# Sosyal Bilimlerde Yeni Araştırmalar

**Editörler**
Doç. Dr. Emel İSLAMOĞLU
Doç.Dr. Sinem YILDIRIMALP

Ankara 2019

*Bu kitabın tüm hakları yazarına ve yayıncısına aittir.*

# Sosyal Bilimlerde Yeni Araştırmalar

**Editörler**
Doç.Dr. Emel İSLAMOĞLU
Doç.Dr. Sinem YILDIRIMALP

**ISBN:** 978-605-7634-26-9

**Genel Yayın Yönetmeni**
Cuma AĞCA

**Sayfa Düzeni / Kapak**
Biçer YILDIRIM

**Baskı & Cilt**
Berikan Matbaacılık / Gersan-ANKARA
Matbaa Sertifika No: 13642

**YAYINEVİ**
BERİKAN YAYINEVİ
Kültür Mah. Kızılırmak Cad. Gonca Apt. No: 61/6
Çankaya-Kızılay/ANKARA
Tel: (0312) 232 62 18 Fax: (0312) 232 14 99

**Hasan ÇÖLGEÇEN/Muharrem ES**
İLO Sözleşmeleri ve Tavsiye Kararları Çerçevesinde Özel İstihdam Büroları....437

**Zehra Binnur AVUNDUK/Halim KAZAN**
New Trends and Industrıal Changes in Production Technology....453

**Özlem ATAN/Öncü Eroğlu PEKTAŞ/Merve Yanar GÜRCE**
Çalışanların İçsel Pazarlama Yaklaşımına Yönelik Algılarının Yenileşimci İş Davranışlarına Etkisi Üzerine Bir Araştırma....467

**Elif Yüksel OKTAY/Yahya ÖZDEMİR**
Türkiye'de Teknoparklarin İstihdama Etkileri....481

**D – SANAT VE MİMARİ'DE ÖNE ÇIKANLAR**
**Emine YAVUZ/N. Nida Çelebi ŞEKER**
Sağlık Yapılarında İç Mekânda Renk Kullanımı....495

**İldem Ayter SEVER/Emine YAVUZ**
Mobil Mekânlarda Kullanılan Mobilyaların Tasarıma Etkileri....507

**N. Nida Çelebi ŞEKER/İldem Ayter SEVER**
Ofislerde Geçici Çalışma Birimi: Örnek Modül Tasarımı....515

**Timur KAPROL**
Modern Dönem Tarih Kodlarında Su İrtifa ve Aktarım Binaları "Çorlu Önerler Su Irtifa Binası Örneği'....525

# Üretim Teknolojisinde Yeni Eğilimler ve Endüstriyel Değişimler

Dr. Arş. Gör. Zehra Binnur AVUNDUK
*İstanbul Üniversitesi-Cerrahpaşa*

Prof. Dr. Halim KAZAN
*İstanbul Üniversitesi*

**Özet**

Endüstri 4.0., üreticilere ürün yaşam döngüsü boyunca ileri düzeyde bilgi-iletişim teknolojileri (BİT) ve üretim imkânlarını kullanma fırsatı sağlayarak, üretim sistemleri ve teknolojisinde devrim yaratmaktadır. Üretim teknolojisi, ışık hızına benzeyen bir hızla geliştiğinden, bu gelişmeleri yakalayamayan firmaların hızla değişen pazarda rekabetçi kalmaları büyük ölçüde zorlaşabilmektedir. Üretim teknolojisindeki yeni eğilimlerin izlenmesi ve ortaya çıkarılması, firmaların rekabetçi pazarda başarılı bir şekilde faaliyet göstermeleri için yeni stratejiler belirlemelerini kolaylaştırabilir. Bu çalışmada, üretim teknolojisi ile ilgili yeni eğilimler şu şekilde tespit edilmiş ve özetlenmiştir: Nesnelerin interneti, makine öğrenmesi, yapay zekâ, robotik süreç otomasyonu, arttırılmış ve sanal gerçeklik, yalın üretim, 3D baskı, eklemeli üretim, büyük veri ve analitiği, blok zinciri, bulut bilişim, akıllı fabrikalar ve üçüncü platform teknolojileri, firmaların üretim sürecini şekillendiren yeni eğilimler arasında yer almaktadır. Bu araştırmanın sonucu olarak, üretim teknolojisindeki dijitalleşmenin, firmaların yeni sanayi çağındaki kilit başarı faktörü olduğu ifade edilebilir.

**Anahtar kelimeler:** Endüstri 4.0., yeni teknoloji, inovasyon, üretim yönetimi, üretim teknolojisi

# New Trends And Industrıal Changes In Productıon Technology

**Abstract**

Industry 4.0 is revolutionizing production systems and technology by providing manufacturers with the opportunity to utilize advanced information-communication technologies (ICT) and production capabilities throughout the product lifecycle. Production technology continues to move at what seems like the speed of light, and

whether the firms have not keep up, that probably makes difficult to stay competitive in rapidly changing market. Tracking and revealing new trends in production technology might facilitate setting new strategies for firms in order to operate successfully in competitive marketplace. In this study, new trends related about production technology have detected and summarized as follows: Internet of things, machine learning, artificial intelligence, robotic process automation, augmented and virtual reality, lean production, 3D printing, additive manufacturing, big data and analytics, blockchain, cloud computing, smart factories and third platform technologies are among the new trends of shaping the firms' production process. As a result of this research is the digitalization in the production technology is the key success factor of the firms in new industrial era.

**Keywords:** Industry 4.0, new technology, innovation, production management, production technology.

## 1. Introduction

In recent years, technological developments at an unprecedented pace, have driven dramatic increases in industrial productivity. These advances have been clearly started since the 1st Industrial Revolution in 18th century with the discovery of steam engine, introduction of mechanical production facilities supported by water and steam power. 2nd Industrial Revolution were started towards the end of the 19th century and its continued into the 20th century ended at the beginning of World War I, by the integration of the assembly line with the using electrical power into manufacturing systems are the milestones of this period. The 3rd Industrial Revolution is also known as the information technology period from the mid-20th century until the beginning of the 2000s, which started after the World War II and increased its momentum after the 1970s. Combining information & communication technologies (IT) and electronics allows for further automation in production process. The digitalization of production and the computer aided manufacturing (CAM), computer aided design (CAD) systems have emerged in this period. Lastly, much discussed term in nowadays, Industry 4.0 concept was first used in Germany at the Hannover Fair in 2011, the world's largest industry fair, can be defined as the whole of systems developed to increase the efficiency and productivity in production by means of the machines interacting with each other through the internet and by using less manpower and producing more qualified and faster production with lower costs.

The aim of this study is contribute to the literature and practitioners by examining the change in production technology with the Industry 4.0, for this

purpose the new concepts brought about by this new industrial revolution were explained with examples. These are; Internet of things, big data and analytics, lean production, additive manufacturing, cloud computing and smart factories.

## 2. New Concepts in Production Technology

Industry 4.0. is very popular on the agenda. Academic studies are increasing on this subject day by day. In the related literature there are valuable contributions by for example, Jazdi (2014) and Lee, Bagheri & Kao (2015) have studied cyber-physical systems; internet of things (IoT) have been studied by Wan *et al.* (2016); Weyrich and Ebert (2016); Wollschlaeger, Sauter and Jasperneite (2017); Boyes *et al.* (2018); cloud manufacturing (Xu, 2012; Liu and Xu, 2016; Thames and Schaefer, 2016); big data (Groves *et al.*, 2013; Gandomi and Haider, 2015; Obitko and Jirkovský, 2015; Khan *et al.*, 2017; Zhou, Yao and Zhang, 2017), process planning and product development (Santos *et al.*, 2017; Trstenjak and Cosic, 2017); smart factories (Shrouf, Ordieres and Miragliotta, 2014; Hozdić, 2015; Prinz *et al.*, 2016); lean production and automation (Kolberg and Zühlke, 2015; Jayaram, 2016; Tortorella and Fettermann, 2017; Wagner, Herrmann and Thiede, 2017); additive manufacturing (Huang *et al.*, 2014; Lipton *et al.*, 2015; Hager, Golonka and Putanowicz, 2016; Eyers and Potter, 2017).

In this part of the study, concepts related with industry 4.0 and its place in production technology are explained.

### 2.1. Internet of Things

There are numerous definition about internet of things (IoT) in the literature. The proper definition would be: "An open and comprehensive network of intelligent objects that have the capacity to auto-organize, share information, data and resources, reacting and acting in face of situations and changes in the environment." (Madakam, Ramaswamy and Tripathi, 2015, p. 165). "IoT that all items were connected to Internet by sensor devices such as Radio Frequency Identification (RFID) in order to accomplish intelligent recognition and network management was first proposed by Auto-ID laboratory in Massachusetts Institute of Technology in 1999. Its core support technology is a wireless sensor network and RFID technology" (Chen and Jin, 2012, p. 561). Smart homes, wearable devices, connected cars are some of the IoT examples. For example, a connected car defined is a vehicle which is able

to optimize it's own maintenance, operation as well as comfort of voyagers using internet connectivity and onboard sensors (Cruise, 2019).

As a good example for smart home technologies that Samsung's innovative smart refrigerator Family Hub that uses the IoT. The company has revealed a few innovative products in Samsung SEAO Forum 2019 event, and one of them is Family Hub Refrigerator and it has packed with artifical intelligence and IoT features (Wong, 2019). This innovative refrigerator has the smart technology that allows users to add to shopping lists, online order groceries, check the weather and manage their schedules. Furthermore, Samsung is adding onto the this product to include the Samsung Connect app, which may help to manage all smart devices in the home such as locks, wireless speakers, security cameras and lights etc. (PYMNTS, 2017).

Queuehop Cloud is another innovative example of inventory tracking and theft prevention by using IoT solution. (Timokhina, 2017). It is a digitized retail environment that brings together the realms of physical retail and e-commerce and where the customers can interact with every piece of merchandise around them. This system simplifies shopping and provides good experience to customers through preventing waiting in the queue. As it is understood from the name "Queuehop" is a combination of the words "queue" and "hop". Moreover, with using online financial services, it offers payment advantages to the customers who do not have cash or credit cards in physical wallet. Customers scan the QR code of the products they choose to buy in physical stores using their smart phones, and then complete their shopping by using online payment tools, finally unlocking the alarm on the product from the alarm remover before leaving the store (*QueueHop | Retail Mobile Self-Checkout*, 2016). The system allows to the owners of the businesses in order to manage their inventory in real time. Consequently, this technology has the potential a kind of disruptive innovation on the entire shopping process, by allowing reallocation of the resources for providing better efficiency and advanced service for customers (Timokhina, 2017).

### 2.2. Big Data and Analytics

Big Data (BD) identifies that the data is just excessively huge to be managed by traditional processing tools and databases. These overlarge data structures are generally made up of a combination of structured and non-structured data from a variety of sources such as forms, blogs, text, comments, photographs, videos, GPS trails, news feeds etc. Google and Walmart are

companies that have been processing Big Data for years. (Gilchrist, 2016, p. 52). It is used in in various business functions such as employee revenue optimization, distribution and logistics optimization, financial services, store behavior analysis, customer relationship analysis, advertising targeting, product variety and price optimization (Mutlu, 2018).

The shared issue among them is the huge amounts of multi-structured data living in multiple disparate systems which can be solved by BD. Therefore BD is used in several ways such as: customer analytics, fraud analytics, compliance analytics, and operational analytics. BD also used in retail amd communications sector for retaining customers or loyalty programs etc. Besides the BD, data analytics is defined as the science of examining raw data with the aim of drawing conclusions about the information. It involves performing an mechanical or algorithmic process to derive insights. Data analytics is used in several industries to allow the enterprises in order to make superior decisions as well as verify or disprove existent models or theories (Arora, 2019).

### 2.3. Additive Manufacturing

Additive manufacturing (AM) also known as "3D (three-dimensional) Printing" is defined "the process of joining materials to make objects from 3D model data, usually layer by layer." AM is clearly a varied type of manufacturing and it has lots of benefits over traditional manufacturing processes (Huang *et al.*, 2014). AM processes work as taking "the information from a CAD file that is later converted to a stereolithography file. In this process, the drawing made in the CAD software is approximated by triangles and sliced containing the information of each layer that is going to be printed" (Wong and Hernandez, 2012). One of the AM system's benefits is that it enables to produce low quantities and customized products with complex geometries, advanced material properties and functionality by time and cost efficient way (Huang *et al.*, 2014). Holmström *et al.*, (2010) defined rapid manufacturing (RM) concept as the systems that produce parts from 3D CAD data. It can be assumed that AM and RM concepts also synonyms.

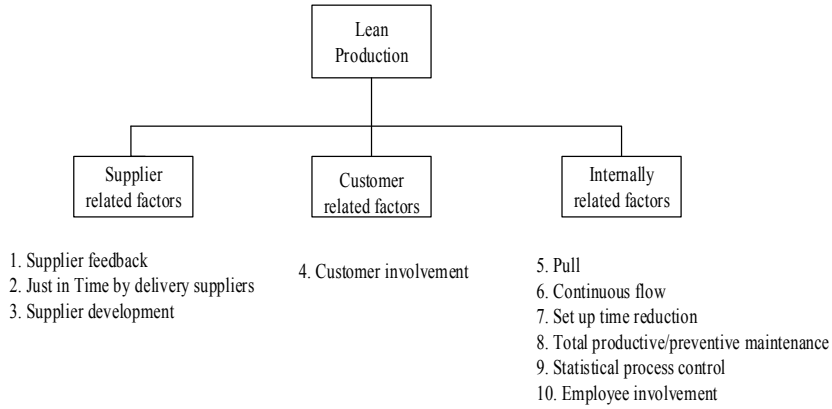
In the AM system, producer be able to make almost any shape parts without the limitations of traditional manufacturing. Furthermore, series of parts with individual changes can be done as readily as identical parts. Besides, there are many advantages of the AM system, listed below (Holmström *et al.*, 2010, p. 688):

- Make production in small quantites are feasible and economical.
- Any tooling is not needed importantly reducing production ramp-up time and expenses.
- Design customization.
- Possibility to change design quickly and reduce waste.
- Allows product to be optimized for function and economical custom products.
- Possibility for simplificative supply chains; lower inventories and shorter lead times.

### 2.4. Lean Production

Lean production (LP) is a system that is oriented on learning of organization through continuous improvements and LP origins is based on the Toyota Production System. The philosophy is that "doing more with less". Hence, it's purpose to reduce unnecessary steps in the working process by the waste elimination which is perceived as any action that does not add value to the product or services (Mrugalska and Wyrwicka, 2017). Shah and Ward (2007) were using a multi-step approach in order to construct development onto the lean manufacturing, and they purified the 48 items items into the ten factors. They were also collected these 10 factors in 3 main groups. These are summarized and showed in the Figure 1.

**Figure 1.** Dimensions of Lean Production




**Resource:** Adapted from Shah and Ward, (2007).

As seen in Figure 1, it can be clearly expressed that the dimensions that constitutes lean production aim to increase productivity and efficiency.

### 2.5. Cloud Computing

Cloud computing (CC) defined as "a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction." (*Cloud Computing | CSRC*, 2018). Cloud computing offers several advantages to the businesses. Some of these are listed below: (Basu, no date; Avram, 2014)

- Offers unlimited storage capabilities, and frees up desktop storage.
- Makes it easier for businesses in order to scale their services.
- Reduces the entry costs dramatically for the small enterprises trying to utilize compute-intensive business analytics that were hither to available merely to the large enterprises.
- Provides cost flexibility. In this way, enterprises can avoid the high upfront costs of purchasing software and hardwares.
- Allows easier group collaboration and business operations are more flexible.
- Can provide access to hardware resources, with no upfront capital investments for users, leading to a faster time to market in enterprises.
- Be able to decrease information technology barriers to innovation.
- Enables home office working for employees and interact with colleagues in real time working in remote sites several time zones away.

### 2.6. Smart Factory

Smart factory concept is a novel approach to production technologies. It has been "manufacturing smart products and they have being supplied with energy from smart grids as well as supplied with water from fresh water reservoirs." The material flow along the product life cycle (PLC) and between adjoining PLC will be accomplished by smart logistics. In Industry 4.0, data stream between different components of the value creation in the networks has interchanged via the cloud systems (Stock and Seliger, 2016). Production of smart personalized product requires high level of information and communication technologies and flexibility integration into the manufacturing system. Additionaly, it considers customer's exact needs and uniquely identifiable. The other characteristics are; products and services integrated

into single extended product and there is superordinate collaboration through production network members (Veza, Mladineo and Gjeldum, 2015). Smart factories refers to multiscale manufacturing by using the IoT and ICT, which consist of smart sensors, computing and predictive analytics and resilient control technologies. These are must be bonded together to transfer, acquire, analyze and interpret the information and to control the manufacturing process as intended (Lee, 2015).

One of the global players, Siemens is a good example with the established smart factories. They called as "Digital Factory" and its provides an extensive portfolio of seamlessly integrated software, hardware and technology-based services to support manufacturing firms global in heighten the efficiency and flexibility of their manufacturing processes and reducing the launch time of the products. Their ultimate goal is the complete digital representation of the entire physical value chain and solution platform for that purpose they were created and named "Digital Enterprise" (*Siemens A.Ş. - Siemens Turkey - Our Business - Digital Factory*, 2019).

In the automotive industry, "Audi has invested 1.3 billion dollars for building a smart factory in Mexico." Another automotive giant, BMW is planning to expand its the highest production plants of globally, in South Carolina-USA for 1 billion dollars and moreover intends to invest 600 million dollars in the project (Rais, 2018).

## 3. Conclusion

The rising of new digital industrial revolution, Industry 4.0 is composed of many novel technological elements. It comprises that such as IoT, additive manufacturing, artificial intelligence, smart factory, cloud computing and a lot of new technological tools. It transformed the traditional production process to more effective, digital, smart and speedy. In consequence of this disruptive technological innovations, highly complicated and customized products be able to manufactured in a simple way and low quantities with low costs. Some of the additional advantages of using these new technologies are; savings time and costs as well as producing high-quality products.

This industrial revolution in the digital age, radically changes the daily life patterns of consumers, employees and businesses. As a result of this change, new business models are being developed, so businesses need to provide fast transformation in their production systems. On the other hand, the rapid advancement of technology easily outdated the innovative products.

Therefore, it is necessary to analyze the areas to be invested wisely. It is important that businesses align their systems to produce more niche areas. Because Industry 4.0 tools allow to produce customized products in an easy, fast and cost-effective way for individualized needs of consumers rather than providing ordinary products with standardized production. The new tools of manufacturing such as 3D production-additive manufacturing, smart factories, automated robots, Internet of things and big data offers a rich portfolio of businesses. By evaluating these opportunities, those who can make revolutionary innovations that might be the first in the market will be able to get a great profit share.

**References**

Arora, S. (2019) *Data Science vs. Big Data vs. Data Analytics*. Available at: https://www.simplilearn.com/data-science-vs-big-data-vs-data-analytics-article (Accessed: 10 April 2019).

Avram, M. G. (2014) 'Advantages and Challenges of Adopting Cloud Computing from an Enterprise Perspective', *Procedia Technology*. Elsevier, 12, pp. 529–534. doi: 10.1016/J.PROTCY.2013.12.525.

Basu, C. (no date) *The Advantages of Cloud Computing for Business | Chron.com*. Available at: https://smallbusiness.chron.com/advantages-cloud-computing-business-21914.html (Accessed: 10 April 2019).

Boyes, H. *et al.* (2018) 'The industrial internet of things (IIoT): An analysis framework', *Computers in Industry*. doi: 10.1016/j.compind.2018.04.015.

Chen, X.-Y. and Jin, Z.-G. (2012) 'Research on Key Technology and Applications for Internet of Things', *Physics Procedia*. doi: 10.1016/j.phpro.2012.05.104.

*Cloud Computing | CSRC* (2018). Available at: https://csrc.nist.gov/projects/cloud-computing (Accessed: 10 April 2019).

Cruise, N. (2019) *What are the best examples of the 'Internet of things'? - Quora*. Available at: https://www.quora.com/What-are-the-best-examples-of-the-Internet-of-things (Accessed: 9 April 2019).

Eyers, D. R. and Potter, A. T. (2017) 'Industrial Additive Manufacturing: A manufacturing systems perspective', *Computers in Industry*. doi: 10.1016/j.compind.2017.08.002.

Gandomi, A. and Haider, M. (2015) 'Beyond the hype: Big data concepts, methods, and analytics', *International Journal of Information Management*. doi: 10.1016/j.ijinfomgt.2014.10.007.

Gilchrist, A. (2016) *Industry 4.0: The Industrial Internet of Things*, *Apress*. doi: 10.1007/978-1-4842-2047-4.

Groves, P. *et al.* (2013) *The Big Data revolution in healthcare*, *McKinsey Global Institute*.

Hager, I., Golonka, A. and Putanowicz, R. (2016) '3D Printing of Buildings and Building Components as the Future of Sustainable Construction?', in *Procedia Engineering*. doi: 10.1016/j.proeng.2016.07.357.

Holmström, J. *et al.* (2010) 'Rapid manufacturing in the spare parts supply chain', *Journal of Manufacturing Technology Management*. Emerald Group Publishing Limited, 21(6), pp. 687–697. doi: 10.1108/17410381011063996.

Hozdić, E. (2015) 'Smart factory for industry 4.0: A review', *International Journal of Modern Manufacturing Technologies*.

Huang, Y. *et al.* (2014) 'Additive Manufacturing: Current State, Future Potential, Gaps and Needs, and Recommendations', *Journal of Manufacturing Science and Engineering*. doi: 10.1115/1.4028725.

Jayaram, A. (2016) 'Lean six sigma approach for global supply chain management using industry 4.0 and IIoT', in *Proceedings of the 2016 2nd International Conference on Contemporary Computing and Informatics, IC3I 2016*. doi: 10.1109/IC3I.2016.7917940.

Jazdi, N. (2014) 'Cyber physical systems in the context of Industry 4.0', in *Proceedings of 2014 IEEE International Conference on Automation, Quality and Testing, Robotics, AQTR 2014*. doi: 10.1109/AQTR.2014.6857843.

Khan, M. *et al.* (2017) 'Big data challenges and opportunities in the hype of Industry 4.0', in *IEEE International Conference on Communications*. doi: 10.1109/ICC.2017.7996801.

Kolberg, D. and Zühlke, D. (2015) 'Lean Automation enabled by Industry 4.0 Technologies', in *IFAC-PapersOnLine*. doi: 10.1016/j.ifacol.2015.06.359.

Lee, J. (2015) 'Smart Factory Systems', *Informatik-Spektrum*. Springer Berlin Heidelberg, 38(3), pp. 230–235. doi: 10.1007/s00287-015-0891-z.

Lee, J., Bagheri, B. and Kao, H. A. (2015) 'A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems', *Manufacturing Letters*. doi: 10.1016/j.mfglet.2014.12.001.

Lipton, J. I. *et al.* (2015) 'Additive manufacturing for the food industry', *Trends in Food Science and Technology*. doi: 10.1016/j.tifs.2015.02.004.

Liu, Y. and Xu, X. (2016) 'Industry 4.0 and Cloud Manufacturing: A Comparative Analysis', in *Volume 2: Materials; Biomanufacturing; Properties, Applications and Systems; Sustainable Manufacturing*. doi: 10.1115/MSEC2016-8726.

Madakam, S., Ramaswamy, R. and Tripathi, S. (2015) 'Internet of Things (IoT): A Literature Review', *Journal of Computer and Communications*. doi: 10.4236/jcc.2015.35021.

Mrugalska, B. and Wyrwicka, M. K. (2017) 'Towards Lean Production in Industry 4.0', in *Procedia Engineering*. doi: 10.1016/j.proeng.2017.03.135.

Mutlu, A. (2018) *Big Data Nedir? Ne İşe Yarar? Kullanım Alanları Nelerdir?* Available at: https://medium.com/@alimutlu.com.tr/big-data-nedir-ne-ışe-yarar-kullanım-alanları-nelerdir-379a0b3596c1 (Accessed: 10 April 2019).

Obitko, M. and Jirkovský, V. (2015) 'Big data semantics in industry 4.0', in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. doi: 10.1007/978-3-319-22867-9_19.

Prinz, C. *et al.* (2016) 'Learning Factory Modules for Smart Factories in Industrie 4.0', in *Procedia CIRP*. doi: 10.1016/j.procir.2016.05.105.

PYMNTS (2017) *Samsung Family Hub IoT Has Smart Fridge | PYMNTS.com*. Available at: https://www.pymnts.com/internet-of-things/2017/samsung-reinvents-the-family-hub-with-iot-smart-fridge/ (Accessed: 11 April 2019).

*QueueHop | Retail Mobile Self-Checkout* (2016). Available at: https://www.home.queuehop.com/ (Accessed: 11 April 2019).

Rais, A. (2018) *Smart factories in the automotive industry*. Available at: https://www.maschinenmarkt.international/smart-factories-in-the-automotive-industry-a-765880/ (Accessed: 11 April 2019).

Santos, K. *et al.* (2017) 'Opportunities Assessment of Product Development Process in Industry 4.0', *Procedia Manufacturing*. doi: 10.1016/j.promfg.2017.07.265.

Shah, R. and Ward, P. T. (2007) 'Defining and developing measures of lean production', *Journal of Operations Management*. John Wiley & Sons, Ltd, 25(4), pp. 785–805. doi: 10.1016/j.jom.2007.01.019.

Shrouf, F., Ordieres, J. and Miragliotta, G. (2014) 'Smart factories in Industry 4.0: A review of the concept and of energy management approached in production based on the Internet of Things paradigm', in *IEEE International Conference on Industrial Engineering and Engineering Management*. doi: 10.1109/IEEM.2014.7058728.

*Siemens A.Ş. - Siemens Turkey - Our Business - Digital Factory* (2019). Available at: http://www.siemens.com.tr/web/1258-18018-1-1/siemens_turkiye_-_en/siemens_turkey/our_business/digital_factory (Accessed: 10 April 2019).

Stock, T. and Seliger, G. (2016) 'Opportunities of Sustainable Manufacturing in Industry 4.0', *Procedia CIRP*, 40, pp. 536–541. doi: 10.1016/j.procir.2016.01.129.

Thames, L. and Schaefer, D. (2016) 'Software-defined Cloud Manufacturing for Industry 4.0', in *Procedia CIRP*. doi: 10.1016/j.procir.2016.07.041.

Timokhina, V. (2017) *6 Cool Examples of Internet of Things Applications and How to Develop One : Eastern Peak*. Available at: https://easternpeak.com/blog/6-cool-examples-of-internet-of-things-applications-and-how-to-develop-one/ (Accessed: 11 April 2019).

Tortorella, G. L. and Fettermann, D. (2017) 'Implementation of Industry 4.0 and lean production in Brazilian manufacturing companies', *International Journal of Production Research*. doi: 10.1080/00207543.2017.1391420.

Trstenjak, M. and Cosic, P. (2017) 'Process Planning in Industry 4.0 Environment', *Procedia Manufacturing*. doi: 10.1016/j.promfg.2017.07.303.

Veza, I., Mladineo, M. and Gjeldum, N. (2015) 'Managing Innovative Production Network of Smart Factories', *IFAC-PapersOnLine*, 48(3), pp. 555–560. doi: 10.1016/j.ifacol.2015.06.139.

Wagner, T., Herrmann, C. and Thiede, S. (2017) 'Industry 4.0 Impacts on Lean Production Systems', in *Procedia CIRP*. doi: 10.1016/j.procir.2017.02.041.

Wan, J. *et al.* (2016) 'Software-Defined Industrial Internet of Things in the Context of Industry 4.0', *IEEE Sensors Journal*. doi: 10.1109/JSEN.2016.2565621.

Weyrich, M. and Ebert, C. (2016) 'Reference architectures for the internet of things', *IEEE Software*. doi: 10.1109/MS.2016.20.

Wollschlaeger, M., Sauter, T. and Jasperneite, J. (2017) 'The future of industrial communication: Automation networks in the era of the internet of things and industry 4.0', *IEEE Industrial Electronics Magazine*. doi: 10.1109/MIE.2017.2649104.

Wong, A. (2019) *Samsung Family Hub Refrigerator now packed with AI and IoT features | TechNave*. Available at: https://technave.com /gadget/Samsung-Family-Hub-Refrigerator-now-packed-with-AI-and-IoT-features-14064.html (Accessed: 11 April 2019).

Wong, K. V. and Hernandez, A. (2012) 'A Review of Additive Manufacturing', *ISRN Mechanical Engineering*. doi: 10.5402/2012/208760.

Xu, X. (2012) 'From cloud computing to cloud manufacturing', *Robotics and Computer-Integrated Manufacturing*. doi: 10.1016/j.rcim.2011.07.002.

Zhou, J., Yao, X. and Zhang, J. (2017) 'Big Data in Wisdom Manufacturing for Industry 4.0', in *Proceedings - 2017 5th International Conference on Enterprise Systems: Industrial Digitalization by Enterprise Systems, ES 2017*. doi: 10.1109/ES.2017.24.