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## How does Internet of Everything enable Digital Transformation: A review and a research agenda from an editorial perspective

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### Abstract

The Internet of (Every) Things (IoE/IoT) have revolutionized technology and industries at large. It has connected multiple domains such as healthcare, safety, education, finance, defense and many more, all under a common integrated platform. As evident, IoE/IoT is declared to be the future and the only possible solution to all technical limitations we are heading up to. Hence, it is of utmost importance for the budding technologists to be aware of the basics of IoE, its development track and the probable application areas which can be benefitted. This article emphasizes on the various industrial application areas which have been exploiting IoE at large and the prospects which are yet unexplored. We connect our findings and discourse towards future research agendas that researchers may explore based on extant trends in literature.

### Keywords

Internet of Things; Digital Transformation; Artificial Intelligence; Smart Devices; Sensors; Actuators.

# How Does Internet of Everything Enable Digital Transformation: A Review and a Research Agenda from an Editorial Perspective

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## Abstract

The Internet of (Every) Things (IoE/IoT) have revolutionized technology and industries at large. It has connected multiple domains such as healthcare, safety, education, finance, defense and many more, all under a common integrated platform. As evident, IoE/IoT is declared to be the future and the only possible solution to all technical limitations we are heading up to. Hence, it is of utmost importance for the budding technologists to be aware of the basics of IoE, its development track and the probable application areas which can be benefitted. This article emphasizes on the various industrial application areas which have been exploiting IoE at large and the prospects which are yet unexplored. We connect our findings and discourse towards future research agendas that researchers may explore based on extant trends in literature.

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## 1. Introduction

With the advances in digital communication protocols and services like 5G technology, the Internet of Things (IoT) has gradually gained prominence. The IoT is a network which connects multiple smart devices to the Internet for the purpose of exchanging meaningful information (Chen, Xu, Liu, Hu, & Wang, 2014). Used to automate and provide services that can be accessed and consumed over smart devices like wearables, the IoT has evolved to become the Internet of Everything (IoE). IoE has evolved from IoT which used to connect homogeneous sensors and actuators over a mesh of services which are rendered over the internet to a mesh of heterogeneous sensors and actuators which are connected over internet protocols and also localized intelligent networks to provide services which have both a localized component and a global connected component (extending Langley et al., 2021). IoE utilizes Artificial Intelligence (AI) for communicating through the information sensors in

accordance with certified government protocols. As the name signifies, devices which are connected through the Internet by means of Wireless Area Networks (WAN), Radio-frequency identification (RFID), Bluetooth, Near-field communication (NFC), Long Term Evolution (LTE) and multiple other smart communication technologies, together forms the backbone of the IoE architecture. IoE architecture is one of the major pillars for achieving digital transformation, whether it is at the firm level or at a national level (Khanna & Kaur, 2020; Liu, Dai, Wang, Shukla, & Imran, 2020).

There are four pillars which combine to produce an effective and reliable approach to Digital Transformation by holding hands with IoE. The basic objectives of Digital Transformation (Vial, 2021) are as follows:

- Exploiting the ability of connecting devices to deliver best user experience - IoE involves multiple devices working in unison. Microelectronics are an integral part of IoE ecosystems.

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11. Advances In Science Technology and Engineering Systems (28)
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13. International Journal of Production Economics (25)
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16. Technology In Society (23)
17. Computer Law and Security Review (22)
18. Journal Of Self Governance and Management Economics (22)
19. Industrial Management and Data Systems (21)
20. Journal of Business Research (19)

Future researchers may look at literature published in these platforms while trying to undertake a

review of literature, besides considering them as potential platforms for dissemination of knowledge based on the rigor of the research and novelty of theoretical contributions. Fig. 2 shows how the domain of IoT and IoE gained prominence over the years and the number of publications increased exponentially with time.

Needless to say, as the trends indicate, IoE is a very fast developing area of academic research, not only in the space of electronics and computer science, but also its applications and explorations in business and management journals are gradually increasing very fast. However it is to be noted that most of the literature is still focused on IoT and IoE literature is yet to find prominence in business and management journals.

### 3. Application areas of IoE

Technology has totally changed the way of our living standards. If we trace back to the period of evolution of human beings, we can observe that slowly and gradually everything has changed with digital transformation changing the way we engage and consume services in workplaces, industrial organizations, personal fronts and day to day life. The positive aspects of technology are enlisted below:

- (a) IoE in academics: IoE has entirely transformed the way of teaching and learning processes, especially in higher education sector. The blackboard, chalk, and dusters have been replaced by smartboard and smart classes

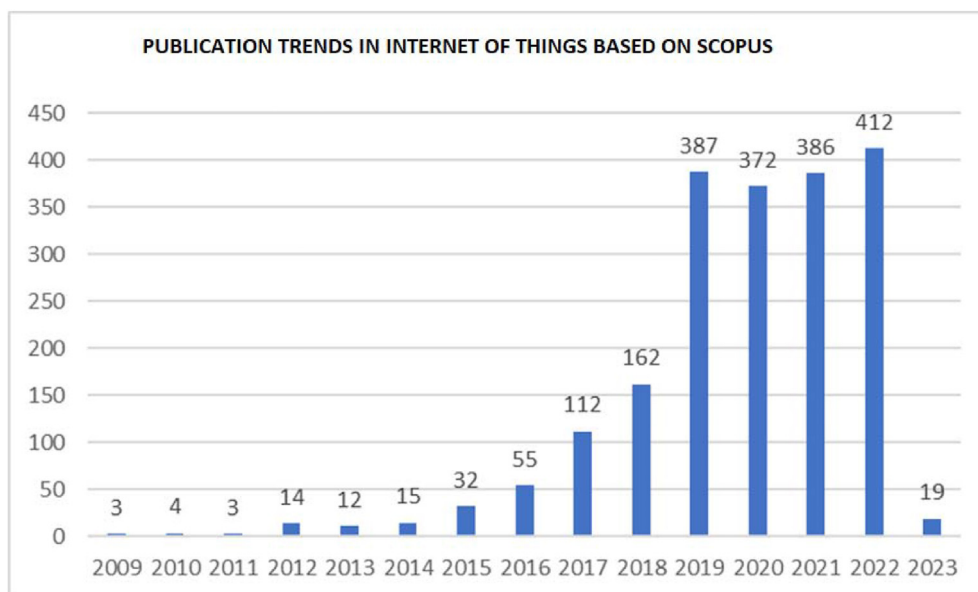


Fig. 2. Publication trend in the domain of IoE over the years.

(Joseph, Kar, Ilavarasan, & Ganesh, 2017). The invention of computers has brought a revolutionary change in our life. Today there are different models and advanced forms of computers available in the market like laptops, iPad, notebooks, smartphones, etc. Teaching has become easier as the videos and images related to different topics can be shown to the students along with teaching. This makes it easy for the students to understand the relevant topic. Teachers nowadays can easily communicate with parents and keep them updated on their child's performance and report issues, if any. In colleges, students are asked to bring laptops, especially in professional courses. It is easier to carry a laptop instead of a heap of notebooks. Many universities have started online courses and assessments for students. The earlier pen and paper-based competitive exams have been replaced by the online mode of examination (Felicia, Wong, Loh, & Juwono, 2021). Thus, it can be stated that remote location and interactive teaching/assessment has been made possible only with the help of IoE. Education at all levels went on unperturbed during the lockdown scenario only by holding hands with IoE. Areas of research which is picking up involve adoption and impact of smart classroom and flipped classroom enabled by technologies like IoE.

- (b) Operational efficiencies at work: Earlier in the offices there were no computers, and the calculations and account maintenance works were performed manually. The manual working process required a lot of time and energy (Kar, Kar, & Gupta, 2021). The development of computers has become a boon. Today there are computers in every office, and they can store a large amount of data and information. The calculations can be easily performed in seconds. IoE has certainly reduced the time and effort of the people. Users of IoE technologies and platforms have reported higher self-efficacies while using these systems for both work and personal needs (Chatterjee, Kar, & Gupta, 2018). Further, through the automation of industrial processes, while being used synchronously with technologies like Artificial Intelligence (AI) and blockchain, IoE is gaining traction in industrial applications extensively.
- (c) Digital payments: The proliferation of online transaction applications for digital payments like Paytm, BHIM UPI, Google pay, etc. is increasingly seen in the digital economy (Kar, 2021), in a country like India after the demonetization. Using

these applications, we can make online payments anywhere instead of paying cash. This has been made possible because of the information technology. Cash needs to be managed well as there is a fear of theft. These technologies encourage cashless transactions rather than cash-based payment. The radio frequency identification (RFID) chips and mobile phone's global positioning systems (GPS) use sensor technologies extensively to automate processes for digital transactions (Alam, Sarma, Chakma, Alam, & Hossain, 2021) and payments. Future research agendas could also cover digital money which is an emerging concept in current times.

- (d) Digital healthcare: IoE has given new hope to the field of medical science through interventions achieved through digital healthcare systems (Kashani, M. H. et al., 2021). The pandemic has accelerated the use of IoE in the healthcare industry. The Internet of Things provides a much more efficient link between patients, doctors, and pharmaceuticals. The traditionally reactive medical cycles can now be proactive.
- Attaching sensors to a patient at home allows doctors to monitor them remotely. Continuous abnormality of parameters immediately alerts the doctor, creating preemptive action. Doctors can use this to monitor at-risk patients such as the elderly and those suffering from chronic diseases.
  - Besides monitoring, IoE can also streamline patient medical records and access, making real-time data available across departments.
  - IoE is being used to optimize the manufacturing process at the pharmaceutical end. The direct result of this is lower drug prices. It is also used for intelligent inventory management.
  - IoE was significantly used in many capacities while dealing with the COVID pandemic (Darshan & Anandakumar, 2015). Telemedicine and vaccine supply chain monitoring were two of IoE's implementations which in recent times have created large impacts.
  - Drones are used to deliver medication and instruments to rural healthcare centers, such as those located in Rwanda and Ghana. Drones are dependent on sensors and geolocation crowdsensing platforms for fulfilling distribution and logistics services.
  - IoE with AI can enable better automated interventions and provide recommendations for patients for cases like mental health and other areas for problem detection.

- (e) Enhanced communications: The whole world is at our tips. Technology has made it easier to communicate with people staying anywhere on the globe. The distances now do not matter as we are connected by technology. It has enhanced the ease of business. Business meetings can easily be conducted by video conferencing. Now there is an ease of trade between different nations by such technological advancements.

5G and IoE: With IoE-enabled devices in mind, 5G connects a higher density (Chettri & Bera, 2019) of devices at higher speeds and makes 'time lag' an extinct parameter. As a result, 5G creates an excellent user experience irrespective of what application, device, or services users require. 5G's adaptability enables businesses and industrial organizations to connect more devices with better capability for less expense. Early 5G IoE use cases focused on: (a) Enterprise and high-speed industrial networking, (b) Customer premise equipment (CPE), (c) Mobile computing, (d) Video broadcasting, (e) Fixed wireless access (FWA). As application grows, 5G IoE use cases will evolve and use public and private networks to stream virtual and augmented reality and 3D. Moreover, 5G applications will be used for critical communications like factory automation, uncrewed aerial vehicles (UAVs) and more (Wang et al., 2018).

- (f) Smart home and urbanization: A smart home uses sensors to control and maintain lighting, resource management, and security systems (Chatterjee, Kar, & Mustafa, 2021). A smart home is a smaller, independent version of a smart city. A smart home system uses natural language processing (NLP) for the contextual processing of voice commands. Internet switches are used to operate the appliances plugged into them. The system takes care of lighting rooms and even playing personalized music as per requirement (Kar, Ilavarasan, Gupta, Janssen, & Kothari, 2019). The security system uses facial recognition to alert the family of the identity of their visitors. Even elderly population are now dependent on IoE for monitoring of their health and security services (Chatterjee, Kar, & Dwivedi, 2022). For example, with Alexa and Siri with their voice recognition systems, it is possible to automate home appliances and control them, while not being in the proximity of the home over internet protocols. Smart homes are extensions of smart city initiatives and extend technological innovations

within habitation for improving quality of life (Zarindast, Sharma, & Wood, 2021).

- (g) Smart Agriculture: Agriculture, as an industry, could massively benefit from the Internet of Things (Goswami, Chakraborty, Das, & Gupta, 2017). The world's human population is estimated to grow to around 10 billion by 2050. As such, governments are prioritizing the scaling up of agricultural systems. This, combined with climate change, has farmers marrying technology to cultivation. Sensors are used to provide details of soil chemistry and fertilizer profiles. Carbon dioxide levels, moisture, temperature, level of acidity, and the presence of appropriate nutrients all contribute to how good a harvest turns out to be. Smart irrigation is an IoE application (Stoces, M. et al., 2016) to regulate and efficiently use water for farming. The IoE system only initiates the water flow when the soil reaches a certain dryness level. It also stops the supply once a certain level of moisture is reached. This reduces wastage caused by human errors (Talavera, J. M. et al., 2017).

- (h) Smart Cities: Sensors on roads and traffic signals send data to the IoE systems. This data, accumulated over time, allows officials to analyze traffic patterns and peak hours. It also helps create solutions for bottlenecks. Commuters can use this information to determine which areas are congested and what alternate routes can be used. A version of this already exists in third-party map services such as Google Maps.

Pollution Monitoring: A prominent problem faced by every country in the world is air pollution. With existing sensors (Zhao et al., 2020), one can easily measure common parameters such as temperature, carbon dioxide levels, smoke, and humidity. Smart cities leverage this technique to gather data about air quality and subsequently develop mitigation methods. Smart cities also use IoE application for under-water environment monitoring and management.

- (i) Wearable devices and mobile crowdsensing: Another visible implementation of the Internet of Things is wearable technology. Wearable technology includes smartwatches, fitness trackers, smart eyewear, and even linked fabric.
- The functionality of smartwatches varies from reading text messages and showing notifications to tracking locations and showing reminders. These wearables are helpful for parents tracking their children (Arias, Wurm, Hoang, & Jin, 2015).

- Wearables play a major role in elderly care. Continuous monitoring and location monitoring, together, keep caregivers in the loop. It doesn't stop there. Nano-sensors can quantitatively predict the risk of possible medical conditions such as cancer. Early detection and prevention are key applications of wearable technology on the medical front (Poongodi, Krishnamurthi, Indrakumari, Suresh, & Balusamy, 2020).
- Combined with head-mounted augmented reality (AR) gear, wearables also provide surgeons with patient history, old data, and real-time current data during surgery.

Over a period of time, the ubiquity of wearables would again start a new research agenda on behavioral attributes of usage and impact of this pervasive technology which is fast finding its way in the household of every family.

### 3.1. Future research agenda

The current interest in IoE research in business and management discipline is on the rise. However, there are huge areas that present opportunities for future work to researchers starting their journey. The areas that future work could look at, while exploring IoE applications are as follows:

- Future work can focus on the barriers of adoption and use of specific IoE technologies while looking closely at the IoE ecosystem artefacts. This would need a breakdown of focus areas in terms of different layers of architecture of IoE systems which involves sensors, actuators, and transducers.
- Future work can look at barriers of implementation of IoE ecosystems both in industrial applications and in consumer applications. Theories of intervention may be suitable in such a context.
- Researchers in IoE may look at connects of skilling and deskilling behaviour surrounding IoE in specific application areas. These deliberations may relate to current debates surrounding Future of Work and sustainability of technology driven interventions.
- Future studies can also focus on areas surrounding the role of IoE in automation and the interaction of IoE with other technological innovations like blockchain, extended reality, metaverse and 3-D printing (Fatima et al., 2021). This would require studying more about processes and deep diving into areas like process

reengineering, through lenses like systems thinking.

- Researchers may also explore areas like design and implementation of IoE architectures so that human computer interaction may be seamless and facilitative, through theoretical underpinnings of design sciences. System architecture specific studies in the specific application areas would be exciting.
- Cyber security, information risk and privacy for information management (Chatterjee & Kar, 2018) is also an area that future researchers can explore for specific IoE applications. These would be critical as IoE applications generate high volumes of data which are stored in servers, and policy research is needed to ensure information assurance.
- Sustainability is increasingly gaining prominence. Areas of how IoE and AI can be used for managing the environment is a big agenda in urbanization (Kar et al., 2019). Areas like clean water management, smart cities management, and smart technology for sustainability are emerging themes of national importance (Herath & Mittal, 2022; Nair, Agrawal, Domnic, & Kumar, 2021).
- Models for the design and development of IoE ecosystems that are more energy efficient and yet have high processing capabilities are also an exciting area of research (Chakraborty & Gupta, 2016). This would eventually need to be developed with nascent areas like Tiny Machine Learning and Federated Learning algorithms so that effective solutions can be developed for globally complex problems without compromising sustainable agendas (Gopinath, Ghanathe, Seshadri, & Sharma, 2019; Li, Fan, Tse, & Lin, 2020).

## 4. Conclusion

This article strives to bring together the history of IoE, how it evolved through the years and has gained major prominence. Given the growth of literature in management literature, we foresee the area to have greater growth in the years to come. Several application areas have been highlighted in this brief survey of literature. We also provide editorial directions to future research agendas for studies involving IoE. Given the proliferation of technologies to enable digital transformation, this area would see immense opportunities in the years to come. The research agenda provided in this article could be areas that young researchers can explore for undertaking doctoral research so that they are publishable in established academic journals.



## References

- Alam, W., Sarma, D., Chakma, R. J., Alam, M. J., & Hossain, S. (2021). Internet of things based smart vending machine using digital payment system. *Indonesian Journal of Electrical Engineering and Informatics (IJEEDI)*, 9(3), 719–731.
- Arias, O., Wurm, J., Hoang, K., & Jin, Y. (2015). Privacy and security in internet of things and wearable devices. *IEEE Transactions on Multi-Scale Computing Systems*, 1(2), 99–109.
- Chakraborty, A., & Gupta, B. (2016). Paradigm phase shift: RF MEMS phase shifters: An overview. *IEEE Microwave Magazine*, 18(1), 22–41.
- Chatterjee, S., & Kar, A. K. (2018). Regulation and governance of the internet of things in India. *Digital Policy, Regulation and Governance*, 20(5), 399–412.
- Chatterjee, S., Kar, A. K., & Dwivedi, Y. K. (2022). Intention to use IoT by aged Indian consumers. *Journal of Computer Information Systems*, 62(4), 655–666.
- Chatterjee, S., Kar, A. K., & Gupta, M. P. (2018). Success of IoT in smart cities of India: An empirical analysis. *Government Information Quarterly*, 35(3), 349–361.
- Chatterjee, S., Kar, A. K., & Mustafa, S. Z. (2021). Securing IoT devices in smart cities of India: From ethical and enterprise information system management perspective. *Enterprise Information Systems*, 15(4), 585–615.
- Chen, S., Xu, H., Liu, D., Hu, B., & Wang, H. (2014). A vision of IoT: Applications, challenges, and opportunities with China perspective. *IEEE Internet of Things Journal*, 1(4), 349–359.
- Chettri, L., & Bera, R. (2019). A comprehensive survey on Internet of Things (IoT) toward 5G wireless systems. *IEEE Internet of Things Journal*, 7(1), 16–32.
- Darshan, K. R., & Anandakumar, K. R. (2015, December). A comprehensive review on usage of Internet of Things (IoT) in healthcare system. In *2015 international conference on emerging research in electronics, computer science and technology (ICERECT)* (pp. 132–136). IEEE.
- Fatima, S., Haleem, A., Bahl, S., Javaid, M., Mahla, S. K., & Singh, S. (2021). Exploring the significant applications of Internet of Things (IoT) with 3D printing using advanced materials in medical field. *Materials Today: Proceedings*, 45, 4844–4851.
- Felicia, A., Wong, W. K., Loh, W. N., & Juwono, F. H. (2021, July). Increasing role of IoT in education sector: A review of internet of educational things (IoEdT).. In *2021 international conference on green energy, computing and sustainable technology (GECOST)* (pp. 1–6). IEEE.
- Gopinath, S., Ghanathe, N., Seshadri, V., & Sharma, R. (2019, June). Compiling KB-sized machine learning models to tiny IoT devices. In *Proceedings of the 40th ACM SIGPLAN conference on programming language design and implementation* (pp. 79–95).
- Goswami, D., Chakraborty, A., Das, P., & Gupta, A. (2017). Fog computing application for smart IOT devices in agile business enterprises. *Global Journal of E-Business and Knowledge Management*, 12, 21–32.
- Herath, H. M., & Mittal, M. (2022). Adoption of artificial intelligence in smart cities: A comprehensive review. *International Journal of Information Management Data Insights*, 2(1), Article 100076.
- Joseph, N., Kar, A. K., Ilavarasan, P. V., & Ganesh, S. (2017). Review of discussions on internet of things (IoT): Insights from twitter analytics. *Journal of Global Information Management (JGIM)*, 25(2), 38–51.
- Kar, A. K. (2021). What affects usage satisfaction in mobile payments? Modelling user generated content to develop the “digital service usage satisfaction model”. *Information Systems Frontiers*, 23(5), 1341–1361.
- Kar, A. K., Ilavarasan, V., Gupta, M. P., Janssen, M., & Kothari, R. (2019). Moving beyond smart cities: Digital nations for social innovation & sustainability. *Information Systems Frontiers*, 21(3), 495–501.
- Kar, S., Kar, A. K., & Gupta, M. P. (2021). Industrial internet of things and emerging digital technologies—modeling professionals' learning behavior. *IEEE Access*, 9, 30017–30034.
- Kashani, M. H., Madanipour, M., Nikravan, M., Asghari, P., & Mahdipour, E. (2021). A systematic review of IoT in healthcare: Applications, techniques, and trends. *Journal of Network and Computer Applications*, 192, Article 103164.
- Khanna, A., & Kaur, S. (2020). Internet of things (IoT), applications and challenges: A comprehensive review. *Wireless Personal Communications*, 114(2), 1687–1762.
- Langley, D. J., van Doorn, J., Ng, I. C., Stieglitz, S., Lazovik, A., & Boonstra, A. (2021). The Internet of Everything: Smart things and their impact on business models. *Journal of Business Research*, 122, 853–863.
- Li, L., Fan, Y., Tse, M., & Lin, K. Y. (2020). A review of applications in federated learning. *Computers & Industrial Engineering*, 149, Article 106854.
- Liu, Y., Dai, H. N., Wang, Q., Shukla, M. K., & Imran, M. (2020). Unmanned aerial vehicle for internet of everything: Opportunities and challenges. *Computer Communications*, 155, 66–83.
- Nair, R. S., Agrawal, R., Domnic, S., & Kumar, A. (2021). Image mining applications for underwater environment management-A review and research agenda. *International Journal of Information Management Data Insights*, 1(2), Article 100023.
- Poongodi, T., Krishnamurthi, R., Indrakumari, R., Suresh, P., & Balusamy, B. (2020). Wearable devices and IoT. In *A handbook of Internet of Things in biomedical and cyber physical system* (pp. 245–273). Cham: Springer.
- Stoces, M., Vaněk, J., Masner, J., & Pavlík, J. (2016). Internet of things (IoT) in agriculture-selected aspects. *Agris On-Line Papers in Economics and Informatics*, 8(665–2016-45107), 83–88.
- Talavera, J. M., Tobón, L. E., Gómez, J. A., Culman, M. A., Aranda, J. M., Parra, D. T., et al. (2017). Review of IoT applications in agro-industrial and environmental fields. *Computers and Electronics in Agriculture*, 142, 283–297.
- Vial, G. (2021). Understanding digital transformation: A review and a research agenda. *Managing Digital Transformation*, 13–66.
- Wang, D., Chen, D., Song, B., Guizani, N., Yu, X., & Du, X. (2018). From IoT to 5G I-IoT: The next generation IoT-based intelligent algorithms and 5G technologies. *IEEE Communications Magazine*, 56(10), 114–120.
- Zarindast, A., Sharma, A., & Wood, J. (2021). Application of text mining in smart lighting literature-an analysis of existing literature and a research agenda. *International Journal of Information Management Data Insights*, 1(2), Article 100032.
- Zhao, Y. L., Tang, J., Huang, H. P., Wang, Z., Chen, T. L., Chiang, C. W., et al. (2020). Development of IoT technologies for air pollution prevention and improvement. *Aerosol and Air Quality Research*, 20(12), 2874–2888.