Smart Factories: A Review of Situation, and Recommendations to Accelerate the Evolution Process

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Abstract. Smart factory has become increasingly important in the last years as an indispensable manufacturing model of the future. In this context, studies on the development of technologies in the field of smart factory systems intensively continue in the world. Turkey is also trying to contribute through national grant mechanisms to encourage technology development efforts in this area. In this study, the situation of smart factory system technologies in Turkey has been explained. By examining the academic studies and by carrying out a questionnaire study to companies and academicians studying in this field, suggestions are made about which of the smart factory system technologies should be given priority to gain momentum in this field.

Keywords: Smart factory · Industry 4.0 · Priority areas

1 Introduction

Current production systems are generally set up as unintelligent systems. Recent trends such as the rise of the fourth industrial revolution (Industry 4.0) enable the overlapping of digital and physical worlds with the help of information technology (IT). Eight (Autonomous Robots, Simulations, Internet of Things (IoT), Cyber-security, Cloud computing, Additive Management, Augmented reality, Big data and analytics) today's and close future's technologies are helping to transform production processes. Innovative information and communication technologies (ICT) have already been in use in production processes. But with Industry 4.0 the momentum of digitalization gained speed in production processes [1]. Industry 4.0 may affect to change traditional production processes to obtain higher efficiencies. Some of the contexts in the Industry 4.0 are;

- Big data and analytics, expresses to the storing and complete evaluation for the making better system management and assist real-time decision making.

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- The expected robotics based production will finally interact with each another and work alongside with employees' and learn from them. This robotic based production will help to reduce the manufacturing cost and production time.
- Simulations will be used widely for the line based production processes to get better real-time production outcomes and represent the physical production processes in a virtual model, which can include production equipment, outcomes, and employees. This will allow the decision makers to evaluate and performance tuning the production equipment settings to obtain the best production process, reduce machine setup times and increase total quality.
- Internet of Things (IoT) refers that more devices will be communicated and interact both with each other and with more centralized controllers when needed. IoT will help to decentralize analytics and decision making in local for the real-time reactions.
- Growing production-related needs increased the communication across main components. Therefore these needs, all collected data, and functionality will increasingly be controlled into the cloud, enabling more data-driven services for production monitoring and control systems and cloud based system help to obtain higher efficiencies. Day by day the performance of cloud technologies in progress and nowadays it is performing reaction times of just several milliseconds.
- Additive manufacturing methods is popularly used in nowadays to produce samples of personalized goods that offer production advantages, such as 3-D printing. Production has kicked off the adoption to the additive manufacturing to reduce the complexity and expensive designs [2]. With using the today's image processing technologies augmented reality based systems have been started to support the variety of services, such as parts in storage and sending repair instructions via mobile devices. These support systems are currently in beginner level, but in the near future, production and storing processes are going to use the augmented reality to support the employees' for real time informing to improve decision making and operations.

Industry 4.0 enables connectivity and communications to increase dramatically. Additionally, critical industrial systems are needed to protect and production processes from cyber security threats. Consequently, secure, complex identity and reliable communications access are necessary.

Today, production systems depend on information systems more than ever. Therefore, intelligent systems are evolving to smart systems. In order a factory to be smart, all processes should be managed [3]. These features enabled the systems to be more efficient and qualified. The Industry 4.0 and its components can be used in the production process to boost the transformation to digitalization. This digitalization process is formed by 3 groups with interaction. The first group is academicians who lead the technology. The second group consists of Research and Development (R&D) driven Small Medium Enterprise's (SMEs) who can produce the hi-tech product. And the last one is the manufacturer (factories, large industry) who can make investment on hi-tech product. All these groups designate the technology maturity level of Turkey. So we focused on these three groups and carried out questionnaires on them.

2 Related Work

The New Industrial Revolution represents the digital transformation of production systems as advances in information and communication technologies. The digitalisation of every stage of the production chain, the provision of machine-human-infrastructure interaction and the development of 'Intelligent Manufacturing Systems' have created a paradigm shift in the industry [4]. The countries that make this change will have an advantage in the global market. "New Industrial Revolution: Intelligent Manufacturing Systems Technology Road Map" study of TUBITAK dated 03.01.2017, evaluated the digital maturity level of the Turkish companies as between Industry 2.0 and Industry 3.0 [5]. It is stated that making value-added production with this level of industry is difficult. Because of this situation, It is possible that Turkey's living in comparative weakening global competitiveness, will lead to reduce of global market share, rise unemployment and decline labour quality. In this case, Turkey has remained low investment, it will slide into an economic vicious circle where low value-added production. On the other hand, if you try to create ground-breaking changes in global competitiveness with stable Industry 4.0 investments, you will get more shares in the global value chain [6]. To break this chain, it is necessary to determine the policies and goals of the country and apply it decisively.

3 National Goals and Policies

National policies underscore the need for strengthening competition and industrial productivity to enhance medium-high technology exports.

A. The Place of Manufacturing Industry Transformation in Policy Documents
   (1) *Supreme Council for Science and Technology (BTYK) Decisions:* According to decree 2016/01, Smart Manufacturing Systems Technology Roadmap is established transition of Turkish industry for increasing international competitiveness in technology production:
      - Developing an implementation and monitoring model for smart manufacturing in coordination with all stakeholders
      - Increasing goal-oriented R&D efforts in critical and pioneering technology areas (cyber-physical systems, AI/sensor/robotics, Internet of Things, big data, cyber security, cloud techs, etc.)
      - Designing support mechanisms for manufacturing infrastructures to develop critical and pioneering technologies

   (2) *Goals for 2023:* The Government's 2023 Goals, which cover the 63-item goals, set for the 100th anniversary of the Republic, and which are road maps, play a leading role in the transformation of the manufacturing industry. Most of the identified objectives have the ability to directly and indirectly influence the manufacturing industry.
   (3) *65th Government Program:* Within the framework of the 65th Government Program, it was aimed to give more support to high-tech investments, to invest

in advanced technology class, to be included in priority investments and to benefit from 5th region support.

(4) *10th Development Plan:* It is targeted that the innovation production capacity be raised by closely pursuing the developments in the field of science and technology and that transformation in the production structure be reached by integrating these innovations into production structure. Realization of Transformation of Production Concentration of R&D is one of the components of Development Plan, which contributes innovation and design activities in the medium-high and high-tech products

(5) *Program for 2018:* Among the main aims and objectives of the Program, Turkey's international competitiveness and in the manufacturing industry to increase its share of world exports by performing the conversion switch to high value added structure and is located to increase the share of high-tech industries. Many policies and measures have been detailed in order to achieve this purpose.

(6) *Turkey Industrial Strategy Document (2015–2018):* In order to accelerate the transformation of the Turkish industry into an industry structure in which high value-added and high-tech products are produced predominantly, the policy of "realizing technological transformation in the industry" was included. For this purpose, 15 action plans have been included and it has been planned to carry out actions at the determined time intervals together with the responsible and cooperating organizations.

(7) *Medium Term Program (2018–2020):* In the Medium Term Programme, the digital transformation (effective use and domestic production of additive manufacturing, robotics, the Internet of Things, big data, augmented reality technologies) roadmap for manufacturing industry will be analysed. Industry and technology development zones will be analysed and restructured with respect to their technical equipment, technology development capacities and utilization levels.

4 Methodology

Smart factory technologies are the production methods of the future. In this study, a research and analysis on smart factory technologies has been carried out. Questionnaires were conducted on three different groups consisting of academicians, R&D companies and manufacturers (factories) to investigate which of the smart factory system technologies should be given priority and suggestions were made based on the questionnaire results.

A. Questionnaire Construction

Three draft questionnaires were prepared as the first step of the data collection process. The method of obtaining expert opinion was followed during the validation phase of the questionnaires. The questions of the draft questionnaires that emerged as a result of the literature research were evaluated by two academicians specialized in the field and ten Information Technology (IT) specialists working in TUBITAK. In accordance with the views of these two groups, the draft forms of the questionnaires have been finalized. During the process of sending questionnaires to academicians, R&D companies and manufacturers, careful attention has been paid to inform the purpose of the questionnaire, the scope, and for what purpose the results are to be used. Questionnaires were applied online using the "Online Surveys" [7] application. An information message containing the purpose of the questionnaire, the scope, for what purpose the results are to be used and the link of the questionnaire was prepared and sent to the designated target group via e-mail. There were 4 questions in the questionnaires: 1 question was about smart factory technology awareness assessment, 1 question was about exploring the sources of smart factory technology awareness, 1 question was about detecting the firm or person's current situation about infrastructure/R&D/P&D/works in this area, 1 question was about detecting the firm or person's investment/R&D/work plans to this area. The 5-point Likert Scale was used in the question intending to determinate prioritization of the smart factory technologies.

B. Selection of the Research Sample

Research sample contains R&D firms that have carried out at least 1 project in the smart factory area, manufacturers (factories) and academicians studying in this field. Questionnaires were submitted to 448 companies and 200 academics who fulfilled these conditions. A total of 150 people, including 76 manufacturers, 36 R&D companies and 38 academicians, participated to the questionnaires.

C. Reliability Analysis of Questionnaire Results

Reliability analysis measures the consistency of responses to a questionnaire according to a pre-determined scale. The results of questionnaires were analyzed by obtaining "Cronbach's alpha" [8] values. IBM SPSS package program was used for this evaluation. The Cronbach Alpha (α) reliability value of the questionnaire for the academicians was determined as 0.884, the Cronbach Alpha (α) reliability value of the questionnaire for the R&D companies was determined as 0.848 and the Cronbach Alpha (α) reliability value of the questionnaire for the manufacturer companies was determined as 0.805. When Table 1 was examined, it was determined that the reliability of the results of the questionnaires are at "good" level.

Table 1. Cronbach's alpha reliability table

Cronbach's alpha	Reliability
$\alpha \geq .9$	Excellent
$.9 > \alpha \geq .8$	Good
$.8 > \alpha \geq .7$	Acceptable
$.7 > \alpha \geq .6$	Questionable
$.6 > \alpha \geq .5$	Poor
$.5 > \alpha$	Unacceptable

D. Limitations and Challenges

A number of difficulties has experienced in obtaining data. TUBITAK business application software has been used in the process of determining the firms and academicians forming the target group. This process took more time than planned due to the high number in target group. The questionnaires were submitted to the obtained contacts through e-mail channel. Because respondent numbers were low, reminder e-mails were sent to increase attendance to the questionnaires. Hence collecting the results of the questionnaires took more time than planned.

E. Results

The questions of questionnaires and answers to these questions are provided below. The analysis of these answers will be discussed in the "Conclusion" section.

Q1. *What is your level of knowledge in Smart Factory Systems and related advanced technologies (Industry 4.0)?* (Fig. 1)

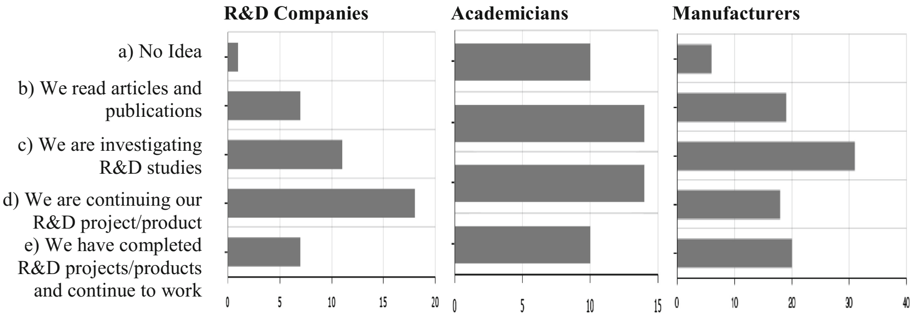

Fig. 1. Answers of first question

Q2. *From which source (s) did you obtain your knowledge of Smart Factory Systems and related advanced technologies (Industry 4.0)?*

Q3. ***(R&D Companies)*** *Would you rate your R&D activities in Smart Factory Systems and related advanced technologies (Industry 4.0)?* (Fig. 2)

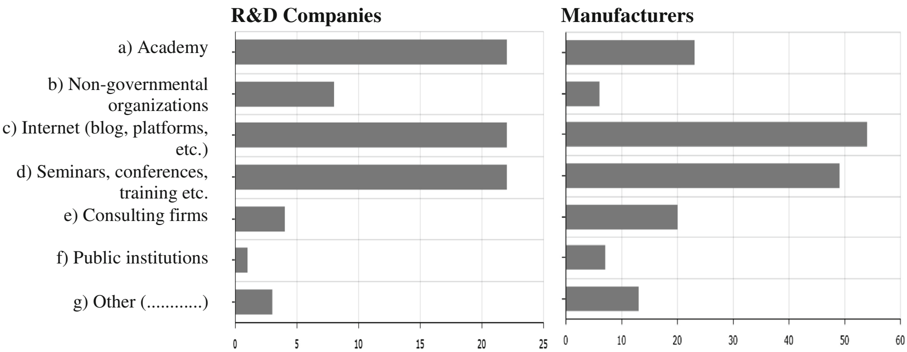

Fig. 2. Answers of second question

(a) *R&D activities in real-time data collection for the production/service or environmental areas using digital sensor networks (Internet of Things (IOT), Wireless/wired Sensor Networks (WSN), Geographic Information Systems (GIS), etc.)*
(b) *Innovative sensor technologies (Industry related physical, chemical, biological, optical, micro-nano sensors; smart actuators; industrial, wireless, digital sensors; artificial vision, innovative sensor applications; development of sensors resistant to extreme conditions)*
(c) *R&D activities in storing and analyzing data related to production/service processes, accessing data independent of time and space (cloud computing and big data)*
(d) *R&D activities in cyber security infrastructure*
(e) *R&D activities in analysis tools, optimization, simulation, etc. technologies*
(f) *R&D activities in collecting and analyzing customer data in design, engineering and production/service processes*
(g) *R&D activities in software supported planning, production/service, supply chain areas*
(h) *R&D activities in the areas of early warning systems related to performance of all production/service processes (intelligent systems, machine learning, virtual reality, etc.)*
(i) *R&D activities in the field of robots (smart manufacturing robots, equipment and software/management systems)*
(j) *R&D activities in M2X infrastructure (Machine-Machine, Machine-Human, Machine-Infrastructure)*
(k) *R&D activities in the area of autonomous production*

(1): No Idea (2): We read articles and publications on related topics (3): We are investigating R & D studies on related topics (4): We are continuing our R & D project/product work on related topics (5): We have completed R & D projects/products in related topics and continue to work (Fig. 3).

Q4. (R&D Companies) *Would you prioritize your investment/research/development plans for Smart Factory Systems and related advanced technologies (Industry 4.0)?*

(1): Not a priority, (2): Long term investment/research/development planned (3): Technical analysis is carried out (4): Short-term investment/research/development will be done (5): Investment/research/development studies started/completed (Fig. 4).

Q3. (Academicians) *Would you rate your article/publication/project work in Smart Factory Systems and related advanced technologies (Industry 4.0)?*

(a) *R&D activities in real-time data collection for the production/service or environmental areas using digital sensor networks (Internet of Things (IOT), Wireless/wired Sensor Networks (WSN), Geographic Information Systems (GIS), etc.)*
(b) *Data processing technologies (big data analysis, processing, correlation, etc.)*
(c) *Cyber security*
(d) *Innovative sensor technologies (Industry related physical, chemical, biological, optical, micro-nano sensors; smart actuators; industrial, wireless, digital sensors; artificial vision, innovative sensor applications; development of sensors resistant to extreme conditions)*

(1): No Idea (2): We read articles and publications on related topics (3): We are investigating R & D studies on related topics (4): We are continuing our R & D project/product work on related topics (5): We have completed R & D projects / products in related topics and continue to work.

	(1)		(2)		(3)		(4)		(5)			
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Ø	±
a)	3x	8,33	5x	13,89	9x	25,00	12x	33,33	7x	19,44	3,42	1,20
b)	7x	19,44	10x	27,78	8x	22,22	7x	19,44	4x	11,11	2,75	1,30
c)	6x	16,67	6x	16,67	8x	22,22	10x	27,78	6x	16,67	3,11	1,35
d)	7x	19,44	12x	33,33	9x	25,00	5x	13,89	3x	8,33	2,58	1,20
e)	5x	13,89	7x	19,44	9x	25,00	10x	27,78	5x	13,89	3,08	1,27
f)	1x	2,78	6x	16,67	10x	27,78	12x	33,33	7x	19,44	3,50	1,08
g)	5x	13,89	6x	16,67	9x	25,00	10x	27,78	6x	16,67	3,17	1,30
h)	6x	16,67	7x	19,44	9x	25,00	8x	22,22	6x	16,67	3,03	1,34
i)	6x	16,67	6x	16,67	11x	30,56	9x	25,00	4x	11,11	2,97	1,25
j)	6x	16,67	10x	27,78	10x	27,78	4x	11,11	6x	16,67	2,83	1,32

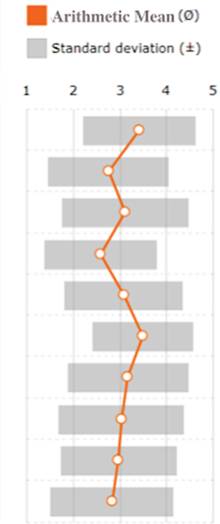

Fig. 3. Answers of R&D companies to third question

(1): Not a priority, (2): Long term investment/research/development planned (3): Technical analysis is carried out (4): Short-term investment/research/development will be done (5): Investment/research/development studies started /completed.

	(1)		(2)		(3)		(4)		(5)			
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Ø	±
a)	5x	13,89	7x	19,44	3x	8,33	6x	16,67	15x	41,67	3,53	1,54
b)	13x	36,11	7x	19,44	2x	5,56	6x	16,67	8x	22,22	2,69	1,64
c)	7x	19,44	6x	16,67	6x	16,67	10x	27,78	7x	19,44	3,11	1,43
d)	7x	19,44	11x	30,56	9x	25,00	2x	5,56	7x	19,44	2,75	1,38
e)	5x	13,89	4x	11,11	7x	19,44	9x	25,00	11x	30,56	3,47	1,40
f)	4x	11,11	8x	22,22	7x	19,44	10x	27,78	7x	19,44	3,22	1,31
g)	6x	16,67	6x	16,67	5x	13,89	10x	27,78	9x	25,00	3,28	1,45
h)	5x	13,89	7x	19,44	5x	13,89	8x	22,22	11x	30,56	3,36	1,46
i)	7x	19,44	8x	22,22	8x	22,22	7x	19,44	6x	16,67	2,92	1,38
j)	7x	19,44	11x	30,56	6x	16,67	6x	16,67	6x	16,67	2,81	1,39
k)	8x	22,22	8x	22,22	7x	19,44	7x	19,44	6x	16,67	2,86	1,42

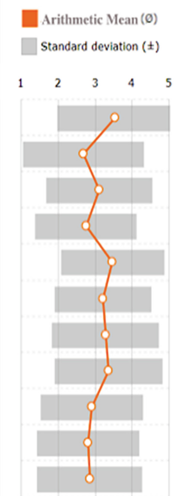

Fig. 4. Answers of R&D companies to fourth question

(e) *Automation (Simulation, Modelling, etc.)*
(f) *Embedded manufacturing materials (equipment, software, decision support systems)*
(g) *Early warning systems (intelligent systems, machine learning, virtual reality, prediction models, etc.)*
(h) *Robots (smart manufacturing robots, equipment and software/management systems)*
(i) *M2X infrastructure (Machine-Machine, Machine-Human, Machine-Infrastructure)*
(j) *Autonomous Systems*

(1): We have knowledge. We don't have studies yet (2): We have read articles and publications on related topics (3): We are investigating academic studies on related topics (4): We are working on academic projects/articles on related topics (5): We have completed/published articles and continue to study (Fig. 5).

(1): We have knowledge. We don't have studies yet (2): We have read articles and publications on related topics (3): We are investigating academic studies on related topics (4): We are working on academic projects/articles on related topics (5): We have completed/published articles and continue to study.

	(1)		(2)		(3)		(4)		(5)			
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Ø	±
a)	11x	28,95	6x	15,79	9x	23,68	6x	15,79	6x	15,79	2,74	1,45
b)	8x	21,05	5x	13,16	7x	18,42	10x	26,32	8x	21,05	3,13	1,46
c)	16x	42,11	9x	23,68	5x	13,16	4x	10,53	4x	10,53	2,24	1,38
d)	19x	50,00	6x	15,79	5x	13,16	7x	18,42	1x	2,63	2,08	1,28
e)	11x	28,95	5x	13,16	7x	18,42	7x	18,42	8x	21,05	2,89	1,54
f)	20x	52,63	8x	21,05	6x	15,79	2x	5,26	2x	5,26	1,89	1,18
g)	12x	31,58	9x	23,68	4x	10,53	6x	15,79	7x	18,42	2,66	1,53
h)	16x	42,11	8x	21,05	6x	15,79	7x	18,42	1x	2,63	2,18	1,25
i)	18x	47,37	5x	13,16	7x	18,42	7x	18,42	1x	2,63	2,16	1,28
j)	13x	34,21	9x	23,68	9x	23,68	3x	7,89	4x	10,53	2,37	1,32

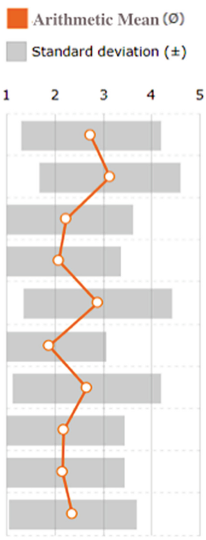

Fig. 5. Answers of academicians to third question

Q4. (Academicians) *Would you prioritize your near-term study plans for Smart Factory Systems and related advanced technologies (Industry 4.0)?*

(1) Not Priority (2) Low Priority (3) Moderate Priority (4) Priority (Fig. 6)

Q3. (Manufacturers) *Would you specify the level of use of Smart Factory Systems and related advanced technologies (Industry 4.0) in your production line processes?*

(1) Not Priority (2) Low Priority (3) Moderate Priority (4) Priority

	(1)		(2)		(3)		(4)			
	Σ	%	Σ	%	Σ	%	Σ	%	Ø	±
a)	7x	18,42	8x	21,05	15x	39,47	8x	21,05	2,63	1,02
b)	3x	7,89	5x	13,16	7x	18,42	23x	60,53	3,32	0,99
c)	10x	26,32	10x	26,32	7x	18,42	11x	28,95	2,50	1,18
d)	15x	39,47	7x	18,42	10x	26,32	6x	15,79	2,18	1,14
e)	9x	23,68	4x	10,53	11x	28,95	14x	36,84	2,79	1,19
f)	19x	50,00	6x	15,79	11x	28,95	2x	5,26	1,89	1,01
g)	7x	18,42	6x	15,79	17x	44,74	8x	21,05	2,68	1,02
h)	14x	36,84	9x	23,68	5x	13,16	10x	26,32	2,29	1,23
i)	13x	34,21	7x	18,42	12x	31,58	6x	15,79	2,29	1,11
j)	9x	23,68	8x	21,05	12x	31,58	9x	23,68	2,55	1,11

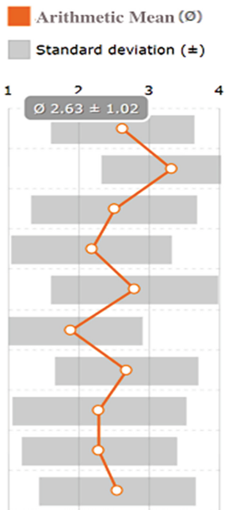

Fig. 6. Answers of academicians to fourth question

(a) *R&D activities in real-time data collection for the production/service or environmental areas using digital sensor networks (Internet of Things (IOT), Wireless/wired Sensor Networks (WSN), Geographic Information Systems (GIS), etc.)*
(b) *Storing and analyzing data related to production/service processes, accessing data independent of time and space (cloud computing and big data)*
(c) *Cyber security Infrastructure*
(d) *Analysis tools, use of optimization, simulation, etc. technologies*
(e) *Collecting and analyzing customer data in design, engineering and production/service processes*
(f) *Software supported planning, production/service, supply chain areas*
(g) *Use of early warning systems on the performance of all your processes (intelligent systems, machine learning, virtual reality, etc.)*
(h) *Robots (smart manufacturing robots, equipment and software/management systems)*
(i) *M2X infrastructure (Machine-Machine, Machine-Human, Machine-Infrastructure)*
(j) *Autonomous Production*

(1): It is not used (2): Little use (3): Moderately use (4): Heavily use (Fig. 7)

Q4. **(Manufacturers)** *Would you ou prioritize your investment plans for the implementation/integration of Smart Factory Systems and related advanced technologies (Industry 4.0) into your existing processes?*

(1): Not a priority, (2): Long term investment planned (3): Technical analysis is carried out (4): Short-term investment will be done (5): Investment studies started/completed (Fig. 8).

(1): It is not used (2): Little use (3): Moderately use (4): Heavily use

	(1)		(2)		(3)		(4)			
	Σ	%	Σ	%	Σ	%	Σ	%	Ø	±
a)	16x	21,92	29x	39,73	13x	17,81	15x	20,55	2,37	1,05
b)	14x	19,18	28x	38,36	17x	23,29	14x	19,18	2,42	1,01
c)	9x	12,33	25x	34,25	25x	34,25	14x	19,18	2,60	0,94
d)	16x	21,92	19x	26,03	25x	34,25	13x	17,81	2,48	1,03
e)	12x	16,44	20x	27,40	29x	39,73	12x	16,44	2,56	0,96
f)	10x	13,70	21x	28,77	23x	31,51	19x	26,03	2,70	1,01
g)	30x	41,10	25x	34,25	12x	16,44	6x	8,22	1,92	0,95
h)	24x	32,88	22x	30,14	17x	23,29	10x	13,70	2,18	1,05
i)	23x	31,94	24x	33,33	16x	22,22	9x	12,50	2,15	1,02
j)	20x	27,40	33x	45,21	17x	23,29	3x	4,11	2,04	0,82

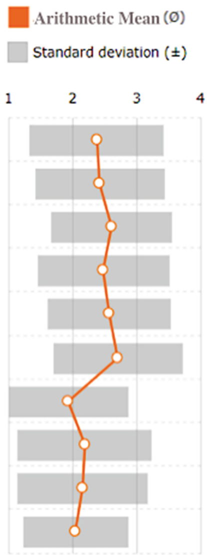

Fig. 7. Answers of manufacturers to third question

(1): Not a priority, (2): Long term investment planned (3): Technical analysis is carried out (4): Short-term investment will be done (5): Investment studies started /completed.

	(1)		(2)		(3)		(4)		(5)			
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Ø	±
a)	8x	10,81	20x	27,03	14x	18,92	12x	16,22	20x	27,03	3,22	1,39
b)	5x	6,76	14x	18,92	18x	24,32	15x	20,27	22x	29,73	3,47	1,28
c)	10x	13,51	8x	10,81	22x	29,73	9x	12,16	25x	33,78	3,42	1,40
d)	6x	8,11	14x	18,92	15x	20,27	19x	25,68	20x	27,03	3,45	1,29
e)	9x	12,16	14x	18,92	20x	27,03	10x	13,51	21x	28,38	3,27	1,38
f)	6x	8,11	13x	17,57	16x	21,62	14x	18,92	25x	33,78	3,53	1,34
g)	10x	13,51	20x	27,03	19x	25,68	13x	17,57	12x	16,22	2,96	1,29
h)	15x	20,27	9x	12,16	19x	25,68	17x	22,97	14x	18,92	3,08	1,39
i)	17x	22,97	13x	17,57	17x	22,97	12x	16,22	15x	20,27	2,93	1,45
j)	13x	17,57	16x	21,62	20x	27,03	18x	24,32	7x	9,46	2,86	1,24

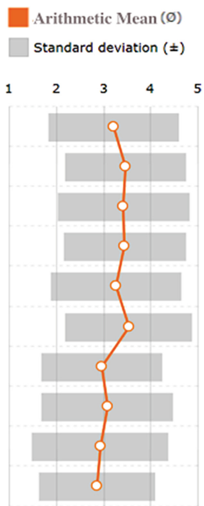

Fig. 8. Answers of manufacturers to fourth question

5 Conclusion

5.1 Level of Knowledge in Smart Factory Systems and Related Advanced Technologies

According to "New Industrial Revolution: Intelligent Manufacturing Systems Technology Road Map" study of TUBITAK dated 03.01.2017, only 22% of the companies that participated in the questionnaire had extensive knowledge on smart factory systems and related advanced technologies. In this study, 78.4% of the R&D companies and 73.97% of the manufacturers have comprehensive knowledge. Over the past 2 years, it has been seen that acquiring comprehensive knowledge has increased 3.5 times and a positive development has been observed. It is thought that 79.2% awareness rate of academicians contributed to this increase in awareness rate. It would be beneficial for the universities to communicate more closely with the industry and transfer their academic knowledge and culture to the industry and to create a similar academic discipline in the industry.

5.2 Information Sources in Smart Factory Systems and Related Advanced Technologies

It was determined that R & D and manufacturer companies participating in the questionnaire obtained 78% of the acquisitions in Smart Factory Systems and related advanced technologies from the following sources:

- Information on the internet
- Seminars, conferences, training, etc. activities
- Academy
- Civil Society Organizations (NGOs)

If more effective and focused work on these 4 sources can be achieved, the level of awareness can be increased and trends can be directed. The effectiveness of these 4 sources can be enhanced by the following suggestions:

- It is recommended to transfer the domestic vision and international goals to all stakeholders and make the correct orientations by using TUBITAK's, Universities' and Ministries' web pages efficiently.
- Companies and universities can be guided by informing them about the conversion to the national smart factory with face-to-face interaction in the seminars that will be organized.
- It is believed that the establishment of support programs that strengthen the communication between the academy and the companies will enable the academicians to be closer to the industry and to be more effective in their R&D work.
- It is evaluated that the source (capital) problem in communication to R&D and manufacturer companies can be solved by preparing special support programs for Civil Society Organizations (NGOs). It is also believed that the NGOs can be brought together with academicians to ensure that the information about smart factory technologies is more academic, up-to-date and international.

5.3 The Level of Use of Smart Factory Systems and Related Advanced Technologies

The following aspects emerged within the scope of the study. These aspects are provided separately for R&D companies and Manufacturers.

R&D Companies:

- The activities in the area of "cyber security" infrastructure are at minimum level
- They cannot perform sufficient R&D work in the areas of "innovative sensor technologies", "early warning systems for the performance of all production processes", "robots", "M2X technologies". These technologies contain costly hardware requirements.
- The activities in "real-time data collection for the production/service or environmental areas using digital sensor networks", "collecting and analyzing customer data in design, engineering and production/service processes", "analysis tools, use of optimization, simulation, etc. technologies", "storing and analyzing data related to production/service processes, accessing data independent of time and space", "software supported planning, production/service, supply chain areas", "autonomous production" has been found to be in relatively better condition.

Manufacturers:

- The activities in the area of "using early warning systems on the performance of all their processes" are at minimum level.
- "Software supported planning, production/service, supply chain technology" used at a relatively high level.
- The use levels of "real-time data collection for the production/service or environmental areas using digital sensor networks", "storing and analyzing data related to production/service processes", "accessing data independent of time and space", "cyber security infrastructure", "use of optimization, simulation, etc. technologies", "collecting and analyzing customer data in design, engineering and production/service processes" are promising, even if not at the expected level.
- The use levels of "Early warning systems for the performance of all production processes", "robots", "M2X technologies, "autonomous production" are below the expected level. It is necessary to take measures to improve the integration and use of these technologies.

The results of this study and the "New Industrial Revolution: Intelligent Manufacturing Systems Technology Road Map" study, appeared to be similar. "New Industrial Revolution: Intelligent Manufacturing Systems Technology Road Map" study evaluated the digital maturity level of the companies as between Industry 2.0 and Industry 3.0. The increase in the level of awareness in the related technology fields of R&D companies and manufacturers in our country has shown that the conversion of smart factories can take place in the medium term. The studies of academicians also accelerated in related fields.

5.4 Investment/Research/Development Plans for Smart Factory Systems and Related Advanced Technologies

The comparison table containing the plans of R&D companies, manufacturers and academicians is presented in Table 2. 1-value is considered priority and 11-value is considered non-priority.

Table 2. Comparison of the plans

Areas	R&D companies	Manufacturers	Academicians
Real-time data collection for the production/service or environmental areas using digital sensor networks (Internet of Things (IOT), Wireless/wired Sensor Networks (WSN), Geographic Information Systems (GIS), etc.)	2	1	4
Innovative sensor technologies (Industry related physical, chemical, biological, optical, micro-nano sensors; smart actuators; industrial, wireless, digital sensors; artificial vision, innovative sensor applications; development of sensors resistant to extreme conditions)	11	10	10
Storing and analyzing data related to production/service processes, accessing data independent of time and space (cloud computing and big data)	4	6	3
Cyber security infrastructure	10	11	6
Analysis tools, optimization, simulation, etc. technologies	5	2	2
Collecting and analyzing customer data in design, engineering and production/service processes	1	5	1
Software supported planning, production/service, supply chain areas	3	4	9
Early warning systems related to performance of all production/service processes (intelligent systems, machine learning, virtual reality, etc.)	6	3	8
Robots (smart manufacturing robots, equipment and software/management systems)	7	7	7
M2X infrastructure (Machine-Machine, Machine-Human, Machine-Infrastructure)	9	9	7
Autonomous production	8	8	5

The R&D study plans of the R&D companies are similar to the investment plans of the manufacturers. Robot, M2X, autonomous production, cyber security infrastructure and innovative sensor technologies are seen to have the lowest level of R&D work and investment plans. These results are believed to be due to the high technology requirements of the related technologies, high investment costs and inadequate domestic product. As the cost of investment increases, it is considered that R&D investments and smart factory transformation investment extend the recycling period and therefore all investment plans are adversely affected. Plans are focused on the following areas: "Real-time data collection for the production/service or environmental areas using digital sensor networks", "Storing and analyzing data related to production/service processes, accessing data independent of time and space", "Analysis tools, optimization, simulation, etc. technologies", "Collecting and analyzing customer data in design, engineering and production/service processes", "Software supported planning, production/service, supply chain areas".

5.5 Suggestions

The reason for the tendency of focusing on the "Real-time data collection for the production/service or environmental areas using digital sensor networks", "Storing and analyzing data related to production/service processes, accessing data independent of time and space", "Analysis tools, optimization, simulation, etc. technologies", "Collecting and analyzing customer data in design, engineering and production/service processes", "Software supported planning, production/service, supply chain areas" is that these areas are software based, costs are lower and it is relatively easy to integrate them into production processes. It is thought that this tendency go round in circles to the demand for supply or vice versa. Investments in smart factory technology with hardware content, incentives for areas that are needed nationally through attractive support programs for R&D activities should be intensified to break this turnaround. It was also observed that the academicians who participated in the survey had almost the same tendency of their plans as the manufacturers and R&D companies. This tendency is due to the fact that software based technology studies can be done more individually, relatively lab independent and work cost is lower. In order to change this tendency of academicians, laboratory support can be given to encourage study in related fields by reducing the cost of laboratory setup/modernization. Thus, the staff-related problems of R&D companies will be reduced as much as possible by triggering national studies in related technologies. In conclusion, it is suggested to construct grant programs with 100% grants in areas where planning of companies is lower. Grant programs can lead organizations to work in these areas.

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