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A survey study on Industry 4.0 readiness level of Italian small and medium enterprises

Alessia M.R. Tortora[(a)]*, Alfano Maria[(b)], Di Pasquale Valentina[(c)], Raffaele Iannone[(d)], Cesare Pianese [(e)]

[(a), (b), (c), (d), (e)] *Department of Industrial Engineering, University of Salerno*

Abstract

The Industry 4.0 (I4.0) paradigm is considered one of the most trending topics in the academic and industrial context, that involves emerging technologies that can make the processes increasingly integrated and provide digital solutions for supporting companies towards the greater flexibility required by the market. To date, the scientific literature strongly addressed the development of enabling technologies and the assessment of their impacts in different industrial contexts. However, there is a lack of studies providing empirical evidence about how manufacturing companies are facing the digital transformation, in particular for smaller industrial realities. For this reason, this paper aims to study the knowledge, readiness, and dissemination level of the I4.0 paradigm and enabling technologies for Italian Micro, Small, and Medium Enterprises (MSMEs). A web-based survey was conducted, and 77 companies were interviewed. The survey results underline that MSMEs still have limited knowledge about I4.0 and are not well prepared for its implementation.

Keywords: I4.0; smart factory; enabling technologies; readiness level; maturity level; survey.

1. INTRODUCTION

The modern industrial context is transforming itself, making more use of digital rather than physical processes that allow to increase customer satisfaction, enhance knowledge, reduce inefficiencies, and improve the ability to decide. Alongside traditional production technologies and established organizational/ management paradigms, new digital

* Alessia M.R. Tortora Tel.: +39 3403272104.
E-mail address: altortora@unisa.it

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technologies are emerging and consequently new managerial approaches, capable of supporting companies towards the greater flexibility required by the market. [1],[2].

Being a company 4.0 means deepening the level of knowledge and intensifying the application of new enabling technologies and focusing on the mechanism through which the greater integration and collaboration of human, physical, and information resources, generates additional value in the company and the supply chain. The I4.0 transformation of companies must necessarily take place through the introduction of new technologies, such as cloud computing, industrial automation, sensors, predictive maintenance, internet of things, simulation, advanced manufacturing solutions, additive manufacturing, augmented reality, big data & analytics, cyber-security, horizontal and vertical integration. The technological basis of I4.0 is ensured by enabling technologies, cyber-physical systems (CPSs), real-time availability of all data, capacity to determine an optimized process at any time based on the information, integration of people, objects, and systems into the value chain [3]. However, is fundamental to adapt technological innovation to the company reality.

This transformation involves inevitable difficulties, much more deeply rooted in small business realities. Factors such as the lack of funding, the high cost of labor, structural problems, the slowness of bureaucracy, and the limited diffusion of technologies, could slow down the evolutionary paths of Micro-Small-Medium Enterprise (MSMEs). The use of technology to increase efficiency in the organization is the main problem that these companies have to address [4]. There is a lack of knowledge on the development and implementation of technologies in the production systems. Moreover, they are unable to evaluate their business to find technological and digital gaps and are not aware of how to apply advanced technologies in their production process to implement the I4.0 paradigm. For this reason, companies have to make a complex choice: continue to apply the strategies and techniques that have worked effectively so far, or embrace the change through the new products and organizational paradigms I4.0 that allow to develop and evolve completely thanks to digital innovation.

In recent years, the scientific literature strongly focused on the theoretical and conceptual framework of the fourth industrial revolution [5] and developed numerous innovative contributions on the use of enabling technologies. Some researchers have studied the impact of these technologies on industrial performance [6]. However, the analysis of the real production context and of what the corporate world is developing and implementing has not been investigated in depth. Considering the national and regional context of the authors, different campaigns for data collection and surveys for measuring the level of readiness and maturity were carried out mainly by professional associations. The scientific literature has worked a lot to support industrial companies by providing a series of models, techniques, solutions, frameworks to help them undertake or achieve a digital transformation, through the implementation of new technologies and to carry out self-assessments of their level of digital maturity.

I4.0 can create better productivity and higher efficiency. In five years, more than 80% of European companies will digitalize their value chain to increase efficiency by up to 18%. By 2020, European industrial companies will invest more than 100 billion Euros annually on I4.0. Based on these aspects, to revive the competitiveness of the regional innovation system and industrial investments, Italy has developed a "Piano Nazionale Impresa 4.0 2017-2020" which provides various concrete measures to support industrial sectors that want to grow and innovate, offering them real support in investments, in the digitalization of production processes, in improving the productivity of workers, in the training of adequate skills and the development of new products and processes. At the same time, the Campania Region adopted several initiatives and measures aimed at supporting companies in the digitalization process. However, it is not known, what are the effects generated by the plan of government measures and by scientific studies on Italian companies, in particular on small and medium enterprises. Thus, this work was conducted to understand how Campania companies are reacting to this series of actions aimed at stimulating transformation 4.0. The goal is to capture the opinions of Campania manufacturers on the issues surrounding the awareness and implementation of the I4.0 paradigm. In this work, we present a first exploratory quantitative analysis to provide empirical evidence about the way this transformation is faced by manufacturing companies.

The survey is part of the project of the University of Salerno "Readiness, maturity and technological level of the local industrial context". The survey aims to assess the level of maturity achieved by the industrial system concerning the use of I4.0 technologies. In particular, the data were collected and processed for the following purposes:

- Identification of the level of knowledge of the company on I4.0 technologies, the level of use of the same as well as the obstacle possibilities related to their application;
- Collection of suggestions, plans, and future projects from the company on the I4.0 theme;

- Identification of the opinions that the University can use to plan development and implementation interventions for I4.0 technologies;
- Comparative analysis of the companies of the Campania, to assess the level of maturity reached by the Campania industrial system about the use of I4.0 technologies.

This paper is structured as follows. Section 2 presents the survey methodology used to reach the study purpose, the characteristics of the sample, and the data collection and analysis process. Section 3 provides the detailed results of the interviews related to Company competitive context, Innovation development, I4.0 awareness level, Benefits and obstacles, Future development, and suggestions. Section 4 presents the discussion of the results, the main conclusions of the interviews, and future developments.

2. METHODOLOGY

A survey approach was adopted for the aim of the paper. The sampling frame was collected from the lists of companies belonging to regional trade associations. A structured web-based survey was devised and deployed for data collection through an open-source platform called "Lime survey". It is an open-source web application that allows the simple and effective creation of questionnaires and online surveys in which an unlimited number of users can participate.

The questionnaire was developed to investigate the level of awareness about I4.0, the aspects of relevance to the company, the innovation activities carried out by the companies, the potential benefits, and obstacles related to the implementation of enabling technologies, and finally the major concern and future-plans for implementation of I4.0. Figure 1 shows the logical structure of the survey, including the main questions groups.

The first set of information collected consisted of three questions related to the company (enterprise dimension, and operational headquarters) and the interviewee (i.e. interviewee professional figure). Then the company's competitive context consisted of a set of three questions related to the main characteristics of the company's core offer.

The innovation questions aimed to evaluate the R&D activities of companies and their participation in projects and collaborations to develop innovation consists of six questions.

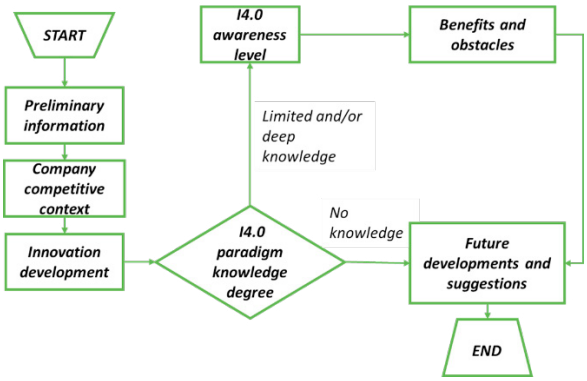

Fig. 1. Structure of the survey.

I4.0 concept refers to the application of ICT for production and automation. The core concepts are digitization, networking, and data analysis. To develop new digital business models or to reach internal digitization, strategies, capabilities, and technologies must be identified and after implemented. Accordingly, it is essential to evaluate the current situation of companies regarding the application of enabling technologies. For these reasons, the awareness I4.0 questions group, including twenty-three questions, represented the central part of the survey and focused on collecting information about the readiness level gained by the industrial system related to the use of I4.0 enabling technologies and financial and economic aid used.

I4.0 concept cannot be successfully implemented unless the enterprises accept it, and they will not embrace it unless all the benefits and challenges of that being identified. For this reason, the analysis of consequences in terms of benefits and obstacles resulting from the introduction of technologies 4.0 is been one of the aims of this work. Therefore, variables such as business activities, employees, technologies adopted, motivations, internal organizational changes, and results were examined. The section about benefits and obstacles contained five questions about benefits guaranteed by the use of technologies and obstacles to the implementation.

Finally, future developments and suggestion groups were related to professional figures introduced, future programs, and forecast of future investments in I4.0 that consists of eleven questions.

To have accurate and consistent statistics, the web-based survey was distributed to 150 industrial practitioners and it was required the survey filling by who has a complete view of the business context and work as Executive Director, R&D Manager, Operational manager, or technical manager. The survey responses were collected between September and December 2019. From 150 sent e-mails and after 3 reminders, 77 complete responses were received and stored in the database. The current study is therefore based on these 77 responses which translate to a response rate of 51%. The paper can be considered as a first exploratory study and it opens up to the possibility to expand the sample of analyses and consequently making cross-cutting assessments to different sectors when the dataset will have a consistent size.

3. RESULTS

In this section, a brief description of the results of the questionnaire is provided. Taking into account the aim of the works of analyzing the current state of MSMEs in Campania about I4.0, the sample consists of 77 companies with corporate headquarters in Campania.

Figure 2 illustrates the distribution of respondents per company size. In particular, the sample is composed of 21% of medium-sized companies, 29% of micro-size, and 50% of small-size.

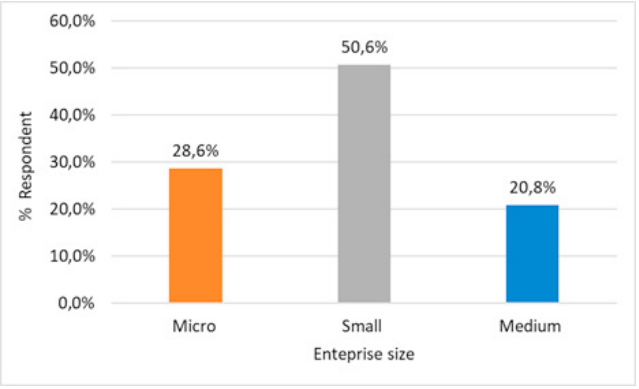

Fig. 2. Distribution of companies' size.

3.1. Company competitive context

As regards the competitive context (Figure 3), among small companies, the 46% of respondents are service providers, and the 41% of respondents are active in the production of goods; instead, the core activity of Micro companies is represented by services (64% of the sample); the distribution of Medium-sized companies core business is composed by the 50% services and 44% goods.

To identify the innovation level of respondents regarding research and development activities, they were asked how often companies lead R&D activities to investigate the effort addressed for innovating their business. The data show that 63% of medium-sized companies systematically carry out research and development activities with an internal research and development department dedicated to these activities; having specifically dedicated resources indicates an investment by the company in innovation; 50% of the Micro companies, on the other hand, do not carry out R&D

activities but the remaining part (32%) occasionally carries out R&D activities using resources from other areas for participation in innovative projects; the small- size companies picture is no clear: the 32% occasionally carry out R&D activities using dedicated resources, the 25% occasionally carry it out by exploiting resources dedicated to other areas while 43% do not carry out research and development.

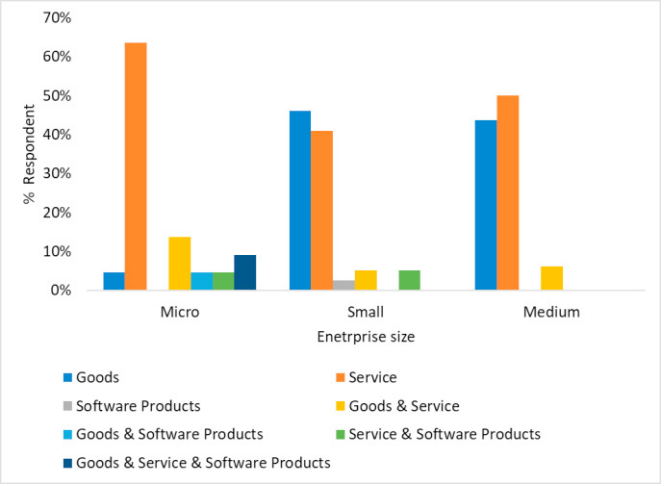

Fig. 3. Companies competitive context.

3.2. Innovation development

As concern the collaboration opportunities developed by respondents (Figure 4), the data shows the 43% of medium-sized companies have collaborated with other entities to develop innovation and in particular, the 60% have collaborated with the University; the 55% of Micro companies have not collaborated with other entities in the last three years, the rest of respondents have occasionally collaborated; while the 43% small enterprises have not collaborated in the last three years but the 81% have collaborated with the University to develop innovation.

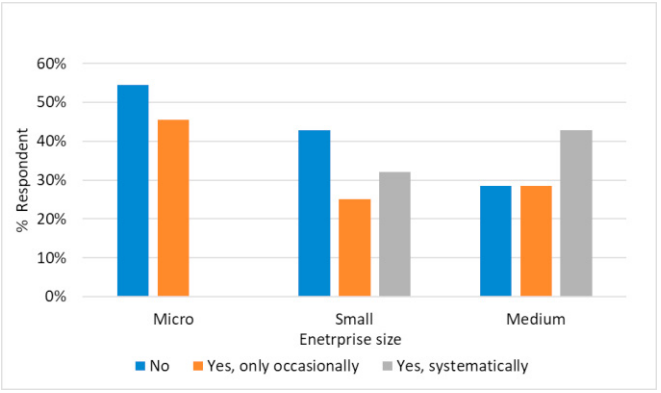

Fig. 4. Collaboration in innovation (last 3 years).

3.3. I4.0 awareness level

Figure 5 shows the I4.0 paradigm knowledge degree. More than half of the medium-sized companies involved in the survey declared to know the I4.0 paradigm; while the 10% of micro-enterprises (8 out of 22) do not know the paradigm, and among the small ones, the 72% (11 out of 39), do not know the I4.0 paradigm yet.

To properly identify the level of respondents' awareness regarding I4.0, they were asked to state the knowledge degree concerning the individual enabling technologies. Table 1, reported in Appendix A, shows the detail of the level of knowledge and the level of application for each enabling technology by company size. The results show that many micro-companies have a basic knowledge of almost all enabling technologies. About 43% of medium companies show a deep knowledge of the cloud and social & mobile technologies. Even small companies seem to have basic knowledge of almost all technologies. Furthermore, participants have been asked the application level for each enabling technology. The 54% of the respondents who claimed to know the I4.0 paradigm currently do not use any technology; the 11% applies only one technology; the 20% applies two technologies and 15% apply more than two technologies. Moreover, an interesting result was shown by small and medium enterprises. On average the 50% of small companies are studying the following technologies in a preliminary way aimed at future applications: big data, cloud, cyber-security, and IoT. On average the 60% of medium ones are preliminary studying collaborative robots, big data/analytics, blockchain, and cyber-security for future applications.

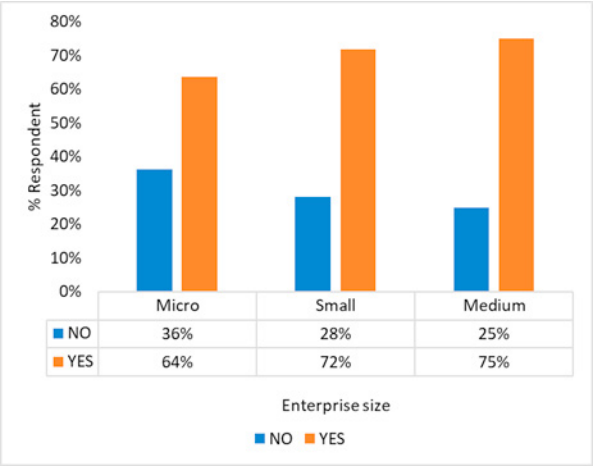

Fig. 5. I4.0 paradigm knowledge degree.

3.4. Benefits and obstacles

The responses showed that the introduction of technologies 4.0 allowed companies to gain several benefits including increasing and improving productivity, reaching new markets and creating new business models, some have succeeded also to customize their products and services. Although there are significant benefits, there are some serious concerns in front of companies that need to be considered and handled. From lack of financial resources, internal digital culture and training, and insufficient talent to implementing new business models that exploit the digital opportunities as well as market revolution, are challenges that need to be studied, and the best solution needs to be identified. Figure 6 shows the results regarding the obstacles (multiple choice and short answers were possible).

The 39% of respondents consider equipment and tools investment as one of the major obstacles, but 35% have difficulty acquiring and training internal skills. A skilled workforce is essential for the development, introduction, and utilization of I4.0 technologies. Participants were asked how they dealt with the problem of acquiring 4.0 skills and 40% of those who have introduced at least one technology said they have addressed the issue through specific training courses.

3.5. Future development and suggestions

To move forward with I4.0, rolling out digital capabilities across the company is essential. This process takes time and significant implementation investments. It is essential to evaluate the digital maturity now and set clear targets for the next five years. Participants were asked about their future business plan for implementing I4.0. Figure 7 shows the

trend of future business investments in enabling technologies. Unfortunately, the situation is not promising, the 35% of respondents have planned no short-term investment, in particular, analyzing the future investment per company size, it is highlighted that almost all Micro-enterprises do not plan to invest in any technology, and even the few who are carrying out a preliminary study on the main aforementioned technologies have planned to not invest before the next 5 years. The small ones claimed to introduce in a shorter horizon for the few technologies on which they are carrying out a study.

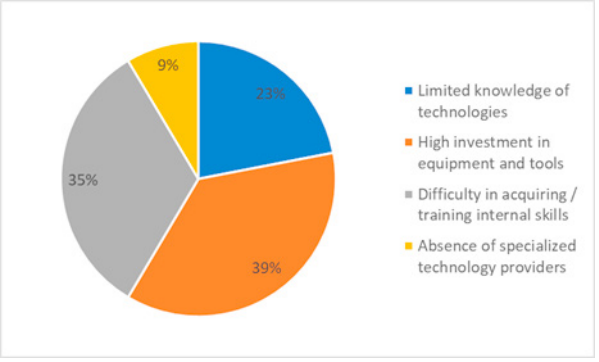

Fig. 6. Obstacles in the way of I4.0 implementation.

Among medium-sized enterprises, the situation does not change much, only 60% plans to introduce IoT technology in the short term. Regardless of company size, the technologies that companies are most interested in for future investments are IoT, social & mobile, cloud e cyber-security. Participants were asked about their interest into various initiatives regional promoted: the 51% of companies are most interested in staff training on I4.0 issues, in particular, they are interested in training courses on software technologies (simulation, system integrator applied to process automation, information and management systems, cloud, cyber-security and business continuity, e-commerce and/or trade systems, mobile and/or internet payment systems) (71%).

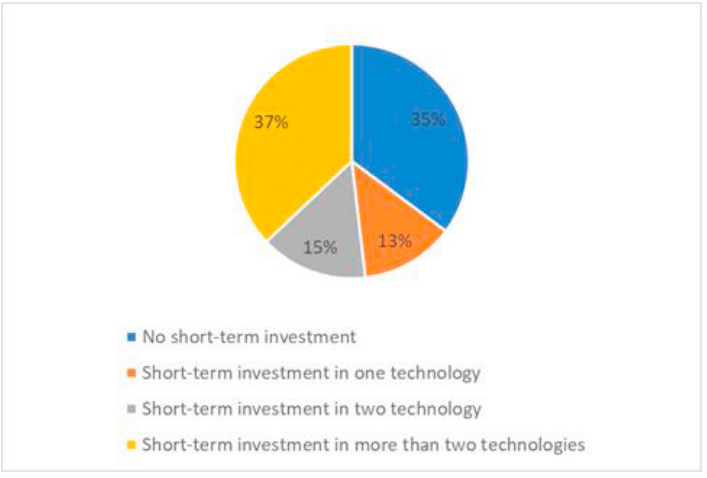

Fig. 7. The possible time span for implementation of I4.0.

4. DISCUSSIONS AND CONCLUSIONS

The digital and technological innovation of the industrial context introduced by I4.0 represents an opportunity, but also a need for companies that want to be competitive in international markets. I4.0 can significantly transform the

way companies operate and enable them to tap into new sources of value. To realize this transformation, manufacturing companies and their managers must achieve an in-depth understanding of the I4.0 concept and explore how it can add value to the specific context of their operations.

The results of this study underline that companies still have limited knowledge of enabling technologies at the basis of the I4.0 paradigm. The results of this survey indicate that Campania manufacturers' knowledge regarding the I4.0 paradigm and its technologies is insufficient. More than 50% of participants in this study demonstrated a basic or low level of knowledge about enabling technologies. This shows that the local business fabric is still far from getting on a path towards transformation I4.0, this situation is even more evident with the decrease in the company size.

Analyzing the level of use of the individual enabling technologies, it appears that MSMEs in most cases are not taking any action on almost all technologies 4.0. Some respondents indicate a low short investment in I4.0 technologies just due to their lack of comprehensive understanding of the I4.0 concept. In addition to the introduction of new operating models in the factory, the I4.0 revolution is also leading to the need to develop adequate skills on the part of the personnel concerned, to make the best use of emerging technologies, fully exploiting the benefits of this continuous evolution.

It is therefore increasingly evident that investing only in new technologies does not guarantee the achievement and keeping of competitive advantage by companies in an I4.0 context; also the workforce must be properly informed and trained to achieve the strategic objectives predefined by the company itself. However, the interviewed underlined that the lack of skilled people around I4.0 is another problem that holds back manufacturers from approaching I4.0. Furthermore, some of them believe that they did not have access to proper equipment and required software, since small and medium-sized manufacturing companies continuously face cost challenges and employ the best strategies to reduce production cost and increase efficiency in the use of labor and technology [7]. As well as, MSMEs are uncertain about the financial and technical requirements of adopting I4.0 and its overall impact on their business model. Companies are fully aware that it is essential to invest not only in technological infrastructure but also in improving leadership skills and training workforces. They also know that absence of digital culture and proper training systems could bring an unsuccessful transformation. Numerous empirical evidence, in various International and Italian territorial contexts, has shown that the collaboration and characteristics of the networks for the diffusion of knowledge and innovation represent one of the key elements for the activation of processes of innovation and cumulative development of local production systems. For this reason, for many years now, the innovation policy guidelines at European, national and regional level have turned to tools aimed at increasing the capacity for relationships between different organizations (businesses, universities, research institutions). Closer collaboration with universities, research bodies, consultants, and innovation managers could be the key element for the adoption of I4.0 within Italian MSMEs.

Digitalization is a mandatory step for companies to reach competitiveness, but many companies are not well-prepared. Several steps need to be performed to draw a factory smarter. By combining the results from this survey with previous works, authors suggest, as future work, a well-structured roadmap that will help all companies, especially MSMEs, with limited financial and technological resources, to gain digitalization and achieving I4.0. The results of this work represent an overview of the current situation and the first step for developing a framework that will help decision-makers to take the next steps with minimal risk. Most companies are still unaware of the potential opportunities that I4.0 technologies can offer, they need to deeply understand different elements of I4.0 and gain proper knowledge, skills, and confidence. The roadmap will support the decision-maker to define these different elements based on the specific organization’s criteria and objectives.

Limitations and future research

This research has some limitations offering new opportunities for future research. Firstly, our work considers enterprises from different industrial sectors and each sector has its characteristics. This naturally affects the relevance given to the different survey dimensions analyzed. A more detailed analysis of differences among sectors could be relevant. Another important characteristic of our sample is that we have considered a small part of the population of small and medium-sized enterprises since the paper can be considered as a first exploratory study. Therefore, our analysis could be extended to gain a more significant finding. Second, our study did not consider, for some of the respondents, the effect of the technologies implemented on industrial performance, which could be a very interesting issue for future research. The real benefit of Industry 4.0 is still a concern for practitioners and such a study could be

helpful for theory and practice. We can consider our research as the first step towards this direction since we provided an empirical base for understanding how enterprises are facing the digitalization process. From this starting point, future research could investigate the advance of the digitalization process at the firm level and its impacts on industrial performance.

Acknowledgements

The project "Readiness, maturity and technological level of the local industrial context" funded by the Ministry of Industry of Campania Region is gratefully acknowledged.

Appendix A.

	Knowledge degree									*Application degree*								
TECHNOLOGIES	**HIGH**	**BASIC**	**NONE**	**HIGH**	**BASIC**	**NONE**	**HIGH**	**BASIC**	**NONE**	**HIGH**	**NO ACTION**	**PRELIMINARY**	**HIGH**	**NO ACTION**	**PRELIMINARY**	**HIGH**	**NO ACTION**	**PRELIMINARY**
Additive Manufacturing	7%	**64%**	29%	18%	**61%**	21%	8%	**58%**	33%	0%	**80%**	20%	14%	**68%**	18%	38%	**63%**	0%
Advanced Manufacturing Solution	14%	**43%**	**43%**	4%	**50%**	46%	8%	**75%**	17%	0%	**88%**	13%	0%	**67%**	33%	0%	30%	**70%**
Big Data/Analytics	21%	**64%**	14%	14%	**54%**	32%	17%	**75%**	8%	8%	**58%**	33%	0%	42%	**58%**	18%	9%	**73%**
Block chain	14%	**57%**	29%	11%	**50%**	39%	0%	**75%**	25%	0%	**60%**	40%	0%	**71%**	29%	11%	33%	**56%**
Cloud	43%	**57%**	0%	36%	**57%**	7%	**50%**	25%	25%	29%	29%	**43%**	19%	27%	**54%**	44%	0%	**56%**
Cyber Security	21%	**71%**	7%	25%	**50%**	25%	**50%**	33%	17%	23%	**62%**	15%	10%	33%	**57%**	30%	20%	**50%**
Industrial Internet of Things	21%	**64%**	14%	21%	**54%**	25%	33%	**50%**	17%	17%	**50%**	33%	0%	43%	**57%**	20%	**40%**	**40%**
Vertical and /or horizontal integration	14%	**71%**	14%	18%	**50%**	32%	42%	**50%**	8%	17%	**58%**	25%	5%	42%	**53%**	**45%**	18%	36%
Nanotechnologies and intelligent materials	7%	**50%**	43%	4%	25%	**71%**	8%	42%	**50%**	0%	**88%**	13%	0%	**75%**	25%	17%	**67%**	17%
Simulation	0%	**57%**	43%	14%	36%	**50%**	8%	**58%**	33%	0%	**100 %**	0%	7%	**57%**	36%	25%	**50%**	25%
Social e mobile	36%	**50%**	14%	29%	**50%**	21%	42%	**58%**	0%	**42%**	33%	25%	27%	27%	**45%**	33%	17%	**50%**
Virtual & Augumented Reality	14%	**57%**	29%	25%	36%	**39%**	**33%**	**33%**	**33%**	0%	**80%**	20%	18%	**47%**	35%	**38%**	**38%**	25%
Wearable Devices	14%	**64%**	21%	7%	**46%**	**46%**	25%	**50%**	25%	9%	**82%**	9%	0%	**60%**	40%	11%	**44%**	**44%**

Micro	Small	Medium	Micro	Small	Medium

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