on the challenges at their organizations, which might hurdle investments in the FoF. One of the main challenges is the justification of investments in smart factories. Several informants have suggested that the Egyptian top-management culture inside many organizations is solely cost-oriented. Which means that it might be difficult to develop an investment justification for the FoF based only on ROI. For example, some informants reported that in the Egyptian context, employees’ salaries could be low in some industries. Thus, the top management might go for additional HR hiring than investing in expensive smart equipment. While, the results suggest that decision makers might lack sufficient information and awareness about FoF technologies, which can hinder future investments, however, with proper the information and knowledge transfer, and well-developed business and use cases, the decision makers in Egyptian manufacturing firms might get convinced to invest in such technologies. In addition, due to the low salaries and required skills in some industries, the whole manufacturing cycle relies heavily on human intervention and interaction. Changing such environment would require substantial business process re-engineering, change management, and massive training and reallocation to the current workforce. Also, some of the informants brought up the classic issue of employee resistance, which they think is glorified when it comes to automation projects.

While the majority of our informants have expressed their positive opinions about the FoF, however, they shared also concerns about the future of the FoF in Egypt. Our results suggest that FoF might be more suitable to certain industries over others. For example, some interviewees mentioned that FoF or full automation could be more adequate and feasible for products, which need high manufacturing precision, like pharmaceuticals and high-tech products. Also, it could be beneficial to industries that have high risks on human-safety. In addition, the results show that the target cases foresee the switch from a traditional factory to a smart factory will be very difficult and would require massive investments and organizational and cultural changes. Hence, FoF technologies could be more feasible to implement in the new "to be established' factories than switching the traditional up-and-running ones. Moreover, some interviewees have suggested that with current economic and minimum wage reforms happening in Egypt after the revolution, it might be economical to invest in FoF in the future and minimize the reliance on low or medium-skilled labour. Furthermore, some industries in Egypt suffer from high turnover rates in their labour power, which can dramatically disturb the production cycles. Thus, automation could minimize the high turnover costs and maintain a flowing production cycle.

6. Conclusions and future research avenues

The existing literature on FoF focus mainly on technical issues e.g., machines autonomy, micro controllers and other cyber-physical challenges. There is a gap in literature on the business side of FoF. Specifically, organization-related challenges, business cases, change management, feasibility and investment justification. While they believe in the many benefits of the FoF, however, our target cases suggest that this switch from a traditional factory to a smart factory is difficult to attain. The informants believe that the "to be established" future factories have more edge to adopt FoF technologies and ideologies. In addition, it could be more economically feasible for them. Also, the results show that FoF might be more useful in some industries over others. Thus, more research and business cases are needed to confirm or refute these results. On the other hand, while ERP systems are considered the backbone for the 4^{th} industrial revolution, however, there is also a gap when it comes to ERP readiness for FoF. Based on the results presented in this study, ERP systems are considered as technologically and operationally ready for this revolution. However, there are perceived challenges when it comes to M2M and machine to ERP communications, as there are no unified standard and protocol. Additionally, several machine vendors rely on their proprietary communication protocols, which could lead to vendor lock-in and could hinder the whole basic concepts of a smart factory and M2M collaboration.

Our study implies at least four suggestions for future research. Firstly, more research is needed on the readiness of ERP systems in other industries or contexts than the ones covered in this study. Secondly, FoF literature needs to focus more on the business and organizational challenges. Thirdly, as costs and expected benefits are the main players in any investment, then more research is needed regarding the economic feasibility of FoF. Fourthly, ERP and machine vendors should collaborate on unifying global communication standards that would pave the way for the 4^{th} industrial. Finally, this study was an effort to answer the question of "are ERP systems ready for the FoF?", however, the question "are factories of today ready for the FoF?" is equally important.

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