POLITECNICO DI MILANO

Dipartimento di Ingegneria Gestionale

IMPLEMENTATION OF INDUSTRY 4.0 ON THE FIELD OF PRODUCTIVE SMES

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ABSTRACT

The main purpose of this document is the creation of a consistent systematic review about the theoretical framework related with the digital manufacturing, also known as Industry 4.0, specially focused on the SMEs (Small and Mediums Enterprises) which activities are in the manufacturing sector. During this document, the reader would discover the actual implementation level of the digital innovations applied, the new tendencies on the sector and the forecasting evolution that the industrial manufacturing are pursuing.

To reach this goal, it is going to be a procedure known as systematic literature review. With it, the actual framework will be identified and critically evaluated, findings of all relevant studies in relation with the digital manufacturing and Industry 4.0 in the SMEs field. The expected output of this review is the creation of a study that will be objective, transparent, systematic and replicable. Searching through published works as well as unpublished, all the possible perspectives of the topic are going to be cover and analysed to find meaningful conclusions.

Keywords: Digital Manufacturing, Industry 4.0, MNEs, Medium and Small Enterprises, Systematic Literature Review,

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Chapter 1. Objective

This paradigm appeared for first time on Germany under the name of Industrie 4.0 as a new strategic initiative for pushing forward digital transformation on the productive systems. With it, Germany want to archive the necessary update of its industry. This would be done through increasing digitalization and interconnection of all the value chain, products, equipment and services. This movement would allow Germany to consolidate its position as technological leader on manufacturing.

"Industrie 4.0" was revived in 2011 at the Hannover Fair as a trend that industry would follow changing multiple perspectives of the future world, not only affecting to the manufacturing or industrial sector but also many others. Knowing this, during the development of this paper the focus is going to be on how this revolution affects to the manufacturer SMEs, this means small and medium enterprises with less than 250 employees.

Related with the manufacturing world, Industry 4.0 and the digitalization of the productive systems has been defined as the industrial revolution number four that is happening progressively but it is not developed completely yet. For this reason, during this paper it will be possible to see the actual state of the implementation and how it is seen by academics and professionals.

Thanks to systematic literature review, a comprehensive framework about Industry 4.0 and manufacturing digitalization is going to be created. Following the premise of being true to reality, study and analyse all possible perspectives of the problem, as well as being critical at the same time as truthful, with the information studied, so that the reader can draw his own conclusions.

Chapter 2. Introduction and State of the Art.

2.1. Industry 4.0

2.1.1. Origins

Table 1. Period, technology innovation and production paradigm of the four industrial revolutions.

	1st industrial revolution	**2nd industrial revolution**	**3rd industrial revolution**	**4th industrial revolution**
Period	1780-1860	1870-1950	1970-2000	2000 -
Technology innovation	steam power & machine tools	electricity	electronic, IT, automation	Internet connected sensors
Production paradigm	craft production	mass production	mass customization	personalized production

Figure 1 Industrial Revolutions. (Bortolini et al. 2017)

- The **First Industrial Revolution** took place in England in the middle of the 18th century and was potentiated by the invention of the steam engine.
- During the second half of 19th century, the **Second Industrial Revolution** came up in Europe and USA. This revolution was characterized by mass production and the replacement of steam by chemical and electrical energy. In order to meet the growing demand, several technologies in industry and mechanization have been developed, such as the assembly line with automatic operations, allowing the increasing of productivity.
- The invention of the Integrated Circuit (microchip) was the technological advancement that has triggered the **Third Industrial Revolution**. The use of electronics and Information Technology in order to achieve further automation in production is the key feature of this revolution that emerged in the last years of 20th century in many industrialized countries around the world.

(Pereira and Romero 2017)

The first three revolutions had following characteristics and outcomes:

- **Mechanization**: Introduction of mechanical manufacturing machines run by water power or steam power.
- **Labour division and large-scale production:** Introduction of labour division and large-scale production by means of electric energy
- **Numerical controlled machines and microprocessors in manufacturing:** Use of electronics and information technology for the automation of manufacturing

(Hoellthaler, Braunreuther, and Reinhart 2018)

The expected outcome of the fourth revolutions represents a new level of organization and control in manufacturing landscapes by using digital technologies. The viability of relevant information at any time takes a crucial role nowadays to allow to productive systems to be as flexible as the demands and clients require. With all this information productive systems pursue the optimization in cost, resources and human workload, reaching a new level of efficiency unknow by this time.

But the crucial part of this information is its usability by the own system automatically. The best way to develop this capability is by the interconnection of every cell/equipment of the value chain with other, creating a networking based on telematic connections through internet.

Figure 2 Assembly on a 4.0 system. (Bortolini et al. 2017)

2.1.2. Involved Technologies

Being the most disruptive change than productive systems have suffer, it is important to highlight its complexity due the high number of different technologies that compose a digitalized system. Each of these technologies are following different path of development, at different speeds. Because that fact, it is hard to see this revolution as something that will be implemented fully in a short period of time but will be something progressive during the next decades.

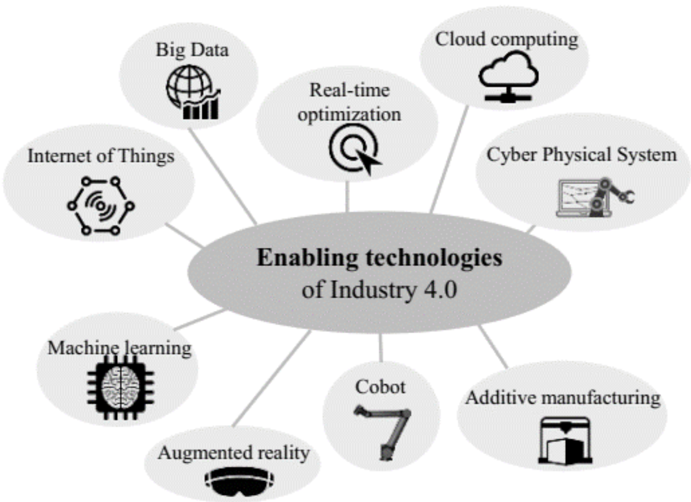

Figure 3 Enabling Technologies of Industry 4.0. (Bortolini et al. 2017)

As it is going to be explained ahead, different levels of development will force to new solutions to have a modular structure due it is not possible to implement the called "Industry 4.0" as a single upgrade of the company. The digitalization of the productive system systems will be a progressive trend that should be implement step by step as the development goes on, making each technological progress feasible and economically worth. Thus, to reach a complete implementation of the digital revolution in any industry is necessary set it up part by part with compatible modules that can be expanded with total compatibility.

2.1.3. Main Obstacles

As many papers point out, the main obstacles of digitalization are many, some of them only affects some companies depending of their size or activities but other problems are common to all of them. The problems that is possible to find analysing documentation about the topics are:

- Cost of the implementation.
- Standardization requirement.
- Lack of strategy.
- Data security.

Cost of the implementation

It is hard to find any specific study about the exact cost or necessary investment that a full implementation of digital technologies applies to a manufacturing process can incur. This is because a set of reasons that, all together makes impossible to do a precise forecast about how much would cost. These reasons are firstly the high variety that manufacturing industry presents, with its own necessities that are completely different for each of them. Secondly, the impossibility of deploy a full update of a factory at one time. It should be something gradual to minimize a possible transitional state that could impact on the performance of the company and its daily activities impacting on the profitability of the chosen solution. And thirdly, some high-tech involved nowadays have a swelled cost that will change rapidly through the time. One example of it the augmented reality devices, which imply an enormous potential to the improvement of production process but now it is impossible to afford as a regular tool for many companies.

As a result, it is not possible to make a complete feasibility report based on costs but practically all the authors studied claim that implementation cost is one of the biggest barriers to entry into the implementation of digital manufacturing.

Standardization requirement.

Thinking about the digital world as a general concept, not only applied to the industry, one of the most complex issue that is possible to address is the compatibility between different devices interconnected to work synchronized. Therefore, digitalized industry is not going to be an exception.

For this reason, manufacturers of smart industrial devices are putting tons on effort on creating standardized protocols and interfaces to provide the maximum flexibility to users, providing solution than fit on their necessities. Despite of this efforts, there is still a long path to walks until it could be possible to affirm that it exists a plug-and-play solution easy to implement.

Lack of strategy.

In addition to the previous point, some author highlight that is strongly recommended a previous standardization culture on the company, where every process is consistently documented, even if this documentation is on a physical format rather than digital.

The adoption of some managerial tools as the ones proposed by the Lean Manufacturing philosophy might help to reach an early adoption and easier implementation of the new digital tools that are proposed on this forth industrial revolution. This is because, studying these tools it is possible so see that a lot of them are inspired by the Toyota's managerial transformation, thus a previous implementation of it is highly recommended.

Data security.

Another possible issue to the implementation of this tools is the relevance than data takes. Normally all the solution proposed on the future of the industry are based on the utilization of Big Data stored on the cloud, computing all this data also with cloud applications, which have a lot of advantages that will be describe ahead but, the biggest obstacle to the utilisation of cloud services are security concerns. "Clearly, there is a major worry that sensitive company data are not really secure in the cloud and might be accessed by third parties. Further reasons for the neglect of cloud services include uncertainty about the geographical location where the company's data are stored and the applicable jurisdiction."(Schröder, n.d.)

2.1.4. The Labour and Economic Impact

"47 per cent of workers in the United States are in occupations that, with a high probability, can be automated over the next 10 to 20 years." (Frey and Osborne, 2013) From this quote it is possible to appreciate the expected impact of the digital technologies in labour market, that also will affect to economical and social aspects of any country. Besides, estimations may have overestimated the technological potential of the new solutions, it is crucial to be aware about the direction that they are pointing.

Taking in to account the productive perspective of the new revolution, some experts only point out the increasing of productivity levels, time saving in operations, rise of quality standards, energetical efficiency, safety of the work, etc. While others remark the social perspective, where human workforce could suffer the collateral effects of the digitalization, specially the unskilled labour which would receive the hardest impact. But, on the other hand, qualified labour demand would rise with the appearance of new technical necessities. As a result, where some see threats, others see opportunities.

As a conclusion, it is clear that industrial digitalization brings a lot of new advantages and improvements to the current systems. The effect of its implementation would improve multiple aspects of our society but it is interesting to have a wide perspective of the whole situation, where is possible to anticipate a transitorily situation until the situation get stabilized, in which could appear new problems that never have been faced before.

2.1.5. Required Framework to Reach a Proper Implementation

Another important aspect to have into account is the necessity of a proper infrastructure to support the implementation of digitalized systems at global level. The industries of the future will need to be surrounded by an equal high-tech infrastructure, especially in telecommunication affairs, but also in regulation, government support and availability of specialised workforce.

Fast Internet Connection

"Fast and more secure data connections are a basic condition for the realisation of Industry 4.0. International Telecommunication Unit (ITU) already defines a transfer rate of at least 2 Mbit per second as a minimum connection. This transmission rate is far from adequate for organising inter-company internet-based production or downstream services, such as the evaluation of real-time data. Stable high-speed transmission paths over fibre optic cable are needed for that.

As an example, Germany fibre optic coverage if only 1 per cent. In addition, small and medium-sized enterprises, especially in production, are often located in rural areas, where there is no fast fibre optic cable. Thus, the need of raise fibre optic coverage in a short time in order to unleash the potential of Industry 4.0 is crucial, besides basis of copper cables can be an interim solution because the achievable transmission speeds will not be sufficient in the future."(Schröder, n.d.)

State Support

"State support in Germany for specific Industry 4.0 projects, at least 450 million euros for a period of five to seven years." (Frauenhofer and Zenit, 2015) Support programmes are directed largely towards small and medium-sized enterprises, although large companies are not excluded.

Legal Framework

The data generated, stored, utilised and transferred in the course of automation, like the deployment of new application, technologies or product liability, rise numerous legal issues. Although these emerging issues are not really new, it can be very complex. The main problems that could appear are:

- Protection of corporate data: Data exchange between companies makes it possible for third parties to obtain an insight into their business strategies. It must therefore be clarified to whom the generated data belong and who is entitled to use them.
- Liability: Networked production means that the attribution of sources of error is not a simple matter without implementation of corresponding regulations on traceability procedures.
- Handling personal data: Networked production means that the attribution of sources of error is not a simple matter without implementation of corresponding regulations on traceability procedures.

(Schröder, n.d.)

2.2. Systematic Literature Review

2.2.1. Introduction to the Method

"The systematic literature review is used as a tool to generate a document where the reader could find a higher perspective of any matter studied. Inside a document of this kind, a large amount of literature is considered to be analysed, with the aim of identify and evaluated it critically to integrate all the relevant content in to a single piece. This piece has the aim of address all the different perspectives that literature would cover about any topic considers. But it is not just a mere recompilation of published document, also it has to be a more comprehensive study of the real state of the researched field, creating a perfect environment where objective conclusions can be reached." (Siddaway, n.d.)

The main characteristics of a high-quality literature review are the follows:

- Establish to what extent existing research has progressed towards clarifying a particular problem.
- Identify relations, contradictions, gaps, and inconsistencies in the literature, and explore reasons for these (e.g. by proposing a new conceptualisation or theory which accounts for the inconsistency).
- Formulate general statements or an overarching conceptualization (make a point, rather than summarizing all the points everyone else has made).
- Comment on, evaluate, extend, or develop theory.
- In doing these things, provide implications for practice and policy.
- Describe directions for future research.

2.2.2. Definition of the Phases

Scooping

Once that a foundation of this thesis has been stablished, it is time to start with the literature review. Following the previous phases explained, initial phase consists in create a solid group of search terms which will be use during an extensive search phase of publications. Having in mind that one of the main features is the coverage of all the possible perspectives relative to the topic, the main keywords and searches are going to be explore through synonyms, different ways of spelling, narrower terms, etc.

In addition, it is important to remark the different path that Industry 4.0 presents. The main aim of this paper is study the actual implementation of the digitalization of productive systems on the SMEs, its current development, impact and performance. As well as provide conclusions about a possible future of this trend. Because of this, the documentation searches will explore at least the most relevant paths that can be allocated, from the different technologies, going through driven social changes, to the influenced economics aspects of this modernization.

Planning

After the shallow search of general information about the Industry 4.0 and the digitalization of the SMEs, a wide field is open to be explore. This is why the search strategy will start basically with these 3 short and simple terms to be expanded, as a tree, along of it. Look for similarities and more specific terms, is interesting to discover what these short terms can inspire.

- Digitalization: Digital revolution, Internet of Thing (IoT), Internet of Services (SaaP), smart services, bigdata, cloud computing.
- SME: Networking, mass customization, SMBs (small and medium business).
- Industry 4.0: Cyber-Physical Systems (CPS), networked production process, Lean Manufacturing.

Once the key-words are defined, the different perspectives of the subject which are going to be considered have to be highlighted to introduce specific subtopics on the search of information. Despite how it has done before, the develop will start from the common topics that literature examine, to move on into more specific details of it.

➢ Economic Potential:	- Macroeconomics. - Flexible Production. - Falling Production Cost. - New Business Models.
➢ Obstacles:	- Lack of Strategy. - Data Security.
➢ Work World:	- Replacement of human workforce. - New way of interaction system - workers. • Automated. • Hybrid. • CPS just as a tool.
➢ Framework:	- Financing. - Skilled Workers. - Infrastructure. - State Support. - Legal Framework (Data treatment).

Table 1 Main topic observed on the literature. (Own creation, 2018)

Despite these perspectives are not going to be an active part of the search, in the sense that they are not going to be introduced on the search engine as keyword or will not be the subjects of scrutiny, they will be helpful to build a preliminary Inclusion - Exclusion criteria. As it will be expose ahead, on the performed searches record, data base's searches return more results than it is possible to be analysed, that is why preliminary criteria is necessary.

Using these criteria is feasible perform a quick review of all the results provided by the data base in base of the tittle as first step and the abstract as second one in case of doubts. Even though this approach seems to be too simplistic, it is only the start point of a search strategy which will provide specific results in base of the different perspectives what should be taken into consideration. The search process will be done following the natural path that the own subject sets.

Search

As the reader will realize, the search process is not static but just the opposite, it is an iterative process that should start again at the end of each "phase" adding the new information obtained. Since it is not possible to know all the different path from the beginning, the strategy we should follow will start with something simple and basic, using only main keywords. The literature found during this first steps will show new path to follow even before dive completely into its content, only with the tittle and the abstract, new info will be revealed. To perform this process properly is crucial to keep it on track constantly, creating a record of:

1. **Keywords Used**: Not only the word also the Boolean connectors, wildcard characters, truncation symbols, etc.
2. **Year of Publication**: Create a reasonable time window where cluster all the data. This would prevent use outdated information.
3. **Database**: If some part of the process should be review, this information will save tons of time.
4. **Number of Coincidences**: The number of results of each search is perfect to create a precise perspective of how the parameters used have performed. Where a high number would mean that the search maybe too wide for the porpoise but it is able to provide new path and, in the other way, a small number of results will mean that the information obtained will be really specific.
5. **Added Result**: Collecting all the sources that will be read afterwards is the most meaningful data. Once the source has past the first selection based on a relevant tittle and abstract where its content is summarized. It is important to do this record because even if some studies' outcomes are irrelevant and they are

excluded from the review, this file could reveal any new path to explore on successive searches.

Review

Regarding to the previous process, next natural step would be go deeper into the content of each selected paper analysing carefully all the information inside, putting special emphasis on the used language and specific terms that could open new path to investigate, likewise on the useful content linked to our topic. Inevitably, during the procedure, some papers that seem to be useful will be reveal at irrelevant or situated on the boundary of studied topic.

In this context, an extensive record of the read articles will help in a large amount of different ways. First of all, it will help readers understanding how many perspectives have been take into consideration, also it will create an introduction to the content that will be discussed afterwards, thus facilitating the understand of the made decisions. The record of the review literature has a wider scope than papers' abstract will cover, being focused on our inclusion/exclusion criteria, the important perspectives than should be cover and the specialised used language that could bring new keywords to future searches. But, specially, its main objective is keep on track any important information present on the document which will be used to cluster all the information by topic. Once that the information of every relevant paper would be clustered, it is going to analysed with a greater perspective of the showed problems seeking relevant conclusions that allow to enlarge the understanding of the whole affair, understanding, the past, the present and a possible future.

Chapter 3. Systematic Literature Review of Industry 4.0 on Manufacturing SMEs Field.

3.1. Literature Research

Following the previous strategy, different searches are going to be perform, starting with the initial data expose on the introduction of this paper to the subject of study. Even if the numbers of coincidences are too high at the beginning, this is a good sign because will provide new meaning to the following searches. Therefore, two different kind of records are going to be made, the first one will keep the information that link the main concepts with relevant fields to future searches, and the second one with the selected papers of each search.

3.1.1. Performed Searches Record

Search Number	**Database**	**Keywords Tittle & Abstract**	**Keywords Full Article**	**Number of Coincidences**	**Year**
1	Science Direct	"Industry 4.0"	-	751	All
Barreto, L., A. Amaral, and T. Pereira. 'Industry 4.0 Implications in Logistics: An Overview'. *Procedia Manufacturing* 13 (2017): 1245–52. https://doi.org/10.1016/j.promfg.2017.09.045.					
Reischauer, Georg. 'Industry 4.0 as Policy-Driven Discourse to Institutionalize Innovation Systems in Manufacturing'. *Technological Forecasting and Social Change*, March 2018. https://doi.org/10.1016/j.techfore.2018.02.012.					

Tjahjono, B., C. Esplugues, E. Ares, and G. Pelaez. 'What Does Industry 4.0 Mean to Supply Chain?' *Procedia Manufacturing* 13 (2017): 1175–82. https://doi.org/10.1016/j.promfg.2017.09.191.
Luque, A., M. Estela Peralta, A. de las Heras, and A. Córdoba. 'State of the Industry 4.0 in the Andalusian Food Sector'. *Procedia Manufacturing* 13 (2017): 1199–1205. https://doi.org/10.1016/j.promfg.2017.09.195.
Man, Johannes Cornelis de, and Jan Ola Strandhagen. 'An Industry 4.0 Research Agenda for Sustainable Business Models'. *Procedia CIRP* 63 (2017): 721–26. https://doi.org/10.1016/j.procir.2017.03.315.

Table 2 Search Number 1 (Own creation, 2018)

<table>
<tr><th>Search Number</th><th>Database</th><th>Keywords
Tittle & Abstract</th><th>Keywords
Full Article</th><th>Number of Coincidences</th><th>Year</th></tr>
<tr><td>2</td><td>Science Direct</td><td>SME OR SMB</td><td>Industry 4.0</td><td>423</td><td>All</td></tr>
<tr><td colspan="6">Issa, Ahmad, Dominik Lucke, and Thomas Bauernhansl. 'Mobilizing SMEs Towards Industrie 4.0-Enabled Smart Products'. Procedia CIRP 63 (2017): 670–74. https://doi.org/10.1016/j.procir.2017.03.346.</td></tr>
<tr><td colspan="6">Colangelo, Eduardo, and Thomas Bauernhansl. 'Usage of Analytical Services in Industry Today and Tomorrow'. Procedia CIRP, Factories of the Future in the digital environment - Proceedings of the 49th CIRP Conference on Manufacturing Systems, 57 (1 January 2016): 276–80. https://doi.org/10.1016/j.procir.2016.11.048.</td></tr>
<tr><td colspan="6">Ibarra, Dorleta, Jaione Ganzarain, and Juan Ignacio Igartua. 'Business Model Innovation through Industry 4.0: A Review'. Procedia Manufacturing 22 (2018): 4–10. https://doi.org/10.1016/j.promfg.2018.03.002.</td></tr>
</table>

Table 3 Search Number 2 (Own creation, 2018)

Search Number	Database	Keywords Tittle & Abstract	Keywords Full Article	Number of Coincidences	Year
3	Science Direct	SME OR SMB	Digitalization	577	All
Pereira, A.C., and F. Romero. 'A Review of the Meanings and the Implications of the Industry 4.0 Concept'. *Procedia Manufacturing* 13 (2017): 1206–14. https://doi.org/10.1016/j.promfg.2017.09.032.					
Gupta, Prashant, A. Seetharaman, and John Rudolph Raj. 'The Usage and Adoption of Cloud Computing by Small and Medium Businesses'. *International Journal of Information Management* 33, no. 5 (October 2013): 861–74. https://doi.org/10.1016/j.ijinfomgt.2013.07.001.					
Uhlemann, Thomas H.-J., Christoph Schock, Christian Lehmann, Stefan Freiberger, and Rolf Steinhilper. 'The Digital Twin: Demonstrating the Potential of Real Time Data Acquisition in Production Systems'. *Procedia Manufacturing* 9 (2017): 113–20. https://doi.org/10.1016/j.promfg.2017.04.043.					

Table 5 Search Number 3 (Own creation, 2018)

Search Number	Database	Keywords Tittle & Abstract	Keywords Full Article	Number of Coincidences	Year
4	Science Direct	SME OR SMB	Digitalization AND Manufacturing	298	2015 - Present
Erol, Selim, and Wilfried Sihn. 'Intelligent Production Planning and Control in the Cloud – towards a Scalable Software Architecture'. *Procedia CIRP* 62 (2017): 571–76. https://doi.org/10.1016/j.procir.2017.01.003.					
Schlegel, Andreas, Tino Langer, and Matthias Putz. 'Developing and Harnessing the Potential of SMEs for Eco-Efficient Flexible Production'. *Procedia Manufacturing* 9 (2017): 41–48. https://doi.org/10.1016/j.promfg.2017.04.028.					
Zhong, Ray Y., Xun Xu, Eberhard Klotz, and Stephen T. Newman. 'Intelligent Manufacturing in the Context of Industry 4.0: A Review'. *Engineering* 3, no. 5 (October 2017): 616–30. https://doi.org/10.1016/J.ENG.2017.05.015.					

Table 4 Search Number 4 (Own creation, 2018)

<table>
<tr><th>Search Number</th><th>Database</th><th>Keywords
Tittle & Abstract</th><th>Keywords
Article</th><th>Number of Coincidences</th><th>Year</th></tr>
<tr><td>5</td><td>Science Direct</td><td>Manufacturing SME</td><td>Industry 4.0</td><td>94</td><td>2015 - Present</td></tr>
<tr><td colspan="6">Coreynen, Wim, Paul Matthyssens, and Wouter Van Bockhaven. ‘Boosting Servitization through Digitization: Pathways and Dynamic Resource Configurations for Manufacturers’. Industrial Marketing Management 60 (January 2017): 42–53. https://doi.org/10.1016/j.indmarman.2016.04.012.</td></tr>
<tr><td colspan="6">Moeuf, A., S. Tamayo, S. Lamouri, R. Pellerin, and A. Lelievre. ‘Strengths and Weaknesses of Small and Medium Sized Enterprises Regarding the Implementation of Lean Manufacturing’. IFAC-PapersOnLine 49, no. 12 (2016): 71–76. https://doi.org/10.1016/j.ifacol.2016.07.552.</td></tr>
<tr><td colspan="6">Spena, Pasquale Russo, Philipp Holzner, Erwin Rauch, Renato Vidoni, and Dominik T. Matt. ‘Requirements for the Design of Flexible and Changeable Manufacturing and Assembly Systems: A SME-Survey’. Procedia CIRP 41 (2016): 207–12. https://doi.org/10.1016/j.procir.2016.01.018.</td></tr>
<tr><td colspan="6">Soroka, Anthony, Ying Liu, Liangxiu Han, and Muhammad Salman Haleem. ‘Big Data Driven Customer Insights for SMEs in Redistributed Manufacturing’. Procedia CIRP 63 (2017): 692–97. https://doi.org/10.1016/j.procir.2017.03.319.</td></tr>
<tr><td colspan="6">Jun, Chanmo, Ju Yeon Lee, Joo-Sung Yoon, and Bo Hyun Kim. ‘Applications’ Integration and Operation Platform to Support Smart Manufacturing by Small and Medium-Sized Enterprises’. Procedia Manufacturing 11 (2017): 1950–57. https://doi.org/10.1016/j.promfg.2017.07.341.</td></tr>
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Table 6 Search Number 5 (Own creation, 2018)

After the searches performed all of the documents would be analysed to extract its main point, the most important information and find new paths for future searches. The previous selection has been done regarding to tittle and abstract of each paper, which summarize its content and give to the reader a quick glance to full content. This allow to the reader to assess if its content fits with his purpose.

Due a detected lack of information on 3 main points of the gather information, a few more searches have been performed to expand information about:

- Government support to Industry 4.0 initiatives with economical amount information.
- Particular application that could be implemented in shop floor.
- Relationship between Lean Manufacturing tools and Industry 4.0.

Search Number	Database	Keywords Tittle & Abstract	Keywords Article	Number of Coincidence s	Year
6	Science Direct	"Industry 4.0" OR "Industrie 4.0"	Government	118	All
Bortolini, Marco, Emilio Ferrari, Mauro Gamberi, Francesco Pilati, and Maurizio Faccio. 'Assembly System Design in the Industry 4.0 Era: A General Framework'. *IFAC-PapersOnLine* 50, no. 1 (July 2017): 5700–5705. https://doi.org/10.1016/j.ifacol.2017.08.1121.					

Table 7 Search Number 6 (Own creation, 2018)

Search Number	Database	Keywords Tittle & Abstract	Keywords Article	Number of Coincidences	Year
7	Science Direct	Shop Floor	"Industry 4.0" OR "Industrie 4.0"	53	2015 - Present
Müller, Rainer, Matthias Vette, Leenhard Hörauf, Christoph Speicher, and Dirk Burkhard. 'Lean Information and Communication Tool to Connect Shop and Top Floor in Small and Medium-Sized Enterprises'. *Procedia Manufacturing* 11 (2017): 1043–52. https://doi.org/10.1016/j.promfg.2017.07.215.					

Table 8 Search Number 7 (Own creation, 2018)

Search Number	Database	Keywords Tittle & Abstract	Keywords Article	Number of Coincidences	Year
8	Science Direct	Lean Manufacturing AND SME		130	2015 - Present
Hoellthaler, Georg, Stefan Braunreuther, and Gunther Reinhart. 'Digital Lean Production an Approach to Identify Potentials for the Migration to a Digitalized Production System in SMEs from a Lean Perspective'. *Procedia CIRP* 67 (2018): 522–27. https://doi.org/10.1016/j.procir.2017.12.255.					

Table 9 Search Number 8 (Own creation, 2018)

3.1.2. Selected Article Record

Principal Papers

Barreto, L., A. Amaral, and T. Pereira. 'Industry 4.0 Implications in Logistics: An Overview'. *Procedia Manufacturing* 13 (2017): 1245–52. https://doi.org/10.1016/j.promfg.2017.09.045.

Mainly focus on the logistic section of the Industry 4.0 paradigm, this article provides a good brief about the technology involved in a general vision of the Indutry4.0. Starting from the explanation of Cyber-Physical System and going through aspects like the future roll of the workforce, vertical & horizontal integration and the effect of government support, to culminate with the specific section of the supply chain that would be involve in this new revolution.

Relevant insights:

1. Enterprise Resource Planning (ERP).
2. Warehouse Management Systems (WMS).
3. Transportation Management Systems (TMS).
4. Intelligent Transportation Systems (ITS).
5. Information Security.
6. Decision – making efficiency.
7. Government Support.

Relevant keywords:

1. Cyber-Physical System.
2. Logistics 4.0.
3. Smart Factory.
4. Industrial Internet of Things (IIoT).
5. Big Data.
6. Cloud – Based Systems.

Missed Information:

1. MSEs perspective.

Reischauer, Georg. 'Industry 4.0 as Policy-Driven Discourse to Institutionalize Innovation Systems in Manufacturing'. *Technological Forecasting and Social Change*, March 2018. https://doi.org/10.1016/j.techfore.2018.02.012.

Providing a social perspective, this paper shows how the concept of the Industry 4.0 would be more effective as a tool in governments hands, which could be used to promote innovation on manufacturing sectors (Small, medium and large enterprises) with the academicals collaboration of research institutes, universities and consultancies groups rather than a spontaneous event drive by the flow of the technological development of the modern society.

Relevant insights:

1. Industry 4.0 as Policy-Driven.
2. Creation of Enterprises Clusters to enlarge the technology diffusion.
3. Collaboration of variated actors to create innovation.

Relevant keywords:

1. Plattform Industrie 4.0 (German Government project).

Missed Information:

1. Lack of information about involved technology.
2. Direct impact on companies.

Tjahjono, B., C. Esplugues, E. Ares, and G. Pelaez. 'What Does Industry 4.0 Mean to Supply Chain?' ***Procedia Manufacturing*** **13 (2017): 1175–82. https://doi.org/10.1016/j.promfg.2017.09.191.**

Addressing the topic from the supply chain perspective, this paper provides a high value information about the technology involve in the digitalization of manufacturing field. It links new digital techniques that could be applied with the impact on standard enterprises related with the industrial sector, not only presents a comprehensive set of KPIs, but also a SWOT analysis.

Relevant insights:

1. Introduction of KPIs to measure the impact of digitalized production.
2. It connects opportunities/threats between digital technologies and supply chain levers.

Relevant keywords:

1. Smart Factories.
2. Smart Industry.
3. Advanced Manufacturing.
4. Industrial Internet of Things (IIoT).
   Additive Manufacturing.

Missed Information:

1. SMEs perspective.

Luque, A., M. Estela Peralta, A. de las Heras, and A. Córdoba. 'State of the Industry 4.0 in the Andalusian Food Sector'. *Procedia Manufacturing* 13 (2017): 1199–1205. https://doi.org/10.1016/j.promfg.2017.09.195.

Even though the presentation of the article was promising, due the dominance of the Andalusian food sector by multitude of small independent companies, the article analyses food sector as a whole, missing a detailed study about how digitalization could affect to SMEs on a strategic a sector as could be food and beverage industry, which also presents a lack of automatization.

Man, Johannes Cornelis de, and Jan Ola Strandhagen. 'An Industry 4.0 Research Agenda for Sustainable Business Models'. *Procedia CIRP* 63 (2017): 721–26. https://doi.org/10.1016/j.procir.2017.03.315.

This article discusses an interesting point of view related with the industry 4.0 from a sustainable manufacturing strategy. Seeking the responsibility of companies to design for environment, remanufacturing, implement reverse logistics and waste management, including how the new digital opportunities can help to make it feasible.

Relevant insights:

1. Application of smart factories to facilitate remanufacturing and recycling practices and a reduction of non-renewable resources.
2. Include customers as part of the value creation through the interconnectivity of smart products.

Relevant keywords:

1. Reverse logistics.
2. Waste management.
3. Sustainable Industry 4.0.
4. Smart Products.

Missed Information:

1. SMEs perspective.
2. Involved technology.

Issa, Ahmad, Dominik Lucke, and Thomas Bauernhansl. 'Mobilizing SMEs Towards Industrie 4.0-Enabled Smart Products'. *Procedia CIRP* 63 (2017): 670–74. https://doi.org/10.1016/j.procir.2017.03.346.

Analysing the topic directly from the SMEs perspective, this article exposes really interesting information about the current situation of the implementation of digital technologies on manufacturer SMEs, pointing out different projects that have been promoted by governments and private companies around the world.

Relevant insights:

1. It shows clearly the commitment of different government to promote Industry 4.0 in SMEs.
2. Particular characteristics of SMEs that make challenging Industry 4.0 implementation.
3. Key features of SMEs that would be affected by the digitalization.

Relevant keywords:

1. Plattform Industrie 4.0.
2. I4.0.
   Factories of the Future (FoF).

Missed Information:

1. SMEs perspective.
2. Involved technology.

Colangelo, Eduardo, and Thomas Bauernhansl. 'Usage of Analytical Services in Industry Today and Tomorrow'. ***Procedia CIRP*****, Factories of the Future in the digital environment - Proceedings of the 49th CIRP Conference on Manufacturing Systems, 57 (1 January 2016): 276–80. https://doi.org/10.1016/j.procir.2016.11.048.**

Focused on the data generated by people and machines, it proposes a new model with Data Analysis as main solution to rising production complexity. The paper shows to be a bit out bordering the topic discussed here but it gives some interesting glances over how SMEs can approach this problem.

Relevant insights:

1. Modularization of Data Analysis (Industry 4.0) to create an affordable solution to SME.
2. It considers the data analysis as a key feature to overcome future production complexity.

Relevant keywords:

1. Big Data.
2. Small Data.
3. Data Mining.
4. Neuronal Networks.
5. Machine Learning.

Missed Information:

1. Focused on the data, it misses all the other perspectives of involved technology.

Ibarra, Dorleta, Jaione Ganzarain, and Juan Ignacio Igartua. 'Business Model Innovation through Industry 4.0: A Review'. *Procedia Manufacturing* 22 (2018): 4–10. https://doi.org/10.1016/j.promfg.2018.03.002.

The author Ibarra in his article "Business model innovation through Industry 4.0: A review" make a great summary about how the industry 4.0 could affect to different parts of companies' business models which shows all the power of that digital technologies brings.

Relevant insights:

1. Gathering of possible change that enterprises will suffer to embrace the digital revolution.

Relevant keywords:

1. Fourth Industrial Revolution.

Missed Information:

1. Specific effects on SMEs.
2. More detailed economic analysis of possible costs and revenues of the adoption of digital strategies.

Pereira, A.C., and F. Romero. 'A Review of the Meanings and the Implications of the Industry 4.0 Concept'. *Procedia Manufacturing* 13 (2017): 1206–14. https://doi.org/10.1016/j.promfg.2017.09.032.

This paper provides a great global vision about what can imply digitalization of manufacturing sector, studying the issue from a large number of perspectives (technologically, socially, economically, etc.)

Relevant insights:

1. Great summary of different aspect that digital manufacturing could affect.

Relevant keywords:

1. Smart Machines.
2. Augmented Operator.

Missed Information:

1. Specific effects on SMEs, even though expose interesting statements that can be applied on the SMEs field.

Gupta, Prashant, A. Seetharaman, and John Rudolph Raj. 'The Usage and Adoption of Cloud Computing by Small and Medium Businesses'. ***International Journal of Information Management*** **33, no. 5 (October 2013): 861–74. https://doi.org/10.1016/j.ijinfomgt.2013.07.001.**

On this paper, it is possible to find great arguments about how the cloud computing services can impact positively and why on the SME. Even it has been on 2013 the main statements done on it are still valid nowadays.

Relevant insights:

1. Great analysis of the SMEs point of view about how they will face the cloud computing technology.
2. Economic analysis.

Relevant keywords:

1. Cloud computing.
2. Software-as-a-Service (SaaS).
3. Platform-as-a-Service (PaaS).
4. Infrastructure-as-a-Service (IaaS).

Missed Information:

1. Rest of technologies that could be implemented to complement the cloud computing service.

Uhlemann, Thomas H.-J., Christoph Schock, Christian Lehmann, Stefan Freiberger, and Rolf Steinhilper. 'The Digital Twin: Demonstrating the Potential of Real Time Data Acquisition in Production Systems'. ***Procedia Manufacturing*** **9 (2017): 113–20. https://doi.org/10.1016/j.promfg.2017.04.043.**

This paper shows how real data acquisition is import to ensure a successful implementation of the digital manufacturing but it does not go into detail of technology or how it will impact in any further way than the previous papers. Even though is present an interesting model about the learning process of the personal involved on the industry 4.0 this paper is outbound of the aim of this study.

Erol, Selim, and Wilfried Sihn. 'Intelligent Production Planning and Control in the Cloud – towards a Scalable Software Architecture'. *Procedia CIRP* 62 (2017): 571–76. https://doi.org/10.1016/j.procir.2017.01.003.

Even it is not reflected on the tittle, this work is completely focused on the productive SMEs. For this reason, it provides meaningful statements about the main challenges that the SMEs should face nowadays, that could be linked with the previous technologies that have been studied from the previous documents.

Relevant insights:

1. Great data about challenges on the productive SMEs.
2. Impact of the digital technologies on SMEs.

Relevant keywords:

1. Cloud-based manufacturing.
2. Process- oriented information systems (PAIS).

Missed Information:

1. Government and social perspective.

Schlegel, Andreas, Tino Langer, and Matthias Putz. 'Developing and Harnessing the Potential of SMEs for Eco-Efficient Flexible Production'. *Procedia Manufacturing* 9 (2017): 41–48. https://doi.org/10.1016/j.promfg.2017.04.028.

On this study is possible to find new solutions for the SMEs problems. These solutions are based on productive SMEs from Germany which seems to be the country leading the investment to digitalise this sector. All the expose ideas are currently in early beta phase but provide a glance about the direction that this technology will take.

Relevant insights:

1. New models of how people will interact with the different parts of the productive system.
2. Challenges that SMEs will face to reach the necessary competitiveness.

Relevant keywords:

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Missed Information:

1. Financial information

Zhong, Ray Y., Xun Xu, Eberhard Klotz, and Stephen T. Newman. 'Intelligent Manufacturing in the Context of Industry 4.0: A Review'. *Engineering* 3, no. 5 (October 2017): 616–30. https://doi.org/10.1016/J.ENG.2017.05.015.

Going through every single technology expose on the previous papers, this one provides a really high-quality summary of different applications already working on multiple parts of the world. Although it is not focused on the SMEs, it has in consideration the productive sector and could be useful to understand better the technologies involved on the digitalization process.

Relevant insights:

1. Great study and explanation of each technology involved.
2. It exposes real examples where digitalization process has been implemented.

Relevant keywords:

-

Missed Information:

1. Perspective of the SMEs.
2. Financial analysis

Coreynen, Wim, Paul Matthyssens, and Wouter Van Bockhaven. 'Boosting Servitization through Digitization: Pathways and Dynamic Resource Configurations for Manufacturers'. *Industrial Marketing Management* 60 (January 2017): 42–53. https://doi.org/10.1016/j.indmarman.2016.04.012.

As many other papers expose before, this one analyses the new trend of complement products with services from a digital perspective. Even though is related with the studied topic, it does from the point of view about how to build the services to complement the products but it does not specify the technology more than the previous papers, thus it is out bounded.

Moeuf, A., S. Tamayo, S. Lamouri, R. Pellerin, and A. Lelievre. 'Strengths and Weaknesses of Small and Medium Sized Enterprises Regarding the Implementation of Lean Manufacturing'. *IFAC-PapersOnLine* 49, no. 12 (2016): 71–76. https://doi.org/10.1016/j.ifacol.2016.07.552.

This paper is in the limit of the topic studied but it has been added because it provides a great perspective of the SMEs characteristics that could stop the implementation of the new digital techniques exposed before. It is really useful to develop the theory of use Lean Manufacturing approach as the first step of the Industry 4.0.

Relevant insights:

1. SMEs characteristics related to the Lean Manufacturing implementation.
2. Global perspective of the current problems of the SMEs to adopt significant changes on its procedures.

Relevant keywords:

1. Lean Manufacturing.
   Management principles.

Missed Information:

1. Technological perspective.

Spena, Pasquale Russo, Philipp Holzner, Erwin Rauch, Renato Vidoni, and Dominik T. Matt. 'Requirements for the Design of Flexible and Changeable Manufacturing and Assembly Systems: A SME-Survey'. *Procedia CIRP* 41 (2016): 207–12. https://doi.org/10.1016/j.procir.2016.01.018.

Starting from the SMEs perspective, here it is possible to find a topic discussed by many papers before which is the flexibility that new trends on markets are demanding. The main strength of this paper is the fact that it develops main specifications of how the productive system should have to reach that necessary flexibility and changeability.

Relevant insights:

1. It exposes the main characteristics and fields of the demanded flexibility.
2. Backup his hypothesis with surveys on productive SMEs.

Relevant keywords:

1. Flexible Manufacturing Systems (FMS)
   Changeable Manufacturing Systems (CMS)

Missed Information:

1. Technological perspective.

Soroka, Anthony, Ying Liu, Liangxiu Han, and Muhammad Salman Haleem. 'Big Data Driven Customer Insights for SMEs in Redistributed Manufacturing'. *Procedia CIRP* 63 (2017): 692–97. https://doi.org/10.1016/j.procir.2017.03.319.

This paper could be consider relatively out bounded because is focused on the new trend that highlight the importance of complement products with services of different kinds. All these services normally take advantage of Big Data potential to predict client necessities before they have to express it or even before the know it. The good point of this paper is that expose relevant information about how this new trend could affect to the SMEs economically.

Relevant insights:
1. Advantages of Big Data + Cloud Services to SMEs.
2. Perspective of how SMEs can afford the manufacturing digitalization.

Relevant keywords:
1. Redistributed manufacturing (RdM).

Missed Information:
1. Deep technological perspective.
2. Specific services that could be more useful to SMEs

Jun, Chanmo, Ju Yeon Lee, Joo-Sung Yoon, and Bo Hyun Kim. 'Applications' Integration and Operation Platform to Support Smart Manufacturing by Small and Medium-Sized Enterprises'. *Procedia Manufacturing* 11 (2017): 1950–57. https://doi.org/10.1016/j.promfg.2017.07.341.

Focused on how new applications can be implemented, this publication shows a specific model of how can be done, explaining some relevant insights previously expose by others papers. It is interesting to have it in to account because can clarify some technologies already explained.

Relevant insights:
1. Specific model of how a cloud base application could be applied.
2. Advantages and challenges to SMEs using cloud base applications.

Relevant keywords:
1. Applications' integration and operation platform (AIOP)

Missed Information:

-

Auxiliar Papers

Bortolini, Marco, Emilio Ferrari, Mauro Gamberi, Francesco Pilati, and Maurizio Faccio. 'Assembly System Design in the Industry 4.0 Era: A General Framework'. ***IFAC-PapersOnLine*** **50, no. 1 (July 2017): 5700–5705. https://doi.org/10.1016/j.ifacol.2017.08.1121.**

From a really informative perspective, this paper exposes the Industry 4.0 technologies, impacts, evolution and development. Although, it presents economic data about government initiatives with the amount invested. Together with other previous paper is really useful to create a comprehensive frame.

Hoellthaler, Georg, Stefan Braunreuther, and Gunther Reinhart. 'Digital Lean ProductionAn Approach to Identify Potentials for the Migration to a Digitalized Production System in SMEs from a Lean Perspective'. ***Procedia CIRP*** **67 (2018): 522–27. https://doi.org/10.1016/j.procir.2017.12.255.**

This paper demonstrates the state of the art regarding lean production as wells as digitization and presents digitization as the next step of lean management in production systems. This study reveals the demand for a methodological approach in a SME environment that quantifies the profitability of the implementation of digital technologies in lean production systems.

Relevant insights:

1. Relation between lean manufacturing and digitalization.
2. Study the case from SMEs' perspective, including the economic issues.

Relevant keywords:

- -

Missed Information:

1. Technologies involved.
2. Implementation model of the digitalization on SMEs.

Müller, Rainer, Matthias Vette, Leenhard Hörauf, Christoph Speicher, and Dirk Burkhard. 'Lean Information and Communication Tool to Connect Shop and Top Floor in Small and Medium-Sized Enterprises'. *Procedia Manufacturing* 11 (2017): 1043–52. https://doi.org/10.1016/j.promfg.2017.07.215.

This paper shows real applications that could be implemented on a near future on productive SMEs going deeper in to the technology, the steps to implement it as well as how this fact affects working methods of employees.

Relevant insights:

3. Close approach to the effects on digitalization on that affect shop floor.
4. Real prototype of how industry 4.0 could be.
5. Take into consideration the perspective of SMEs on these changes.

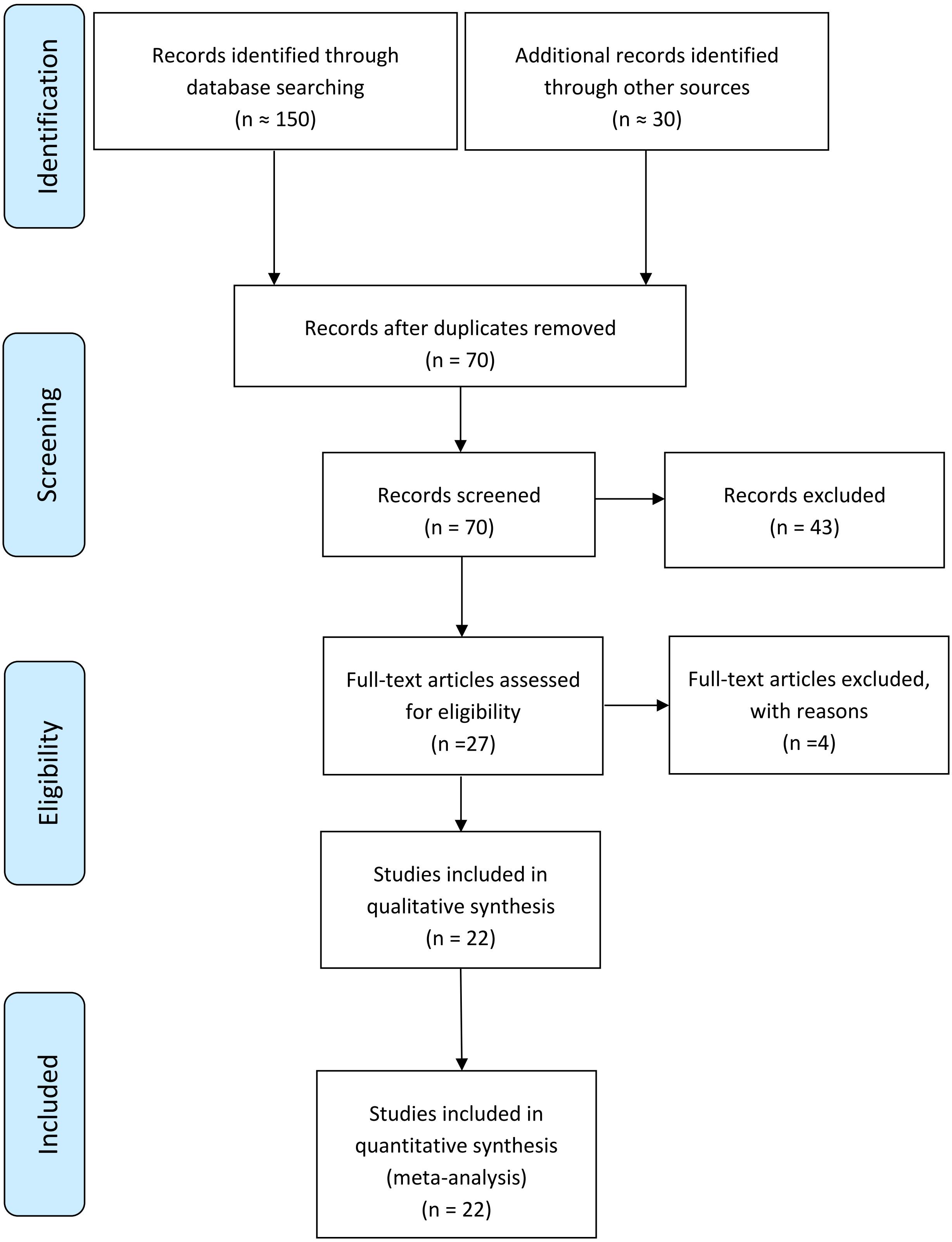
Relevant keywords:

1. Enterprise Resource Planning (ERP)
2. Manufacturing Executive Systems (MES)
   Shop floor-information-application (SIA).

Missed Information:

1. Economic analysis

3.1.3. PRISMA Flow Diagram



3.2. Clustered information and discussion.

In this section, all the main topic detected on the literature are going to be collected, allowing to compare the different points of view existent on the literature. As it has been exposed before, the discussed topic has many perspectives or subcategories that should be treated separately. For this reason, the organization of the collected information will star with the most relevant and generic topic about the digitalization of productive system, to move deeper into the question.

The study of the documentation will start defining what is the strategic plan behind the concept Industry 4.0 and what the experts expect of its application to the manufacturing sector. This mean leaving aside for a moment the social impact and the SMEs perspective, this section will start explaining the theory about the manufacturing process digitalization, how this change affects to every character on the value chain and how every aspect could change in a future when this trend will be developed fully. These activities include:

- Cyber – Physical Systems (CPS): This concept is typically used to describe a whole value chain that is interconnected digitally, sharing information in real time and reacting according with this information in a quasi-automated way. This will be a starting point to see how the digitalization will affect to factories as a whole, to move after it to the detail on every player of the value chain.
- Impact on Shop Floor: Section focused on how shop floor is going to be affected, explaining in detail different prototypes of solutions that could be implemented in a future. How the shop floor will interact with the demand changes, the increase of flexibility and mass customization of products.
- Impact on the Supply Chain: As a key character and one with higher management complexity, supply chain also will be deeply affected mainly in how they receive information from clients and supplier, but also how they can handle better their own information, that now, can be generated automatically by the own products.

After a quick glance of what are the expectation of the technologies on the previous sections. Next step will analyse new involved technologies. This point is going to explain deeply which those innovations are, their actual state of development and their feasibility. Moreover, in this section the SMEs perspectives of the problem take relevance because different kinds of technology, their complexity and their cost create a huge gap between what could be really promising to big corporation but impossible to afford for SMEs.

Continuing through the SMEs issue, this will be the most important part of the development of this document, where the affordability, benefits and challenges to the

SMEs are going to be exposed. The analysis will focus on how they can implement these new technologies to improve their position in a market that has becoming more and more competitive over the years due globalization.

3.2.1 Cyber-Physical Systems

“Cyber-physical systems are considered as enabling technology that allows multiple innovative applications and also the innovation of an enterprise's business model. Cyber-physical systems refer to technical systems that are embedded into larger systems such as devices, buildings, infrastructures, and production facilities. Cyber-physical systems capture, record, and interpret data from the environment and react to signals in the environment. In contrast to other technologies, cyber-physical systems regulate themselves as they are able to communicate with both human actors and other devices both at a local and global level.”(Reischauer 2018)

“These recent developments have enabled not only the virtually endless possibilities of interconnecting human beings and machines in a cyber-physical system context using information obtained from different sources but also direct communications between machines. The implementation of this kind of network within the production and operations environment is termed Industry 4.0. (…) These new systems focus their resources on the introduction of intelligent products and industrial processes that will allow the industry to face rapid changes in shopping patterns”(Tjahjono et al. 2017)

“It is seen as networks of manufacturing resources that are autonomous, capable of controlling themselves in response to different situations, self-configuring, knowledge-based, sensor-equipped and spatially dispersed and that also incorporate the relevant planning and management systems”(Man and Strandhagen 2017)

“The term Cyber Physical Systems refers to the close conjoining of and coordination between the physical assets and their computational capabilities, where hardware and software components are deeply intertwined, demonstrating multiple and distinct behavioural modalities, and interacting with each other in diverse ways that change with context.” (Issa, Lucke, and Bauernhansl 2017)

Observing these four authors it possible to create a clear image of what they expect from the digitalization of the productive world. Based on multimodal set of sensors, future production systems should be able to react automatically to any detected change as well as to any change from the managerial sections, as could be:

- Trend adjustment on the forecasted demand.
- Changes on the production plan due urgent orders.
- Automated readjust of the production orders because component procurement restrictions.
- Automatic release of a maintenance order due a detected variation of abnormal function out of control parameters.

The data interpretation, computation and communications take relevance on any productive system as soon as unexpected event shows up. Assuming that production is already programmed, based on a demand forecast of a fixed time window, experience shows that even if that forecast had taken in to account all the available data, behaviour of included variables and had been optimised, random events impossible to predict will appear. These events that organizations can not anticipate might have external or internal origin, as could be a mechanical failure in a machine or a simple cancelation order from a client that was supposed to be fixed.

Nowadays, unexpected events generate endless problems to execute an optimised production planning due its lack of flexibility. Normally the reaction time of any system is a constraint but with the implementation of CPSs this reaction could decrease drastically thanks to the interconnected devices and departments of production systems.

Applications of CPSs

Industries/companies	Aims	Improvements	Future research
Power systems, USA and Canada	• CPS test bed implemented in RTDS and OPNET	• Providing a realistic cyber-physical testing environment in real time	• Studying CPS vulnerabilities in various power system models
Children keeper service, Korea	• Proposing a key design method for CPSs	• Designing CPSs with high-quality more feasibly and practically	• Data-driven CPS decision-making models
Water distribution networks, USA	• Integrated simulation method for reflecting the operation and interaction of CP networks	• Facilitating modeling CPSs	• Extending the models and techniques for other CPS domains
Civil structure, USA	• Developing and assessing CPSs for real-time hybrid structural testing	• Illustrating the feasibility of virtualizing CPS components	• Improving hydraulic actuator models • Quantifying further scalability of the proposed approach
Fire handling. China	• Developing a simulation model for emergency handling problems	• Obtaining optimal sensing and robot scheduling policies	• Increasing computational time for more complicated scenarios
Autonomous vehicles, USA and Germany	• Proposing a parallel programming model for CPSs	• Guaranteeing timeliness for complex real-time tasks	• Addressing the dynamic nature of CPSs in the proposed model
Intelligent manufacturing, Sweden and USA	• Associating a CPS with holons, agents, and function blocks • Using CPS to digitalize pneumatics with applications	• Ease of system implementation in decentralized or cloud environment • Maximized flexibility and advanced condition monitoring • Self-adjusting and self-adopting subsystem	• Practical in dynamic manufacturing with uncertainty • Time-sensitive networking for synchronized motion control • Distributed decision-making and self-organization between (sub)systems
Healthcare, Brazil	• Model-based architecture for validating medical CPSs	• Providing enough information to perform medical tests	• Proposing architecture for other medical device models
Communication, China	• Analyzing the features of machine-to-machine, wireless sensor networks, CPS, and the IoT • Reviewing home machine-to-machine networks	• Outlining the challenges related to CPS design	• Future design of CPSs

RTDS: real-time digital simulator; CP: cyber-physical.

Table 10 Examples of Cyber Physical Systems. (Zhong et al. 2017)

As it is possible to see in Zhong's article, fields where the CPS concept is applicable are multiple, from the healthcare system to autonomous vehicles. As an example, if this approach is implemented to a whole city, roads can know traffic flow at any moment and transmit this data to autonomous vehicles to recalculate the optimal route it in real time.

The example of the city looks outbound of the industrial field, but the same idea could be extrapolated to factory, a warehouse or an intermodal transport system, where the material flow would be optimised according to current situation. In somehow it is possible to assess that new digitalised era is oriented into the decision-making improvement as a first step, to move forward into an automatization of decision implementation in a future, as soon as decision making phase become trustable, being deeply tested and evaluated.

Human factor in Industry 4.0

One of the most interesting papers analysed is the one of Andreas Schlegela, Tino Langera and Matthias Putza where they expose how digital technology will affect productive SMEs and all the actors involved on it. They propose three scenarios about how workforce would interact with CPS:

- In the so-called **"Automation scenario"**, people are directed by CPS. Information is processed and distributed in real time. The intelligent cyber-physical systems control themselves and guide the employees. In this scenario, people either act as an executive body, which requires only a low level of qualification, or are responsible for the commissioning, monitoring and maintenance of CPS as highly specialized experts.
- In the **"Assistance scenario"**: people use CPS. Here, too, the information is processed and distributed in real time. Intelligent network objects, however, initiate decisions and provide information and services to employees. Ultimately, people decide individually or in the group, and optimize the processes and systems.
- In addition, a **"Hybrid scenario"** is discussed. This provides for a co-operative distribution of roles between people and intelligent CPS, based on current requirements and situations.

According to these scenarios, it is possible to forecast different developments in staffing and qualification requirements. Highly qualified specialists will be indispensable for future industrial value creation; jobs with low qualification requirements tend to become less. As a result of the demographic change.(Schlegel, Langer, and Putz 2017)

The interaction of workforce with CPSs, and how the definitive implementation of digital technology on factories will affect it, is one of the biggest issues that Industry 4.0 have to face. On the literature is possible to find evidences that human workforce is not even close to be replaced in short term perspective but it would be irresponsible to claim that will not be affected by digitalisation.

The different between the three scenarios is the occurrence probability, being more probable the "Assistance Scenario" in the short term, but it would be really hard to see a complete implementation the "Automation Scenario" in a few years, being "Hybrid Scenario" in the middle of them. It is possible to imagine a factory where staff use CSP as a tool to improve their productivity and efficiency, basing their decisions in the real time information that system could generate, process and provide. As a result, shop floor staff will need a new set of aptitudes and specialized knowledge on digital systems which they have to work with. This affirmation means that some unspecialized jobs that exist nowadays in the industry, in a few years would require abilities as good analytical analysis of the information, being familiarized with digital systems and great capability to be adapted to new situations, working under pressure. On the other hand, new job positions will appear to provide all the necessary services that CPSs' maintenance will require.

Main Features of the Industry 4.0	Main issues affecting traditional Business Model	Main requirements to face digital transformation
Interoperability	Networking and reduction of barriers	Standardization
Virtualization	Flexibility and personalization	Work organization
Decentralization of decision making	Individualized mass production	Availability of products
	Local production	New Business Models
Real-time capability	Low price	Know-how protections
Service orientation	Smart goods and services	Availability of skilled workers
Modularity	Fragmentation of the value chain	Research investment
	Globalization and decentralization of production	Professional development
	V-H integrated production systems	Legal frameworks

Table 11 Features, challenges and requirements related to the Industry 4.0. (Ibarra, Ganzarain, and Igartua 2018)

3.2.2 Direct Impact on Productive Systems

Concepts	Major characteristics	Supporting technologies	Major research	Applications
Intelligent manufacturing	• AI-based smart decision-making • Advanced automotive production • Adaptive and flexible manufacturing systems	• Big data processing • Advanced robotics • Industrial connectivity services • Last-generation sensors	• Advanced manufacturing decision-making models • Human-machine integration • AI-enabled machine learning • Machine-to-machine connectivity	• A smart manufacturing system with a portrait of an ISO STEP tolerancing standard • A product life-cycle test bed enabling intelligent manufacturing • Agent-based IMSs • Intelligent manufacturing planning and control systems
IoT-enabled manufacturing	• Auto-ID technology-based smart manufacturing system • Real-time data collection • Real-time visibility and traceability of production processes • Real-time manufacturing decision-making	• IoT • Wireless production • BDA • Cloud computing	• Real-time data-driven decision-making models • Real-time data visualization • SMO modeling • Models of SMO behaviors	• An RFID-based resources management system • An IoT-enabled smart construction production system • An RFID-based job shop WIP inventories management system • An RFID-enabled real-time production planning and scheduling system
Cloud manufacturing	• Manufacturing service distribution and sharing • Intelligent capability management • Manufacturing cloud service management	• Cloud computing • IoT • Virtualization method • Service-oriented technology	• Modeling of manufacturing resources and capabilities • Manufacturing services configuration • Manufacturing cloud architecture	• Data visualization in a cloud manufacturing shop floor • QoS-based service composition selection in a cloud manufacturing system • Smart cloud manufacturing using the IoT • A semantic web-based framework in cloud manufacturing

Auto-ID: automatic identification; STEP: standard for the exchange of product model data; QoS: quality of service.

Table 12 Key concepts of digitalization. (Zhong et al. 2017)

At this point, the focus is going to be on the implementation of previous scenarios to manufacturing sector, where some authors define a clear path to follow with multiple directions, where intelligent manufacturing, Internet of Things and Cloud Computing take a lot of weigh to reach the sector improvements.

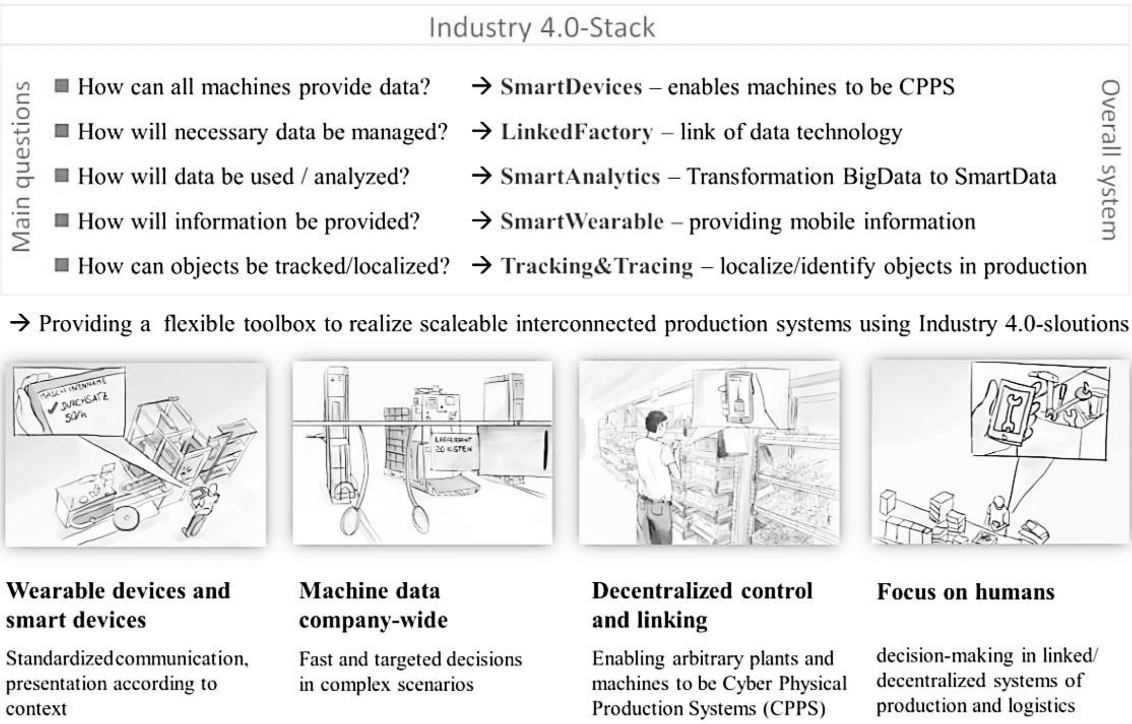


Figure 4 Intended Solution regarding the Industry 4.0. (Schlegel, Langer, and Putz 2017)

The previous sketch shows how authors imagine the future of the productive systems, as a group of interconnected smart personal devices, tuned with digital services, to bring information to systems users at any time, any where they need crucial information.

Involved Technologies

"Advanced robotics and artificial intelligence, hi-tech sensors, cloud computing, the Internet of Things, data capture and analytics, digital fabrication (including 3D printing), software-as-a-service and other new marketing models, mobile devices, platforms that use algorithms to direct motor vehicles (including navigation tools, ride-sharing apps, delivery and ride services, and autonomous vehicles), and the embedding of all these elements in an interoperable global value chain, shared by many companies from many countries. (…) Industry 4.0 also promotes the use of big data, IoT and Artificial Intelligence (AI) as one. This revolution envisages an environment whereby smart machines can communicate with one another, not only to enable the automation of production lines but also to analyse and understand a certain level of production issues and, with minimal human involvement, to solve them."(Tjahjono et al. 2017)

It is possible to anticipate the complexity of the exposed scenario, where a lot of new technologies have to works synchronized between them, and also, with the workers involved on productive system to create a digital ecosystem. First problem to face is the different level of development and implementation of each of these new techniques:

Smart Wearables

In the future factories, humans will have a strong creative role within a highly complex and flexible production. To support this role individually tailored information systems are required that provide only the information needed for a specific situation. These situations may include plant maintenance or economic evaluation. Depending on the actual context the information has to be displayed completely different or even transformed. Intuitive visualizations and interaction patterns support humans to fully focus on their actual work. As commodity hardware finds its way into production, the developed software is ready for use on multiple stationary or mobile devices (PC, smartphones, and tablets).

Smart Analytics

However, exposing the available data and linking it with sources from different systems allows for the generation of entirely new sets of information. This derived information can be used, for instance, to better cope with the complexity of modern production systems by empowering employees. A representative sample is the condition monitoring and prediction of a time to failure for observed productive components or resources. Physical sensors provide the required monitoring data and innovative algorithms aim to predict malfunctions of production components. By feeding methods of e.g. artificial intelligence efficient analysis may be enabled.

Product-ID

Localization are fundamental for future production environments with smart objects and seamless traceability of parts (Tracking & AutoID). Capturing and validating product data in real-time helps to avoid errors and increases control through improved quality monitoring and process logging. One of the problems is that not every identification technology is equally well suited for different use cases. Hence, innovative solutions combine RAIN RFID with other solutions like Bluetooth Smart or 2D bar codes.

"By using RFID technology, physical manufacturing flows such as the movements of materials and associated information flows such as the visibility and traceability of various manufacturing operations can be seamlessly integrated" (Zhong et al. 2017)

Cloud Computing

"Cloud computing is similar to an electricity grid, where resources like hardware, software, information are pooled and shared with the end-user via the internet, which is used as a medium of exchange. Users do not know the exact location of their digital data. The framework provided by cloud computing is in the form of high quality leased IT resources instead of building the IT infrastructure from scratch.

In the area of Data Analytics this approach means that using Cloud Computing main services, it is possible to define three implementation levels:

1. **Software-as-a-Service (SaaS):** Instead of installing software on the client's machine, applications like Word processing, CRM (Customer Relationship Management), ERP (Enterprise Resource Planning) are available over the internet for the consumption of the end-user. Users have multiple commercial vendors offering this service as: Yahoo Mail, Gmail, Hotmail, TurboTax Online, Microsoft Office Live, Google Apps, Salesforce.com, Cisco WebEx, SuccessFactors (HRM tool) etc.

- Using the user IT, provider's applications running on a cloud infrastructure avoiding to lunch updates as regular patches, frequent version upgrades etc., on user devices. Being the most mature cloud model, it can achieve economies of scale thanks to its modularity, giving to the user the option to choose which services exactly need and for how much time, through new business model on software license, month/year subscriptions.

2. **Platform-as-a-Service (PaaS):** Instead of buying the software licenses for platforms like operating systems, databases and middleware, these platforms and the software development kits (SDKs) and tools (like Java, .NET, Python, Ruby on Rails) are made available over the Internet. Commercial vendors include Microsoft Azure Services, Amazon Web Services (AWS), Salesforce's Force.com, Google App Engine platform, IBM Cloudburst, Amazon's relational database services, Rackspace cloud sites.
    - As a natural step forward of the previous model, these applications are created exclusively to the user that hire the service, being able even to modify the application to their personal necessities.

3. **Infrastructure-as-a-Service (IaaS):** This refers to the tangible physical devices (raw computing) like virtual computers, servers, storage devices, network transfer, which are physically located in one central place (data centre) but they can be accessed and used over the internet using the login authentication systems and passwords from any dumb terminal or device. Commercial vendors include Amazon EC2 (Elastic Compute Cloud), Elastic Block Storage (EBS) and Simple Storage Service (S3), Rackspace cloud servers, Joyent and Terremark." (Gupta, Seetharaman, and Raj 2013)
    - Without ownership of the infrastructure, users can access to provision processing, storage, networks, and other fundamental computing resources. Users can log in into the external system to use all its power, just sending a request and receiving the output of it, where all the computing process happens in the data centre.

In the case of analytical models, we speak of **Analytics-as-a-Service (AaaS)**. These are considered a special form of PaaS, as models provided by third parties can be purchased and executed on a cloud infrastructure." (Gupta, Seetharaman, and Raj 2013)

Exploring literature, it is possible to realise that cloud computing is one of the most promising concept on the digital world and, more important, it is already available with few offers that improve the previous software offer model, being cheaper, easier to maintain and more adaptable to user necessities. So many authors agree on its definition and how should be provided to companies.

"Despite the significant benefits of cloud computing, critical challenges affect the reliability of this ongoing concept. Researchers and service providers have conducted numerous studies to identify and classify issues related to cloud computing. (…) The most significant concern about cloud computing is related to:

- Privacy subjects and security.
- Data management and resource allocation.
- Load balancing, scalability and availability.
- Migration to clouds and compatibility.

Interoperability and communication between clouds reduce the reliability and efficiency of cloud-based systems, but with current advances in ICT, cloud computing can be considered as "the fifth utility," along with water, electricity, gas, and telephone." (Zhong et al. 2017)

This solution will provide a new level of flexibility never seen before, where users can access to their data anywhere through internet, with any device, independently of it computational power to execute really complex task just sending a request.

Internet of Things (IoT)

Internet of Thing involve the start of industry 4.0 implementation where production resources are converted into smart objects that can be tracked and interconnected to interact with the system automatically to develop any manufacturing process more efficiently and effectively according to the programmed logic. With IoT compatible devices, the interaction between humans and machines changes drastically, also machines with each other, based always in an intelligent perception.

IoT could be seen has the enabler of other branches of Industry 4.0 as the well-known Big Data concept, that will be explained, as well as the creation of an interconnected network inside factories, where information is share on real time to all the actors, allowing a quick decision making based on current requirements.

"RFID tags and readers are deployed to typical manufacturing sites such as shop floors, assembly lines, and warehouses, where smart objects are created by equipping manufacturing objects with RFID devices. This allows shop-floor disturbances to be detected and fed back to the manufacturing system on a real-time basis, thereby improving the effectiveness and efficiency of manufacturing and production decision-making. Several real-life cases of IoT-enabled manufacturing have been reported. To improve manufacturing flexibility, an RFID-enabled real-time production management system for a motorcycle assembly line was introduced. This manufacturing system is used in Loncin Motor Co., Ltd. to collect real-time production data from raw materials, work-in-progress (WIP) items, and staff so that items of interest are enhanced in terms of visibility, traceability, and trackability." (Zhong et al. 2017)

Industries/companies	Aims	Improvements	Future research
Smart community, Canada and China	• Neighborhood watch • Pervasive healthcare	• Value-added services such as utility management and social networking • Suspicious event detection in neighborhood watch	• Cooperative authentication • Detecting unreliable nodes • Target tracking and intrusion detection
A cloud implementation using Aneka, Australia	• Sharing data between application developers • IoT application-specific framework	• A seamless independent IoT working architecture • Open and dynamic resource provisioning	• Integrated IoT and cloud computing • Big data for IoT applications
Healthcare and social applications, USA	• Improving the quality of human life • Examining potential societal impacts	• Enabling ambient intelligence • Ubiquitous communication • Increased processing capabilities	• IoT theory for management and operations • IoT data complexity analysis • IoT-enabled global business and commerce
Machine-to-machine measurement, Ireland and France	• Easing the interpretation of sensor data • Combining domains	• Cross-domain connection • Improved performance • Enhanced interpretation from users	• Domain knowledge extraction • Interoperable ontologies and datasets
Smart cities, Padova, Italy	• Providing open access to selected subsets • Building an urban IoT system	• Improved energy efficiency • Reduced traffic congestion • Smart lighting and parking	• Smart city data analysis • Smart connectivity • System extension
IoT Gateway system, China	• Helping telecom operators transmit data • Controlling functions for sensor network	• Improved functions such as data display, topology, etc. • Enhanced data transmission	• Advanced IoT Gateway functions • Security management
IoT application framework, India and France	• Developing an IoT application framework • Implementing the methodology to support stakeholders' actions	• Improved productivity of stakeholders • Improved collaborative work	• Mapping algorithm cognizant of heterogeneity • Developing concise notion for Srijan development language • Testing support for IoT application development
IoT-enabled energy management, Italy and Spain	• Illustrating energy management at production level • Proposing IoT-based energy management in production • Providing a framework to support the integration of energy data	• Integrated energy data management • Improved energy efficiency • Enhanced energy data analysis	• Conventional hypothesis testing • System extension
IoT-enabled real-time information capturing and integration framework, China	• Providing a new paradigm of IoT to manufacturing • Designing a real-time manufacturing information integration service	• Real-time information capturing • Improved logistics	• Optimal production using captured data • Prediction model of production exceptions

Table 13 Application of IoT. (Zhong et al. 2017)

Thanks to the author Zhong, it is possible to see the variety of application where IoT are currently being used and its improvements on different sectors. As other technologies already explained, this one has the characteristics of being completely modular, allowing companies to implement it step by step according to they necessities and capabilities to invest.

Big Data Analysis

"Big data analytics is about two things. Firstly, big data – the gigabytes or terabytes of data that a company can hold. Secondly analytics – the tools and techniques that are used to analyse the data. A 21st century business will potentially have data from many streams such as emails, electronic business records, website logs, social media, production monitoring systems, etc. According to it, in the period up until 2003 a total of 5 exabytes (1018 bytes) of data were created by human beings, yet in the now in 2017, it takes only two days to create this amount" (Soroka et al. 2017)

The types of data that will be handled in the industry will come fundamentally from the sensory measurements and from the industrial information systems (ERP and CRM) already implemented, but also from external sources as could be the own market where company are operating. This means that the volumes of data handled in industrial environments are really large, this paradigm is completely new and until the emergence of Big Data did not exist but one of the first problems that must be faced is modelling and computing this data.

The need to understand and measure the different factors in such a way can predict its impact and quickly correct throughout the supply chain, makes crucial technological solutions for the identification and monitoring of risk factors inherent in the production environment. Using algorithms that evaluate the impact of risk factors in relation to the state of the supply and production chain, providing support for more agile and effective decision making would impact positively the industry in many aspects, being possible to archive a rise on quality of products as well as service level maintaining a competitive position on market.

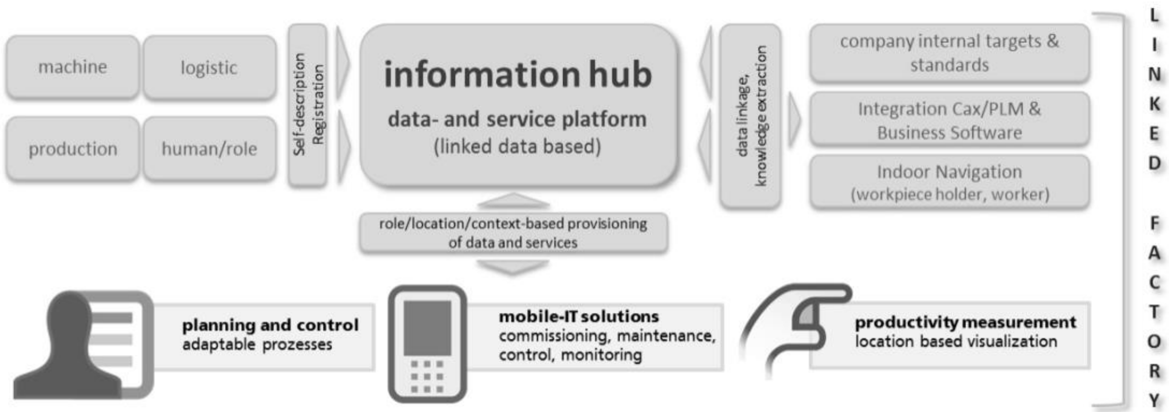


Figure 5 Components of a Smart Factory concept.(Schlegel, Langer, and Putz 2017)

Implementation Examples

Smart design

With the rapid development of new technologies such as VR and augmented reality (AR), traditional design will be upgraded and will enter into a "smart era." Design software such as computer-aided design (CAD) and computer-aided manufacturing (CAM) is able to interact with physical smart prototype systems in real time, enabled by three-dimensional (3D) printing integrated with CPSs and AR.

Connected machines

In Industry 4.0, smart machines can be achieved with the help of smart robots and various other types of smart objects that are capable of real-time sensing and of interacting with each other. For example, CPS-enabled smart machine tools are able to capture real-time data and send them to a cloud-based central system so that machine tools and their twinned services can be synchronized to provide smart manufacturing solutions. (Zhong et al. 2017)

Real time monitoring

Monitoring is an important aspect for the operations, maintenance, and optimal scheduling of Industry 4.0 manufacturing systems. The widespread deployment of various types of sensors makes it possible to achieve smart monitoring. For example, data and information on various manufacturing factors such as temperature, electricity consumption, and vibrations and speed can be obtained in real time.

Adaptive control

Production control can be achieved by developing cyber-physical production-control systems. Smart control is mainly executed in order to physically manage various smart machines or tools through a cloud-enabled platform. End-users are able to switch off a machine or robot via their smart phones.

Optimized scheduling

The smart scheduling layer mainly includes advanced models and algorithms to draw on the data captured by sensors. Data-driven techniques and advanced decision architecture can be used for smart scheduling. For example, in order to achieve real-time, reliable scheduling and execution, distributed smart models using a hierarchical interactive architecture can be used.

Impact on the Shop Floor

Thanks to some interesting articles that show minimum viable product (MVP) of their applications, the idea of how are going to be the future factories can be clarified. Müller for instance expose the idea of how Industry 4.0 should be applied at shop floor level in an assembly line. “Shop floor-information-application (SIA) : It consists of a production-app and smart devices such as tablet and smart pen.”(Müller et al. 2017). Muller’s idea is going to be summarize to the reader and analysed to link it with a future implementation on SMEs.

Information Transfer

Problems of Nowadays Information Transfer:

- Systems have grown historically as isolated applications, without suitable interfaces that enable the integration of further systems.
- Systems are stationary and often not very intuitive.
- Researches about: Consistent shared of data, complete integration of all systems and uniform structure of information to ensure data exchange have been performed but not completely implemented.
- Technology used: Barcode, quick response code or RFID (passive/active), to reduce gap between objects and information level.

Future Action to Optimize Production Processes:

- Disruption between real and virtual world should be reduced.
- Make current and comprehensive information available through a human - centred approach and socio-technical systems.
- Support the employee in its different roles by providing correct information for documented processes.

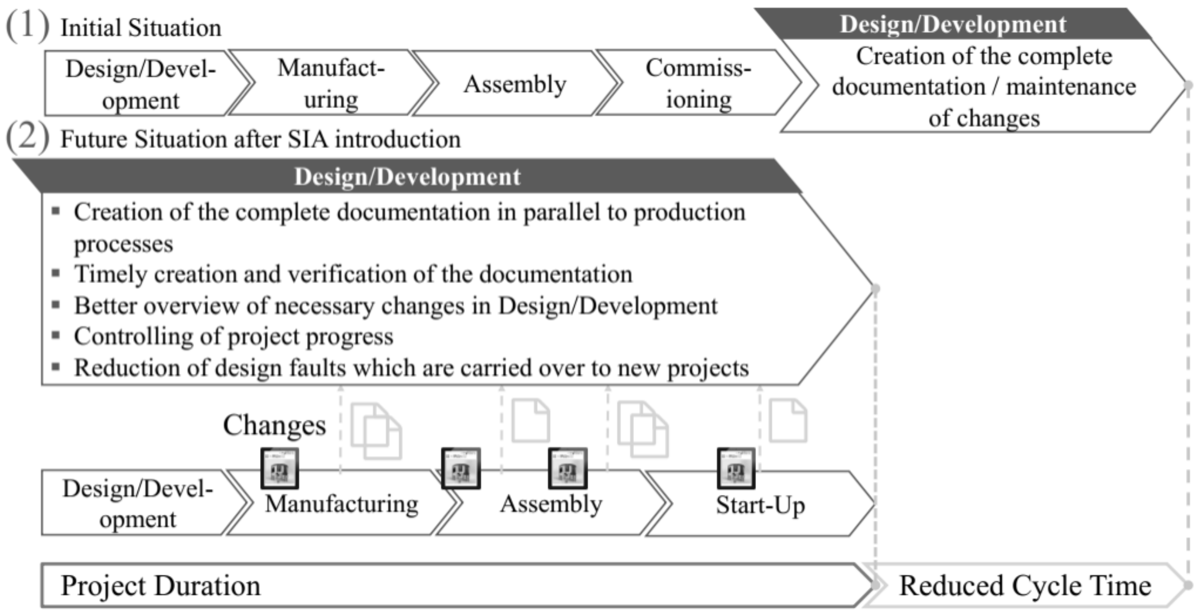


Figure 6 Advantages by using the SIA and new business processes. (Müller et al. 2017)

Through digitization and by digital gathering of changes on the shop floor, further significant saving potential is achieved. This enables the developers and designers to notify changes simultaneously to the production process. With the developed production-app this also reduces the chance that construction mistakes of machine modules are carried over to new projects. Because of the timely feedback after the detection of a mistake in shop floor the CAD data of these modules can be updated. Therefore, a shop floor information application, consisting of Smart Devices and production-app, is developed and implemented." (Müller et al. 2017)

The main problem cover here is documentation inaccuracy. When a worker starts a production or assembly order, normally he has all the technical documentation together with assembly parts, but sometimes, on technical documentation of different sources mistakes appears (Ref. numbers that do not match, changes on the assembly sequence that are not update, changes on the assembly procedures, etc.). Normally these mistakes are detected by workers and recorded as a handwrite note on the side of the production order, hoping this note escalate to the proper engineering department. Beside probably the engineering department are informed of this error and they corrected, the lag between correction and information transfer could create this desynchronization. Thanks to Müller solution, this lag would be reduced to its minimal values, where information transfer would be instant as soon as any change is save. But how it can be implemented on a production line?

Human-Machine Interface

"In the context of Industry 4.0, the human-machine interface requires a rethinking of all existing forms of work organization and efficient workplace design. Acceptance and motivation of the employees are a decisive criterion for the successful introduction and use of an application. Software-ergonomic user interfaces are a determining factor which allows the dialogue between human and machine. The process for designing interactive systems is described in norm "ISO 9241-210 ergonomics of human-system interaction". The norm provides a first orientation in dialogue design. DIN EN ISO 9241-110 contains seven principles regarding dialog design and represents a manual for the design of the user interface (software) and the developed system. The seven principles are adequacy, self-explanatory, controllability, expectation, fault tolerance, individualization and learning support." (Müller et al. 2017)

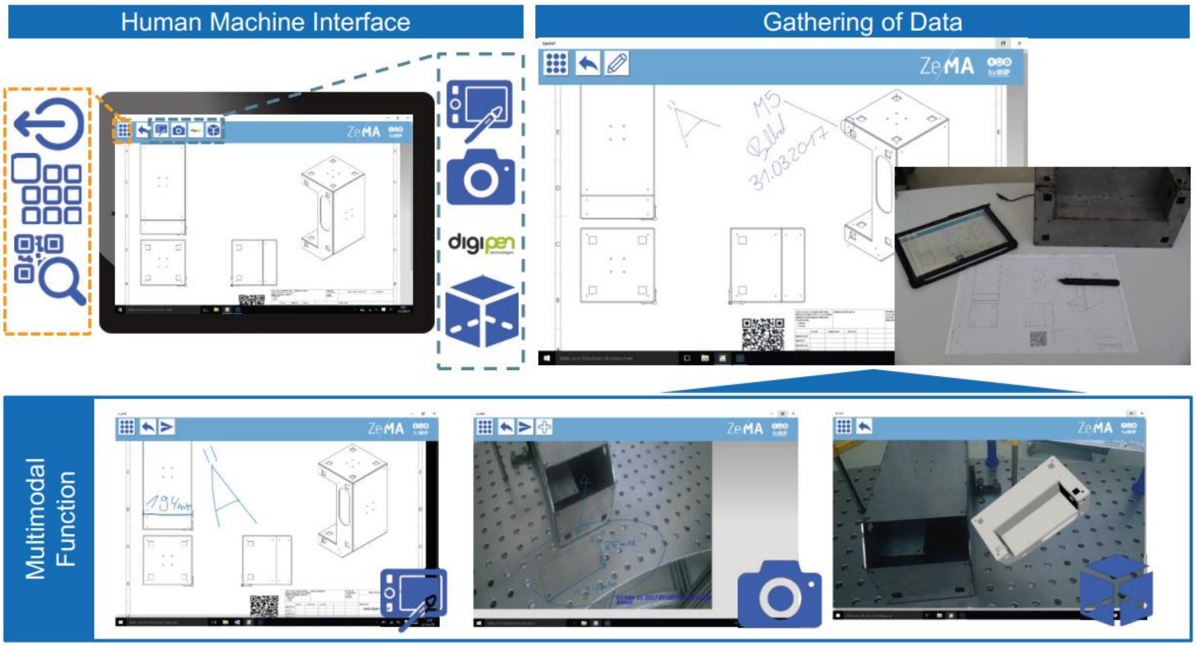


Fig. 5. Main functionalities of the production-app

Figure 7 Main functionalities of the production app.(Müller et al. 2017)

Main characteristics of the production app:

1. QR-Scan: The employee moves the tablet over the QR-Code on the technical drawing. Subsequently, a data download of the digital technical drawing from a server to the temporary memory of the Tablet-PC is carried out. As a result, the previously analogous drawing is visualized on the shop floor on the screen of the Tablet-PC.

2. Interactive information:
    a. Tablet-Pen: the employee can perform the following elementary tasks according to DIN EN ISO 9241-420: 2011: drawing, accurate pointing, fast pointing, selecting and pulling.
    b. Take Picture: It is conceivable that he takes a snapshot of a component that is still in production. The image of the component can thus be coupled with the technical drawing.
    c. Smart-Pen: After completion of the handwriting modification with the Smart-Pen, a digital twin of the analogue technical drawing is generated on the tablet.
    d. 3D-Model: While engineers, designers and foreman are able to read 2D drawings, customers, unskilled workers, salespeople, buyers, and suppliers often struggle with them. On the other hand, viewing a 3D representation does not require such technical knowledge

    After the information has been completed by one of the main functions, the changes noted on the technical drawing are sent to the development / design department. The transmission of the information is performed.

3. Send-Email: The email is received by the design/development department manager. The information gives him an overview on changes in the project. Considering all information and current projects, he can perform his capacity planning for his team. In the future, the production-app shall be extended with a capacity planning tool.

(Müller et al. 2017)

Impact on the Supply Chain

Speaking about the Supply Chain specifically, digital revolution will produce a big impact of this sector of manufacturing systems. As we can see on the previous proposition, just speed up information transfer could archive a huge improvement on efficiency, but with digital technologies also allow to increase information quality and accuracy. Specially on supply chain, the most promising technology is RFID and wireless transfer of small packages of information to support goods tracking in real time.

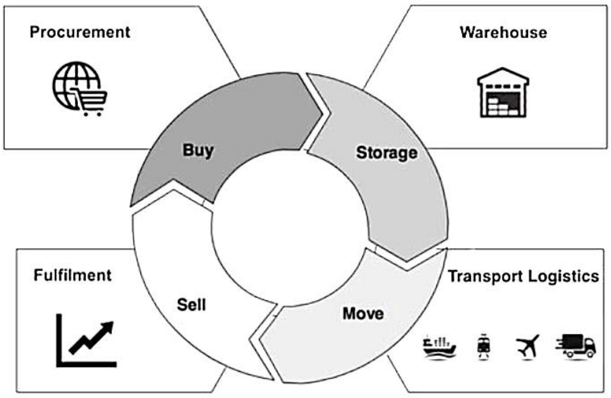


Figure 8 Supply Chain Levers. (Tjahjono et al. 2017)

Buy:

- Quality.
- Standard for the raw materials.
- Reject rate.
- Service level.
- Order accuracy.

Storage:

- Truck time at the dock.
- Accurate receipts received.
- Time from receiving to pick location.
- Labour hours consumed per order.
- Time from picked order to departure.

Move:

- Truckload capacity.
- Turnaround time.
- Shipment visibility.
- On-time pickups.
- On-time delivery.

Sell:

- Product availability.
- Customer experience.
- Response time.
- Time to market.

Technologies	Impact?	If Yes, Why?
Virtual and augmented reality	YES	It standardises how to perform the different processes involved when the truck arrives at the dock. It enables the reduction of the time.
Additive manufacturing – 3D Printing	NO	-
Simulation	NO	-
Big Data analytics	NO	-
Cloud technology	NO	-
Cybersecurity	NO	-
The Internet of Things	YES	All the devices and sensors enable the obtaining of data that can be used to increase the efficiency of the load and unload of the truck. It would result in reducing the time the truck is at the dock.
Miniaturization of electronics	YES	By using these elements, there is no need of checking the quality of the products received or the ones which are going to be delivered. This occurs because it is known in advanced the conditions of the products transported. It avoids "last time surprises" like inadequate quality or non-compliance of requirements.
Automatic Identification and data collection (AIDC)	YES	The exact position where items are located/need to be located at the truck are known in advanced. Moreover, the location and position of items inside the truck is also pre-established. It enables to save time.
Radio-frequency Identification (RFID)	YES	The exact position where items are located/need to be located at the truck are known in advanced. Moreover, the location and position of items inside the truck is also pre-established. It enables to save time.
Robotics, drones and nanotechnology	YES	Loading or unloading is done more efficiently and safely, for instance being able to transport different products of different sizes with one single pallet truck.
Machine-to-Machine Communication (M2M)	YES	It helps for instance to know the type of truck arriving with the number of carriers, the amount of items and the type of product among others. By using this information plan the materials required to unload or load in advanced is possible.
Business Intelligence (BI)	YES	By using all the information collected from different sources of the organization, it can be reduced the time the truck is at the dock by having all materials required in advanced. Helps to plan automatically and change plans if unexpected situations occur.

Table 14 Opportunities of digital technologies on warehouse . (Tjahjono et al. 2017)

Because it is one of the most complex element on a productive system, on every aspect of the supply process is possible to imagine improvements that few years ago might be impossible but take sense as soon as digital technologies are implemented. Although it is really promising, it is crucial to have in mind that a full implementation is really complex, requesting a lot of work, investment and knowledge of each specific process. But thanks to its modular nature, different digital technologies can be applied step by step, waiting to the best moment to invest.

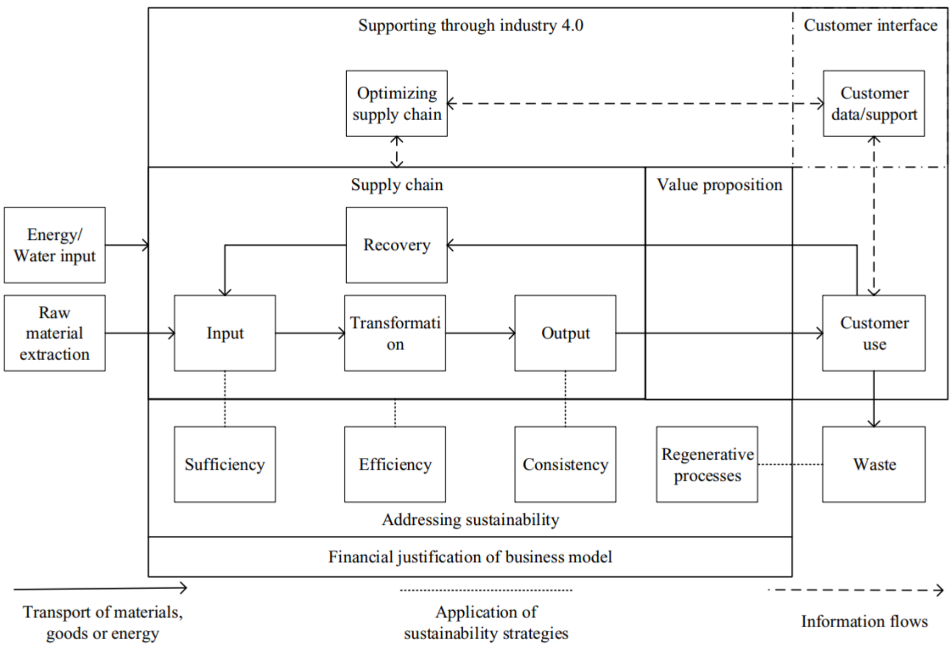


Fig. 1: Connecting sustainability and industry 4.0 to the business model, based on [2,8,10,16]

Figure 9 Connecting sustainability and Industry 4.0. (Man and Strandhagen 2017)

3.2.4. Implementation on SME – Challenges to Face and Financial Justification.

"SMEs are defined as businesses with annual sales turnover of not more than $100 million or employing no more than 200 staff. In OECD countries (Organization for Economic Cooperation and Development, Paris) more than 95% of the enterprises are SMEs. These SMEs provide 60–70% of jobs. Two thirds of all the EU (European Union) jobs are provided by SMEs. They provide 78% of the jobs in Japan. India has about 3 million SMEs accounting for 50% of its industrial output." (Gupta, Seetharaman, and Raj 2013)

"In the manufacturing sector 20 % of all enterprises are SMEs. They account for 59% of the employment in this sector and 44 % of the value added. About 80% of the value added is contributed by small and medium sized companies with more than 20 and less than 250 employees. The sectors where small and medium enterprises create almost half of the value added are machinery and equipment, fabricated metal products and food. Other important sectors for SMEs are rubber and plastics, chemicals and electrical equipment."(Erol and Sihn 2017)

Most of the time, SMEs are underestimated despite the important contribution that perform to economy at multiple levels, local, national and even international. Normally the discussion about innovation, digital revolution and Industry 4.0 is focused on big multinational companies but new technologies could produce even a more important impact applied to SME. In fact, some of previous proposal are completely out of the scope of a SME with limited resources, economical as well as professional knowledge, but other would be a huge revolution to this companies even if looks like a simplistic implementation or an early step of the total development.

However, productive and manufacturer SMEs have particular characteristics that are going to be exposed to justify how they can get benefits from Industry 4.0 paradigm. In first place, challenges due their nature are going to be reveal to create a clear idea of what should be improve and corrected, to afterward link these issues with digital solution previously analysed, always making emphasis in the feasibility of the implementation with SMEs' constrains.

Challenges

New technologies and globalization decrease the importance of economies of scale in many activities. Therefore, smaller firms potentially will have the chance to increase their overall contribution in the value chain, where SMEs have specific strengths and weaknesses. Typical problems faced by SMEs, which are even more acute in a globalized and technology-driven environment, are:

- Lack of financing and limited internal resources.
- Difficulties in exploiting technology (Lack of high-technical knowledge).
- Constrained managerial capabilities due lack of expertise.
- Low productivity volumes.
- Local management with short-term strategy.
- Non-functional organisation.
- Lack of method and procedure.

(Soroka et al. 2017; Rauch, Dallasega, and Matt 2017)

"SMEs are also the first-in-row to experience economic turbulences. In fact, SMEs disproportionately negatively contributed to employment decline during years 2008 to 2013 but also contributed disproportionately to the subsequent recovery in 2014. Among the most pressing problems that SMEs experience in recent years are an increasing competition, lack of financial resources, shortage of qualified staff and regulation. Production costs are a problem that SMEs face ever since due to a relatively (in comparison to large firms) high share of human labour in manufacturing processes.

Despite the reluctance to initiate and maintain cooperation SMEs are usually strongly embedded in a supply chain network where they are completely dependent of larger players. The competency, responsibility and costs of managing such a network is then out of their own hands, e.g. in the automotive sector, with the price of a strong dependency on the focal firm."(Erol and Sihn 2017)

Highlighting the last statement, SMEs on productive sector are normally linked to larger companies in somehow. It not strange to see industrial parks near production factories of big multinational that are full of SME providing services to this multinational. The nature of this services is really wide, from cleaning services to high-end technological solutions as well as providing subassembly parts or logistic services. Some examples could be: Almussafes on Valencia, related to Ford, Aeropolis on Seville, related to Airbus or the city of Wolfsburg, related to Volkswagen.

This larger companies lead the industry on determinate regions where they are surrounded of multiple SMEs working directly to them. As a result, large enterprises demand high quality level and professionalism to companies less capable than them, which push SME to improve their service level and quality their outcome products. Because their intrinsic power to negotiate, large companies create a competitive atmosphere between their supplier, who see a great opportunity on the implementation of digital technologies to stand out over competence.

Short-range Planning

For SMEs short-range planning is crucial as actual resource capacities need to be evaluated against the order situation and requested delivery dates. In many cases small enterprises have substantial problems to reliably evaluate their actual state of production regarding work load and inventory because:

- Data on inventory and work load often simply does not exist as adequate information systems are not available.
- In case a respective infrastructure exists, data is not always reliable as completion confirmation and inventory is not performed on a regular basis or is performed only on a coarse-grained process level.
- Data on qualifications and availability of staff, specifications of machines and their potential for flexibility is often missing or imprecise to be able to plan.

Control systems

"Control activities in SMEs are usually based on a combination of principles and technical systems, e.g. CONWIP or Kanban, that determines the rules and tools how orders are routed through production and which conditions must apply for a production process to be under control. In practice, SMEs have only limited knowledge of such control principles and therefore often adhere to simple first-in-first out (FIFO) principles for order release in combination with simple push control. The result is:

- High rate of delays.
- High inventory levels.
- Unbalanced human and technical resources.

"Control activities in SMEs require an approach that allows to implement simple control principles and scale them up to more sophisticated principles as an SME grows both in terms of order frequency and in terms of product variety. A key requirement for SMEs is the possibility to access actual data from the shop floor. Therefore, interfaces must be provided that allow for a rapid vertical integration of planning, control and execution layers."(Erol and Sihn 2017)

On Erol and Sihn statement about improve human – CPS interface, the Müller proposition called SIA represent a great solution to EMSs who, with an investment that fits their necessities, would improve drastically their control systems and procedures.

IT Systems

"Perhaps equally important consideration is that SMEs often do not have inhouse capabilities for the selection, installation, configuration and maintenance of complex IT systems. Such factors are a potential barrier to big data analytics in SMEs. However, the emergence of cloud computing, could provide a means to access complex IT systems. Studies have suggested that cloud computing will become attractive option for many SMEs due to its flexible cost structure and scalability. Although interoperability between cloud computing platforms / applications as well as cloud and 'desktop' systems may present challenges."(Soroka et al. 2017)

"Cyber-Physical Systems as well as production-oriented IT-systems, such as Enterprise Resource Planning (ERP) and Manufacturing Executive Systems (MES), are a standard to enable horizontal and vertical networking. With ERP and MES, a good starting point for the implementation of I4.0 technologies have already been created. However, the adjustments to the existing IT-system landscape require a high commitment of resources such as time, capital and labour. These resources can rarely be provided by SME. CPS and Lean production apps offer an adequate solution in order to achieve a complete networking on both the horizontal and vertical level, to control the scope of investment as well as to maintain existing and proven IT systems." (Müller et al. 2017)

High diversity on digitalization level of SMEs

"The environment and capabilities of SMEs related to manufacturing information are underdeveloped compared to those of large companies, due to practical limitations (cost, personnel, etc.) on their IT adoption. For this reason, SMEs need new strategies to build appropriate smart factories.

As each SME has a different level of manufacturing information and processes, the functions demanded of a manufacturing information system may also differ from one company to another. Also, it is very difficult to operate a manufacturing information system, and to procure and maintain qualified personnel to analyse the acquired data. Therefore, to facilitate a smart manufacturing environment for SMEs, a set of management strategies is needed in order to select, integrate, and operate the desired functions for each company."(Jun et al. 2017)

"On the business and organisational level challenges are the development of new business models and employee training, that are especially demanding for SME. SMEs need tailored information and implementation solutions that fit to their size and needs, in order to canalize and support this transformation. (…) I4KMU is a 3-year, funded project by the German Federal Ministry of Education and Research (BMBF) to support a new funding scheme focusing the rapid and targeted development of innovative Cyber-Physical Systems (CPS) and innovative smart products manufactured by German SMEs." (Issa, Lucke, and Bauernhansl 2017)

Opportunities

Aspect that SMEs should identify to evaluate industry 4.0 feasibility:

- Key Resources and Facilities.
- Key Infrastructure Capabilities.
- Core I4.0 Skills.
- Knowledge of Industrial Sectors (Markets).
- Awarded Standards.
- Size and location of the SME according to the SME criteria of the EU.
- Field of application such as logistics, manufacturing, assembly or research and development and further robotics, worker assistants or planning assistants.
- Information, characterizing the knowledge transfer between the I4.0 test environment and the SME, as required hardware and software infrastructure and competences.

Process Optimization

New enabling technologies such as Big Data, Cloud Computing, Collaborative Robots, Additive Manufacturing, Artificial Vision or Augmented Reality are introduced just to optimize the value creation architecture (key resources and activities) due to increasing efficiency and improving performance (reducing costs, time and failures, employee training, etc.). This could be the first step for traditional manufacturing companies to embrace the Industry 4.0 without addressing high risks.

Customer Interface Improvement

By the introduction of technologies, new ways of interaction through new or improved touchpoints are created, allowing a better understanding of customers' needs and greater customer experiences. Once internal and external process are optimized, this could be the next investment to add more value to the traditional business.

New Ecosystems and Value Networks

Sharing the uncertainty with other agents or achieving new required skills and resources from associates, due to the introduction digital enabler technology should provide vertical as well as horizontal integration through actors of the supply chain. By this way, “the focal firm’s value creation process is linked with the stakeholders’ processes. Moving from value chains to ecosystems and, in consequence, increasing stakeholders’ knowledge”. (Ibarra, Ganzarain, and Igartua 2018)

Flexibility

Describes the ability of a production system to adjust the manufacturing system very quickly and with little cost. In this context, the changes – possible reachable system states – are defined through predefined packages of measures and are limited by certain flexibility corridors at the time planning:

1. Variant flexibility: Ability to manufacture / to assemble more variants of a product.
2. Quantity flexibility: Ability to adapt the production system to fluctuating volumes.
3. Technology flexibility: the ability of manufacturing and assembly system to be used for a number of technologies.
4. Successor flexibility: ability to use equipment or parts also for future products.
5. External flexibility: ability to change the system by exchanging elements (example replacing robot gripper).
6. Internal flexibility: ability to change system without modifications (example automatic tool change).
7. Personnel deployment flexibility: ability to operate with more or fewer employees and with different qualifications.

Changeability

“Describes the ability of a factory or production system to switch from one product family to another, changing the production capacity accordingly. This can have an important influence on the production and logistics systems as well as on the building structure and the organizational or operational structure.” (Spena et al. 2016)

Cloud Computing

Although this concept has been explained before along with many other, cloud computer deserves special mention on SMEs' section due the potential that this technology has to influence drastically how they are working currently. In the literature, as soon as the subject is focus on SME, the cloud computing power is pointed out.

"Cloud technology, which has been on the rise in recent years, can be a very good alternative for SMEs with no IT infrastructure. One of the cloud services, software as a service (SaaS), systematically provides standardized applications online with no resource management of the program require. The use of the cloud-based applications' integration and operation platform (AIOP) to facilitate a smart manufacturing environment for SMEs. The suggested platform is provided for SMEs to use desired functions in the form of Software-as-a-Service."(Jun et al. 2017)

"Due to the subscription model on software, there is a huge cost savings for small firms. The entry cost for small firms utilizing business analytics, which needs lots of computing power, has been lowered. A 70% cost reduction has been observed since adopting AWS (Amazon Web Services) as the cloud vendor. AWS has also reduced their prices a couple of time, in the past three years, in spite of the absence of competitive forces. European SMEs, who are more risk averse, compared to USA SMEs, appreciate this reduction of fixed IT assets cost as well reduction of maintenance costs of IT assets, resulting in lowering the entry barrier."(Gupta, Seetharaman, and Raj 2013)

Based on the model explained before, SaaS provide the best opportunity to SME to find a solution that can be adapted to their necessities without invest too many time or internal resources to its development and maintenance.

Benefits:

- Service-based approaches reduce the Total Cost of Ownership (TCO).
- Economical subscription fees to managerial applications as:
    1. ERP (Enterprise Resource Planning)
    2. CRM (Customer Relationship Management)
    3. SFA (Sales Force Automation)
    4. SCM (Supply Chain Management)
- SMBs find the cloud easy to use, convenient, adequately secured for their business and their business privacy is well protected.

- Avoid costs of buying and maintaining their own datacentre.
- Ease of use and convenience proposition for SMEs that can access their data anytime, anywhere via any connected device.
- Possibility to share and collaborate with other companies in highly competitive environment.

"Small firms can now get their latest office applications from a reputed branded company like Microsoft (US$ 6 per user per month for up to 50 users). This is an affordable price for small business. On the other hand, Google Apps has small business pricing of US$ 5 per user per month or US$ 50 per user per year with no restrictions on number of users" (Jun et al. 2017)

"One of the biggest advantages of moving to cloud computing is the opportunity cost of freeing up some of the IT administrative time, which can now be applied to the business aspects of growing the core business of SMBs. Due to cloud computing, innovation is nurtured as the entry barrier (in terms of cost) gets lowered."(Gupta, Seetharaman, and Raj 2013)

On balance, cloud computing gives multiple benefits to any company in terms of interoperability, productivity, efficiency and capabilities to compete with larger companies at same level. Especially for SME, this kind of specifications on their operations would be impossible to afford in a more traditional way, without the help that digital technologies provide with models as monthly/yearly subscription.

As we did before, it is really interesting to analyse how Müllers fits his solution to improve the interaction between CPS and users, using the cloud computing as an enabler to his implementation. Where he saw the main limitation of his solution on the initial investment on IT equipment and development cost, now, thanks to the new cloud computing business model, this constrain can be overcome.

"A concept or a technological development, which supports the employee in SMEs in the reception and provision of context-related information on the shop floor and which distributes this information to organizational departments, according to needs and requirements, does not currently exist. (...) To cut costs and increase efficiency and flexibility, especially small and medium-sized enterprises would benefit most while using Cloud Computing. They can use the benefits for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction."(Müller et al. 2017)

Evolution from Lean Manufacturing Philosophy

Going through the literature is possible to find some authors that support the idea about digitalization is the natural step forward of lean manufacturing approach. This idea has multiple implication to Industry 4.0, specially on SMEs, where is possible to notice a serious lean manufacturing lack in terms of implementation, but on the other hand define perfectly the path to follow for companies that look at digitalization with uncertainty because high investment, advanced knowledge and internal process changes.

"Digitization should be applied when lean principles are carried out and manufacturing processes are geared to each other – e.g. resulting in robust processes, consequent reduction of processing times, accuracy and elimination of waste – in order to have the basis for an economical implementation for digital technologies. Furthermore, digitization should be perceived as supporter of lean manufacturing. The symbiosis of lean and digital is expected to have high potential regarding the containment of complexity and raising flexibility as well as efficiency and productivity, but the implementation of lean processes and digital technologies is often conducted rudimentally."(Hoellthaler, Braunreuther, and Reinhart 2018)

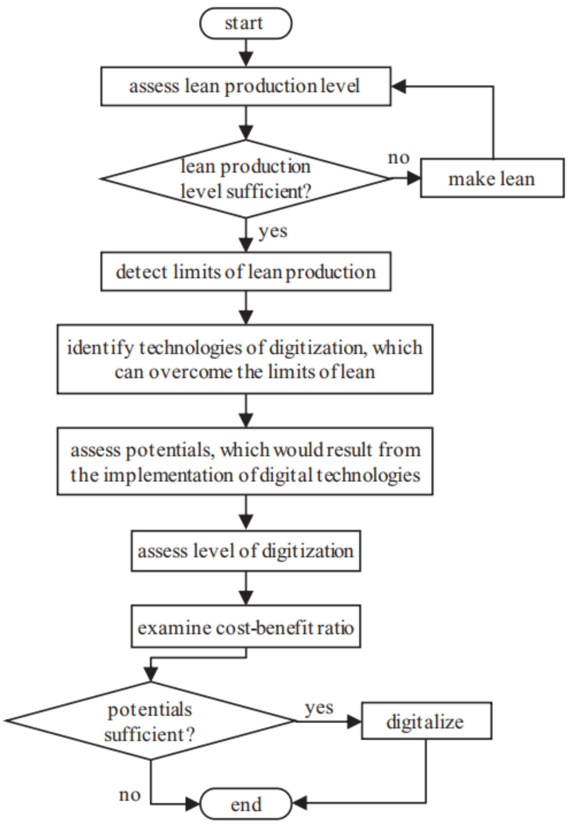


Figure 10 Model for the identification profitable digitalization. (Hoellthaler, Braunreuther, and Reinhart 2018)

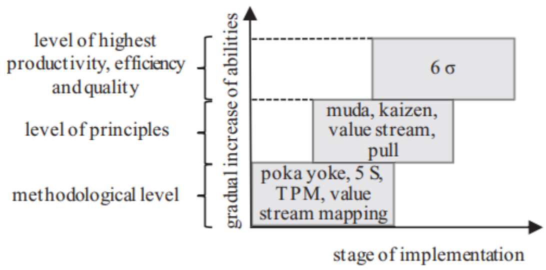


Figure 11 Levels of lean production. (Hoellthaler, Braunreuther, and Reinhart 2018)

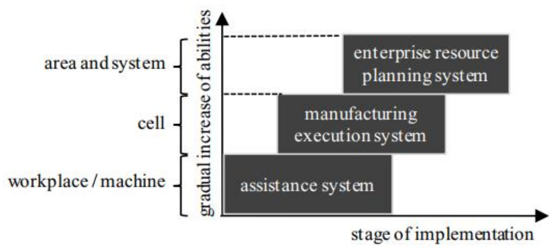


Figure 12 Categories and levels for digitalization. (Hoellthaler, Braunreuther, and Reinhart 2018)

According with the Figure 10, digitalization of productive systems becomes relevant as soon as lean manufacturing has reach its limit, where process complexity can not be handle with traditional tools proposed by lean. Furthermore, some advanced lean tools as six sigma requires high level of data computation, not only to analyse it but also to generate relevant outputs that help to the decision maker.

"Lean management is the permanent, consequent and integrated assignment of a bundle of principles, methods and actions for an effective and efficient planning, design and control of the whole supply chain of industrial goods and services. (…). Methods of lean production are predestined to raise the efficiency of the production department by focusing on value adding processes and reducing non-value adding processes (…) Less individualized products facilitate the utilization of the stated core principles, as e.g. a manageable number of manufacturing processes can be standardized and synchronized more efficiently. If the level of mass customization rises, the implementation of lean manufacturing becomes more and more difficult (...) Lean production and digitization seem to be two different approaches by first view, one is rather a philosophy and organizational approach and the other one sets its focus on technologies. But lean production and digitization represent two paths with identical objectives: Raising efficiency and productivity. Lean manufacturing tools and digitization are meant to make complexity of a production system manageable and to align companies towards the customers' value." (Hoellthaler, Braunreuther, and Reinhart 2018)

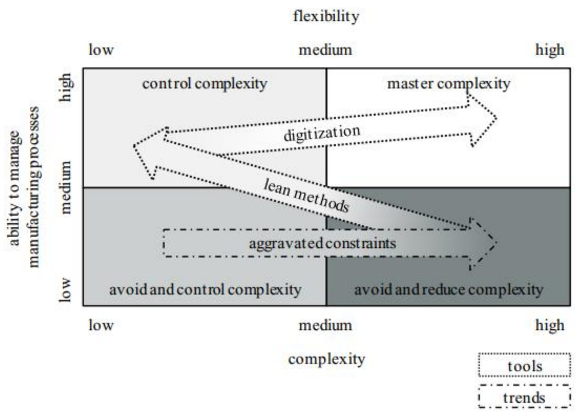


Figure 13 Impact of Lean methods a digitalization on complexity. (Hoellthaler, Braunreuther, and Reinhart 2018)

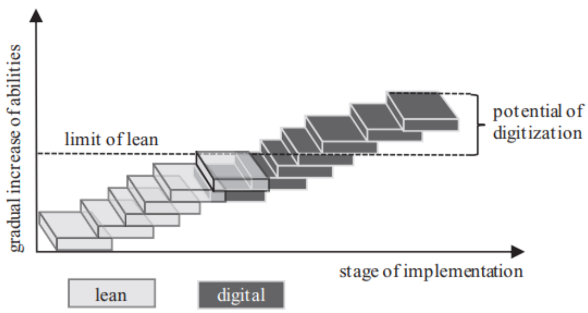


Figure 14 Gradual increase of abilities. (Hoellthaler, Braunreuther, and Reinhart 2018)

"The lack of expertise that is observed in SMEs is the main element in conflict with the Lean Manufacturing management principles. This lack of expertise affects several fields like computer science and information flow, problem solving or even Lean tools. This demands a substantial effort on employees training on the Lean philosophy and on the different Lean implementation methods" (Moeuf et al. 2016)

Government Initiatives to promote the Industry 4.0

Finally, another important fact that affects Industry 4.0 implementation drastically is government support to deploy industrial digitalisation. It is possible to find on literature that major world powers on industrial sector are promoting this technology on their big multinationals as well as on SMEs. For the transformation of current traditional products and manufacturing towards CPS and smart factories, several initiatives and approaches already exist. Some European countries developed national policies to financially support I40 related initiatives:

- Germany: "Industrie 4.0" platform launched in 2010 aims at founding with € 1 billion private projects and applied research centres as well to provide tax benefits for investments in technological start-ups.
  - To support SMEs on a national level, such as competence centers "Mittelstand 4.0," the "Future Work Lab", the "Allianz Industrie 4.0 Baden-Württemberg," as well as the chambers of commerce support, provides information tailored for SMEs. These test environments provide hardware such as machines or assembly lines, software infrastructure and development, and testing competences to SMEs
- United Kingdom invested £ 0.8 billion to develop high-value manufacturing centres, called "Catapult centres", to support companies to access research and expertise in specific manufacturing areas.
- France recently presented its "Industrie du Futur" initiative which funds with €10 billion subsidized loans for small and medium enterprises (SMEs) to foster the country re-industrialization adopting cutting edge digital technologie.
- Italy: In 2016, they allocated €13 billion for the "Piano nazionale Industria 4.0" plan to promote R&D activities and private investments, through fiscal benefits, in I40 enabling technologies.
- Netherlands: They launched a research program called "Smart Industry" which have been active in the last years.

Furthermore, at European level Horizon 2020 (H2020) research program finances demonstration projects aimed at developing smart, digital, human-centred and customer focused manufacturing solutions.

Finally, outside Europe:

- USA: "Manufacturing USA" program invests $ 0.5 billion to create a network of American institutes for manufacturing innovation to scale-up at national level advanced technologies and processes leveraging industrial, academic and governmental resources and expertise."

    - The Industrial Internet Consortium (IIC) which was founded in the US by large companies such as AT&T, Cisco, General Electric, Intel and IBM focus on the development of the internet of things application in industrial environments. Here, one key element in the strategy is the setup of test environments for developing, testing and evaluation.
- China: Initiative called “Made in China 2025” has also been funded by the government, which draws direct inspiration from Germany's "Industrie 4.0" initiative.
- South Korea: They created a SME Support Center at KITECH brings SMEs in contact with 25 research institutes in order to solve their challenges.

(Bortolini et al. 2017; Issa, Lucke, and Bauernhansl 2017; Ibarra, Ganzarain, and Igartua 2018)

3.3 Global state of the Industry 4.0 on the Productive MNEs

Looking to the information exposed previously, a realistic framework about how the situation of the Industry 4.0 on the SMEs is, can be done. Based on strong links of the diverse perspectives analysed, but also in underlying information, it is possible to identify the implementation criticalities likewise the most feasible road to enhance it.

Nowadays, in every organization, especially on industrial ones, the common thoughts are that the progress have to come along with innovation and technological development, where a higher technology will provide better productivity, efficiency and competitiveness, so, as consequence, better profits to the organization. Generally speaking, this could be true but in the productive SMEs case, this affirmation creates multiple shadows, having to take in to account many issues and constrains that this technological paradigm has. So how should a SME face the Industry 4.0 approach from the beginning?

First of all, the company should analyse its own productive system, business model, value proposition and their financial power to invest in new technological assets. Assuming that digitalization has enough potential to enhance any company activities, companies needs to isolate which of its characteristics could improve, mainly because, as it has been possible to see through this document, Industry 4.0 concept have many branches that differ in implementation cost, maintenance cost, technology maturity, possibility of gradual implementation and needs of trained workforce to operate it. So, organizations that might want to follow this paradigm should be aware about the previous specifications that their system should present to ensure success, specially SMEs, who are much more sensitive to any investment of this kind than large companies, not only in terms of financial resources but also in operational capabilities.

1. Technologies that fits in their value proposition. Ex: Cloud computing at managerial level, RFID at logistic level, augmented reality at assembly level, etc.
2. Economic feasibility.
3. Technology maturity to cover their aspirations.
4. Desire level of implementation to reach.
5. Willing of the workforce to absorb new technologies and procedures.

Once that the organization is committed to deploy a technological solution according to the previous reasoning, the next step is study the specific process that they want to boost with digital technologies. This specific analysis should be focus on operative and managerial level, because digital systems have the constrain that are not open to interpretation, every process have to be strongly standardise with reliable documentation to take advantage of digital data computation power.

Type	Lean Production methods	micro	small	medium	large
Machinery and equipment	Low Cost Automation	◔	◕	●	◑
	OEE Overall Equipment Effectiveness	○	◔	◕	●
	Preventive Maintenance	◔	◑	●	●
	Setup Time Reduction (SMED)	◔	◕	●	●
	Total Productive Maintenance	○	◔	◕	●
Material flow and layout	Cellular Manufacturing	○	◕	●	◕
	First in first out (FIFO)	●	●	●	●
	One-piece-flow	○	◔	◕	●
	Simulation software (e.g. MatFlow)	○	○	◑	●
	Optimization of the supply chain	○	◕	●	●
	Value Stream Mapping	○	◕	●	●
	Work station design	◔	◕	●	●
Organization and staff	5S	◔	●	●	●
	Autonomous work groups	○	◕	●	●
	Benchmarking	●	●	●	●
	Ideas Management	●	●	◕	◕
	Job rotation	◔	◕	◕	●
	Lean Office (Administration)	○	◔	◑	●
	Kaizen (CIP-Meetings)	◑	●	●	●
	Standardisation	◑	◕	●	●
Production planning and control	Just in Sequence	○	◔	◑	●
	Just in Time	◑	●	●	●
	Kanban	○	◕	◕	●
	Line Balancing and Muda reduction	○	◔	◑	●
	Milkrun	○	◔	◑	●
	PPS Simulation software	○	○	◑	●
	Economic (optimal) lot size	○	◑	●	●
	Visual Management	◑	●	●	●
Quality	FMEA	○	○	◑	●
	Poka Yoke	◔	◕	●	●
	Quality Circles	○	◑	●	●
	Quality Function Deployment	○	○	◑	●
	Six-Sigma	○	○	◑	●
	Statistical Process Control (SPC)	○	◔	●	●
	Supplier Development	○	◔	◕	●
	Total Quality Management	○	◔	◕	●
	Zero Defect (Jidoka)	○	●	●	●

unsuitable ○   less suitable ◔   suitable ◑   well suitable ◕   very suitable ●

Figure 15 Cluster of Lean Production methods by their suitability for different enterprise size classes. (Matt and Rauch 2013)

On this point is where the main weakness of SMEs can be identified. Many authors pointed out the low level of implementation of Lean Manufacturing tools that could be use as a good measure of industrial managerial maturity, which imply standardisation and managerial education of the workforce. It is possible to identify on Figure 15 that as smaller is the company, less implementation they are able to reach.

But analysing it on detail, is interesting to point out how standardization, the main pillar for a successful digitalization is already suitable even in micro companies, but other complementary features that will help to the Industry 4.0 implementation are weaker, especially the ones related with software solution and the existence of a Lean department, which would act as the facilitator to ensure a smooth implementation of new procedures.

This weak on the managerial culture should not be taken as an obstacle to discourage SMEs through digitalization process but it is important to take it in to account, being sure that it is possible to overcome it before make a drastic change at operative level. The deploy of a digital system that is not completely stable and adapted to their environment could be highly counterproductive, generating frustration on the team that have to deal with it daily. In particular, this situation can derivate in undesired situations where the new system is not working properly, the old traditional one is remaining but without the necessary attention.

Commonly, to minimize any negative impact on the productive system, new implementations should be done progressively starting with a pilot program to expand it a soon as prove their reliability. It is a this point where the highly modularization that solutions on Industry 4.0 brings a great opportunity to SMEs, in order to achieve its objective of full integration with flexible and sustainable functionalities, that could be carry out based on the available resources.

All things considered, the current Industry 4.0 implementation on SMEs could be consider low compared with larger companies but it could not be denied it enormous potential to achieve better process efficiency and competitiveness, indeed the future of the industry will pass through this disruptive technological advancements that will eliminate the boundaries between the virtual and physical world, integrating workers, smart machines, smart products, machines, production systems and processes.

Moreover, government support provides to SMEs a golden opportunity to follow the future trend raising their competitiveness in an industrial world that is being more and more challenging over the years. Consequently, the number of digitalised SMEs already started to rise exponentially.

Chapter 4: Conclusion

Since its creation, the term industry 4.0 has aroused great interest because it represents the future of the industrial sector, where information becomes one of the most valuable assets within the production systems. This information is generated, computed and used in a completely autonomous way by the system itself thanks to the telematic interconnection of all its elements, which allows it to react in real time to any change in its environment.

During this publication, many aspects of this so-called fourth industrial revolution have been analysed, paying special attention to how it should be addressed by small and medium-sized companies in the industrial sector. This is a subject that arouses great interest because, due to the intrinsic characteristics of this type of companies, they make them great candidates to take advantage of all the potential that industrial digitalization can offer. Industry 4.0 represents an enormous potential to SME in many areas and its implementation will have effects in the entire value chain, improving production and engineering processes, enhancing the quality of products and services, optimizing the relationship between customers and organizations, bringing new business opportunities and economic benefits, changing the education requirements and transforming the current work environment.

But, in spite of all the possible benefits for SMEs, it is very important to keep in mind all the limitations that this presents in order to have a realistic perspective of how they should carry out the adoption of these new technologies. The small size of SMEs makes them highly sensitive to any innovation or change, whether with positive or negative effects. That is why, although in the literature the perception about industry 4.0 is highly positive and any analysis is favourable to the implementation of their proposals, in the case of SMEs it is convenient to be sceptical.

This is where we find the core of the analysis. Despite all the virtues of industrial digitalization, which have already been explained, it is not possible to extrapolate these virtues to any SME assuming that they will have the expected effect or even the same as in a large company. The intrinsic characteristics of each one is very diverse, their planning range is short, their training in industrial management low, the control systems are not standardized and the computer systems normally insufficient to absorb a total digitalization.

That is why the modularization of these systems plays a fundamental role in its future implementation. Many manufacturers of control systems and smart devices have this in mind, betting on increasingly modular, expandable and retro compatible systems, both with devices from the same firm and with devices from other manufacturers. This modularity in the hardware, together with the software-level modularity proposed by the cloud computing services, makes the scalability of the systems can be progressive and smooth.

Bibliography

Bortolini, Marco, Emilio Ferrari, Mauro Gamberi, Francesco Pilati, and Maurizio Faccio. 2017. 'Assembly System Design in the Industry 4.0 Era: A General Framework'. *IFAC-PapersOnLine* 50 (1): 5700–5705. https://doi.org/10.1016/j.ifacol.2017.08.1121.

Erol, Selim, and Wilfried Sihn. 2017. 'Intelligent Production Planning and Control in the Cloud – towards a Scalable Software Architecture'. *Procedia CIRP* 62: 571–76. https://doi.org/10.1016/j.procir.2017.01.003.

Gupta, Prashant, A. Seetharaman, and John Rudolph Raj. 2013. 'The Usage and Adoption of Cloud Computing by Small and Medium Businesses'. *International Journal of Information Management* 33 (5): 861–74. https://doi.org/10.1016/j.ijinfomgt.2013.07.001.

Hoellthaler, Georg, Stefan Braunreuther, and Gunther Reinhart. 2018. 'Digital Lean ProductionAn Approach to Identify Potentials for the Migration to a Digitalized Production System in SMEs from a Lean Perspective'. *Procedia CIRP* 67: 522–27. https://doi.org/10.1016/j.procir.2017.12.255.

Ibarra, Dorleta, Jaione Ganzarain, and Juan Ignacio Igartua. 2018. 'Business Model Innovation through Industry 4.0: A Review'. *Procedia Manufacturing* 22: 4–10. https://doi.org/10.1016/j.promfg.2018.03.002.

Issa, Ahmad, Dominik Lucke, and Thomas Bauernhansl. 2017. 'Mobilizing SMEs Towards Industrie 4.0-Enabled Smart Products'. *Procedia CIRP* 63: 670–74. https://doi.org/10.1016/j.procir.2017.03.346.

Jun, Chanmo, Ju Yeon Lee, Joo-Sung Yoon, and Bo Hyun Kim. 2017. 'Applications' Integration and Operation Platform to Support Smart Manufacturing by Small and Medium-Sized Enterprises'. *Procedia Manufacturing* 11: 1950–57. https://doi.org/10.1016/j.promfg.2017.07.341.

Man, Johannes Cornelis de, and Jan Ola Strandhagen. 2017. 'An Industry 4.0 Research Agenda for Sustainable Business Models'. *Procedia CIRP* 63: 721–26. https://doi.org/10.1016/j.procir.2017.03.315.

Moeuf, A., S. Tamayo, S. Lamouri, R. Pellerin, and A. Lelievre. 2016. 'Strengths and Weaknesses of Small and Medium Sized Enterprises Regarding the Implementation of Lean Manufacturing'. *IFAC-PapersOnLine* 49 (12): 71–76. https://doi.org/10.1016/j.ifacol.2016.07.552.

Müller, Rainer, Matthias Vette, Leenhard Hörauf, Christoph Speicher, and Dirk Burkhard. 2017. 'Lean Information and Communication Tool to Connect Shop and Top Floor in Small and Medium-Sized Enterprises'. *Procedia Manufacturing* 11: 1043–52. https://doi.org/10.1016/j.promfg.2017.07.215.

Pereira, A.C., and F. Romero. 2017. 'A Review of the Meanings and the Implications of the Industry 4.0 Concept'. *Procedia Manufacturing* 13: 1206–14. https://doi.org/10.1016/j.promfg.2017.09.032.

Rauch, Erwin, Patrick Dallasega, and Dominik T. Matt. 2017. 'Critical Factors for Introducing Lean Product Development to Small and Medium Sized Enterprises in Italy'. *Procedia CIRP* 60: 362–67. https://doi.org/10.1016/j.procir.2017.01.031.

Reischauer, Georg. 2018. 'Industry 4.0 as Policy-Driven Discourse to Institutionalize Innovation Systems in Manufacturing'. *Technological Forecasting and Social Change*, March. https://doi.org/10.1016/j.techfore.2018.02.012.

Schlegel, Andreas, Tino Langer, and Matthias Putz. 2017. 'Developing and Harnessing the Potential of SMEs for Eco-Efficient Flexible Production'. *Procedia Manufacturing* 9: 41–48. https://doi.org/10.1016/j.promfg.2017.04.028.

Schröder, Christian. n.d. 'The Challenges of Industry 4.0 for Small and Medium-Sized Enterprises', 28.

Siddaway, Dr Andy. n.d. 'WHAT IS A SYSTEMATIC LITERATURE REVIEW AND HOW DO I DO ONE?', 13.

Soroka, Anthony, Ying Liu, Liangxiu Han, and Muhammad Salman Haleem. 2017. 'Big Data Driven Customer Insights for SMEs in Redistributed Manufacturing'. *Procedia CIRP* 63: 692–97. https://doi.org/10.1016/j.procir.2017.03.319.

Spena, Pasquale Russo, Philipp Holzner, Erwin Rauch, Renato Vidoni, and Dominik T. Matt. 2016. 'Requirements for the Design of Flexible and Changeable Manufacturing and Assembly Systems: A SME-Survey'. *Procedia CIRP* 41: 207–12. https://doi.org/10.1016/j.procir.2016.01.018.

Tjahjono, B., C. Esplugues, E. Ares, and G. Pelaez. 2017. 'What Does Industry 4.0 Mean to Supply Chain?' *Procedia Manufacturing* 13: 1175–82. https://doi.org/10.1016/j.promfg.2017.09.191.

Zhong, Ray Y., Xun Xu, Eberhard Klotz, and Stephen T. Newman. 2017. 'Intelligent Manufacturing in the Context of Industry 4.0: A Review'. *Engineering* 3 (5): 616–30. https://doi.org/10.1016/J.ENG.2017.05.015.