Has the Internet of Things made a real difference to the management of projects?

Martek, I., Hosseini, M. R., Edwards, D. J., & Elghaish, F. (2023). Has the Internet of Things made a real difference to the management of projects? . In G. M. Winch, M. Brunet, & D. Cao (Eds.), *Research Handbook on Complex Project Organizing* (pp. 335-343). (Research Handbooks in Business and Management). Edward Elgar Publishing Ltd.

Published in:
Research Handbook on Complex Project Organizing

Document Version:
Peer reviewed version

Queen's University Belfast - Research Portal:
Link to publication record in Queen's University Belfast Research Portal

Publisher rights
Copyright 2023, Edward Elgar.
This work is made available online in accordance with the publisher’s policies. Please refer to any applicable terms of use of the publisher.

General rights
Copyright for the publications made accessible via the Queen's University Belfast Research Portal is retained by the author(s) and / or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy
The Research Portal is Queen's institutional repository that provides access to Queen's research output. Every effort has been made to ensure that content in the Research Portal does not infringe any person's rights, or applicable UK laws. If you discover content in the Research Portal that you believe breaches copyright or violates any law, please contact openaccess@qub.ac.uk.

Open Access
This research has been made openly available by Queen's academics and its Open Research team. We would love to hear how access to this research benefits you. – Share your feedback with us: http://go.qub.ac.uk/oa-feedback

Download date:20. Apr. 2024

Has the 'internet of things' made a real difference to the management of construction projects?

Igor Martek
Deakin University

M. Reza Hosseini
Deakin University

David John Edwards
Birmingham City University

Faris Elghaish
Queen's University Belfast

The 'internet of things' (IoT) is a wonderful development. That is the consensus. For engineers who love technical things, what could be more desirable than a technology that links together every other technology. The rationale, of course, is that the IoT is useful; and will in time undoubtedly become essential. Here is how Parise et. al., explain what we have all come to accept.

> *"In ordinary conditions and especially in critical conditions, a prompt availability of all the needed data is essential to decision making. Therefore, IoT is able to assist the solution of problems in real-time, offers opportunities to integrate the physical world into a computer-based systems, producing efficient enhancements, welfares, and assisting human works."* [1]

Good business decisions, project management decisions, indeed all decisions, are predicated on effectively responding to the environment and the changes occurring within it. Decisions axiomatically require the pursuit of a goal or outcome – some adjustment between a current situation leading to a more optimal future sought after status. While the goal may be defined, the current situation may be less transparent. Of course, in the past, when the world was less complex, the status of a situation may have been readily apparent. But given the multiple interdependencies of numerous factors that combine to generate a 'present status' in modern project management, an existing status quo may be both highly dynamic as well as opaque. Consequently, IoT offers a way forward in unmasking project situational opacity. If 'good' decisions are to be made, they must be informed by 'good' data. Three vectors figure in the quality of situational awareness informing decision response. These are the comprehensiveness of the range of environmental input sources, the quality of the data inputs from those sources, and timeliness (initial speed and refresh turn-around time) with which that data is received. [2]

Historical background to the fourth industrial revolution

Historically, project management proceeded through human monitoring of multiple data sources. Firstly, required information was identified. This has become a set, established protocol, codified through experience, entrenched in educational programs, and manifested in management practices. Those sources and their management have become disciplines in their own right, and include quantity surveying, procurements and sourcing, budgeting, supply management, logistics, scheduling, cash-flow management, and so on. Secondly, that data, such as it exists, has to be manually mined by search routines of printed materials or computer downloads, files, logs, reports, meeting notes, and other data repositories. And thirdly, even when all this is ostensibly computerized, its access, retrieval and, most importantly, its interpretation, has remained a human activity. The promise of IoT is that it will not only deliver a higher level of situational awareness of the environmental events impacting a project, but also integrate multiple realities into a holistic, unified ‘truth’ from which a singular, optimal course of action – one with the highest probability of apprehending the desired project outcome – can be defined. [3]

The question is, how close are we to IoT actually delivering such optimal outcomes?

In pre-industrial times, most manufacturing was conducted in what today would be described as ‘cottage industries.’ Individuals woke up, got to work making baskets, cheese or knives, and sold them in the market place. The First Industrial Revolution, which arose in England over the period 1760 to 1830, saw workers gathered together into factories. They no longer operated on their own, or to their own schedules, but were corralled into collectives, with precise work routines, work periods and work quotas. No individual produced a finished product, but instead, production lines saw myriads of people churn out components that were ultimately combined into mass produced products. Workers worked for wages; not for subsistence or profit. While it is well appreciated that this accelerated national economic growth, it did not necessarily improve the well-being of the factory worker, who often toiled in terrible conditions. [4] Indeed, it was Karl Marx’s observation of the first industrial revolution that led to his formulation of the Communist Manifesto, and ultimately of Communism. Of the institutionalized worker, Marx wrote:

> *“Alienation appears not merely in the result but also in the process of production within productive activity itself. Being alienated from the objects of his labor and from the process of production, man is alienated from himself. He cannot fully develop the many sides of his personality.”* [5]

The Second Industrial Revolution received its impetus from technologies that shifted the burden of labor from humans to machines. Electricity, coal-fired power and the internal combustion engine, along with the advent of telephones, trains and ships, heralded an age of invention and innovation that accelerated the pace of mass production, mass dissemination, and mass markets. It ran for about one hundred years, from the 1870s to the 1970s. [6] The Third Industrial Revolution is the one the majority of us have been living through. It is characterized by electronics, the internet and the world-wide-web, and specifically, the computer. This phase began in the 1970s, and has made globalization possible by making linkages between every business and every individual on the planet (at least theoretically) a reality. [7] We are now on the cusp of the Fourth Industrial Revolution (I4.0). This is where computing moves from being a mere work tool to an instrument shaping reality. Its not so much the individual laptops, but the global network that connects them, and the corresponding doorway to an almost infinite set of data-linkages that are thus made accessible. The world’s population in 2020 was 7 billion, but that population collectively owned 50 billion connected devices. [1]

There are a variety of technologies associated with I4.0 and this is growing, but nine key innovations represent the cornerstones of the ‘revolution.’ 1) Advanced robots: Machines able to replicate human activities with greater speed, precision, durability and reliability. 2) Cloud: Open access data storage systems allowing multi-party real-time communications. 3) Simulation: Real-time high-speed data integration that projects present situations into the future, facilitating decision-making. 4) Vertical and horizontal integration: Generating algorithms that optimize logistics, manufacturing and knowledge flows in order to optimize complex activities under uncertainty. 5) Additive manufacturing: Decentralization of manufacturing and elimination of transportation and inventory through 3D printing. 6) Cyber security: High level networking between intelligent machines. 7) Industrial internet: Multidirectional, real-time communication both up and down end-to-end manufacturing value-chains that streamline and optimize end-user needs with supplier capabilities. 8) Augmented reality: Integration of information displays in order to enhance conceptualization, understanding and utility. 9) Big data analytics: Assimilation of vast and diverse data sources that generate ‘big picture’ understanding of underlying trends, with the view to policy and strategic decision-making. [8]

The feature that connects all of these is of course the internet; hence the ‘internet of things’ (IoT). The IoT has been very dry defined as:

> *“A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols.”* [9]

The potential and vulnerabilities of IoT

With the history and background out of the way, it remains to be seen to what degree the vast potential of the IoT has been realized by industries. Oil and gas (O&G) projects are high-risk, high-capital asset concerns. Consequently, O&G companies are prone to run digital twins (DT) of their assets in order to test and assess safety and efficiency in simulation before implementing in practice. Development in O&G DTs, however, remains in infancy. DTs are used to provide insights on production rates, operational conditions, system bottlenecks, as well as to test structural integrity, control responsiveness and potential failure points. Yet, to date, much of these routines remain grounded in Industry 3 computerizations. To the extent that I4.0 has been implemented, the greatest progress is reported to be in the area of asset risk assessment, where AI is used to create learning algorithms to identify and remediate asset malfunctions. An emerging area is in virtual training, which on face-value appears peripheral to the real business of O&G operations. However, the industry is forecasting an employee crisis, anticipating that around 50% of its workforce will retire in the near future, triggering a consequent loss of tacit knowledge and experience. In facing what the industry dubs the ‘big-crew change,’ it is invoking a recruitment and training program to be run on a global scale over global platforms. [10, 11]

Further implementation of I4.0 initiatives have, however, run up against complications. For one, as has already been made plain, the vindication of IoT is founded squarely in its ability to deliver fast, accurate and full data necessary to decision-making – data that is more reliable and more relevant and more complete than can be accumulated by human activity alone. Yet difficulties remain in interfacing between project functions, such as between designers, clients, industry at large, and the various branches of operators. Data remains siloed, and to the extent walls are broken down, but not fully, risks of any single critical information not being shared where needed, kills the erstwhile benefits of a greater cumulative information free-flow. Moreover, data has to be standardized and codified in order to be universally interpreted and appraised, and how this should to be done remains unresolved. Similarly, storage, curation and reuse are additional fully unanticipated further challenges. Indeed, the plethora of information bombarding decision-makers has been documented as counter-productive, having the effect of grey-noise that must be washed out of systems in order for the limited meaningful data to be extracted. [11, 12]

Then there is the problem of cyber security. In the US, 75% of companies operating in the energy sector report having experienced cyber-related attacks. This can compromise operations by means unavailable to criminals prior to IoT implementations. Tampering of sensors and such like can also corrode operability, and this is a growing concern. Not only can facilities now be shut down from the other side of the world, when once this was impossible, but designs can be stolen and intellectual property and innovations appropriated with apparent ease. The US, again, reports trillions of dollars-worth of technology being purloined by the Chinese alone, yearly, all by way of the internet. Critically, despite the potential, and despite progress made, IoT has not yet been able to deliver measurable benefits. It is reported that transition to IoT dependent operations is extremely costly and disruptive, but has so far only added marginal operational improvements. [11, 13]

The vulnerabilities that capital assets and business operations are exposed to through hackings and other cyber-attacks highlights a further weakness of IoT; network dependency. The functionality of I4.0 actualized projects are only as good as the network into which they are embedded. And networks are not always at the standard required in order to deliver full IoT functionality. A just released study by Saragih et. al. [14], points out that telecommunication network providers are not keeping up with the 5G upgrades and other demands that IoT relies on in order to operate optimally. In other words, companies and projects cannot put IoT dependent capabilities into effect where network infrastructure is not state-of-the-art; and that is most everywhere. All that can be hoped for is a closed-loop system, but that is not true IoT. A stronger criticism, and one that interrogates the philosophical justification for IoT, is that while it serves to manage greater environmental complexity, that increased complexity is at least partially attributable to the emergence of IoT. That is, IoT is a self-serving solution to problems it is complicit in creating. As Ghimire et. al., put it:

> *"With advances in technologies, the amount of information that has to be incorporated into decision-making... steadily increases. The resulting huge amount of information, if not harnessed properly, leads to an information overload."* [2]

Supply chain management

Supply chain management (SCM) is another discipline endeared to IoT. Surprisingly perhaps, the majority of IoT research in this domain emphasizes the tracking and tracing of perishable foodstuffs. Lobster shipments, for example, are high-value items that need to move, say, from Nicaraguan wharfs to New York restaurant dining tables, in a matter of hours. Not only is speed and location the issue, but so also temperature, humidity, weather, etc., all of which can be remotely monitored. [15] IoT is particularly suited to SCM in manufacturing, too, since it provides, in theory, a seamless monitoring of the movement of goods from supplier, through factories, distributors, and finally retailors and customers. The working paradigm is that IoT increases product lifespan, improves quality, reduces waste, all for a lower cost. The elements that make up SCM IoT are fairly fundamental. Almeida et. al., describe three components. First, sensing nodes, such as cameras, digital readers, and environmental scanners, identify current statuses. Second, wireless communications transfer status information to a central processing hub. Finally, the collective data is processed for holistic status evaluation. [16] Mostafa et. al., broadly concur, but describe SCM IoT as occurring in four steps. Sensors, such as RFIDs, actuators and controllers provide 'perception.' Next, protocols, such as Zigbee and 6LoWPAN, effect data 'transmission.' A 'computational layer' processes the data through algorithms, and finally further software packages, such as MQTT, AMQP and CoAP, respond (without the aid of human intervention) through an 'application layer.' [17]

But once again, there are challenges. Security concerns remain unresolved. Some 70% of research on SCM IoT broaches this point. [18] Reliance on third-party applications comes with suspicion, while firms rarely have the hardware or software resources to secure against hostile outsider intrusions. Then again, while firms 'cooperate' upstream and downstream with suppliers and customers, they remain shy about unnecessarily revealing aspects of their business process. For one, these may be considered proprietary advantage, for another, should things go wrong, this will be more apparent to the injured party and exposes firms to litigation. Blockchain models are an emerging remedy, however, in short, trust and desires for privacy have not kept pace with technology. Neither has interoperability been resolved. Firms within the value-chain need to interface, and to some degree at least, that means synchronizing technological packages as well as data standards. This may lock firms into relationships, limiting their ability to remain agile and shift to other partners as competitive demands dictate. Ironically, the flexibility afforded by IoT would then have the counterproductive effect of ossifying supply chains into rigid systems. And here lies a further objection; IoT requires participating firms in a supply-chain to align strategic objectives, which again may not be practical, let alone ideal outcome, for anyone. [17, 19]

All this aside, the improved ‘traceability’ afforded by IoT remains merely a subservient company goal to that of profit, or even broader strategic objectives. This is far from assured under current conditions. A survey of 235 German companies, which are leaders in technological adoption, found that if IoT is to truly deliver, it would involve the installation of literally hundreds of components and devices, combined with massive organizational disruption and workforce reskilling. On average, the assessment was that in order to achieve a workable transformation to IoT SCM, some 50% of planned capital investment would have to go into a company’s transition over a minimum of five years; and all without a firm indication of the tangible benefits to be extracted. [20, 21] What is interesting however, and what presents as an emerging global competitive threat, is that the Chinese government is prepared to foot the bill for the exorbitant costs associated with initiating its own nationally grounded, fully integrated IoT business environment. [22]

The role of research in progressing IoT uptake

Despite the reservations and objections, there is no going back. IoT is here to stay. So, with the challenges identified, where to from here? Well, there is one more deficiency, and that lies in the nature of research being undertaken that would support a transition to IoT. The scope of research achieved to date can be gleaned from a range of literature reviews. [13, 18] These outline technological capabilities, industrial applications, benefits, as well as hindrances. However, what comes across as conspicuously under-represented is discussion of the means by which to effect transition to an IoT business model. Marnewick and Marnewick map a range of critical success factors that would be required to make the transition. For them, leadership roles would have to shift to become less authoritarian. Indeed, the whole of organizational culture would have to change to embrace agility. People within the organization will need to be less risk averse while being more empowered. Project management routines will need to be less rigid and teamwork and collaboration will need to improve. [23] What should strike the reader is how superficial such recommendations are. More to the point, assuming this really is the remedy needed, what would such vague prescriptions even mean in practice, and how should these recommendations be realised?

Hirman et. al., outline an implementation framework for project management transition to I4.0 in a seven phased model: 1) Define the company vision for I4.0; 2) Identify company processes; 3) Implement a full data management system; 4) Digitize all data; 5) Implement horizontal integration across the organization; 6) Install data analysis systems; and 7) Initiate self-managed production and logistics. [24] While, this recipe appears more tangible, it falls far short on specifics and cannot be considered a workable template. What appears to be taking place is that academics are talking to other academics, and not to industry. Consider the simplicity of this recommendation:

> *“The whole implementation process can be realized in one step if the company is small but in most cases the implementation project is too large.”* [24]

The advice from Whitmore et. al.’s, study reads like a self-help slogan:

> *“Think big; start small; learn fast.”* [25]

Turning to project managers, how should they ready themselves for I4.0? The advice is: 1) Promote agility; 2) Evolve intellectual capacity; 3) Embrace resource dynamics; and 4) Refine emotional intelligence. [26] Numerous researchers have suggested a range of transformational leadership, managerial and even administrative styles that must accompany I4.0 integration. Thee and Nang, however, see I4.0 simply piling more demands on project managers than they currently carry. They identify six roles traditional project managers undertake; roles such as adhering to budgets, schedules, and scope. Under an I4.0 paradigm, traditional roles remain, but are expanded to encompass at least ten more – things like, 'complex systems execution strategy formulation and delivery,' and 'supporting the tracking and managing of a complex autonomous fleet,' to name two. [27] Alternatively, in the view of Clarkson, who cuts through the confusion on what an I4.0 career entails:

> *"65% of children… will end-up working in completely new jobs that don't yet exist."* [28]

None of this is said to gratuitously disparage the research being done, but only to highlight that the transition pathway to an IoT economy remains fraught with real and present unknowns.

The real impact of IoT on business and society

While IoT has been identified as a 'game-changer' in project management, [29, 30] the question once again remains, how is the game being changed? The TW Project Group, who are a leading European-based consultancy on project management, explain the benefits of I4.0 and IoT in this way:

> *"Let's take the example of a project manager working in the construction sector. He can use a tablet and write reports during site inspections. He can thus take pictures of a damaged or incorrectly labeled door or cable and then insert them directly into the report together with the relevant annotations. In this way, in essence, it is possible to generate a site inspection report in an extremely simple, fast and effective way… Digitization therefore saves time and a large amount of telephone calls."* [31]

This is progress; for sure. However, this is not I4.0 or IoT; it is merely the project management profession catching up with Industry 3. At this point, project management enthusiasts will invoke BIM as evidence of the advancements being achieved by the profession. While a valid assertion, BIM, as utilized widely today also remains in the realm of Industry 3. To be clear, I4.0 is where machines talk to machines, while BIM is merely a real-time platform for assimilating project data that still relies on human interface. [32, 33]

In short, IoT can be characterized as big, linked and open. Big in the sense that it will ultimately impact the whole world, requiring global integration from infrastructure architecture to legislative and regulatory alignments across nations. Linked in the sense that individuals, companies and even countries will become subject to network interdependencies never seen before in history, demanding cooperation and trust at a scale never yet achieved. And open in the sense that stakeholders will now become exposed to influences, both friendly as well as hostile that cannot easily be kept at bay. [34] In 2021 alone, US$120 trillion is being invested in IoT devices, while Forbes predicts expenditure will continue to grow at a rate of 7.3% per annum. Over the next ten years some 125,000,000,000 IoT devices are forecast to become globally interconnected. Yet, while the transition to 14.0 is set to improve lives, it may also well exacerbate the divide between rich and poor. Partly this is because investment in IoT is so uneven. WiFi speed in Asia has shot up from 26.7 Mbps, in 2017, to 54.2 Mbps, currently. The USA has gone from 37.1 to 83.8 over the same period. By contrast, today, much of Europe still hovers at about 32.8 Mbps, Latin America at 16.8 and Africa at 11.2. [35]

The cost of IoT lies not only in the technology, but in the collateral damage being caused. Smart devices rely on rare earth metals, such as cerium, neodymium, terbium and holmium, which have magnetic properties; lithium is used in batteries; gallium is used in LEDs; tantalum in capacitors. Apart from the fact that China controls 80% of world supply (and Afghanistan controls a further US3 trillion in reserves) these materials pollute ground water when mined and pollute the earth when later dumped. Unlike radioactive materials, the toxicity of these metals does not decay. Recycling rates are as low as 4%, half of the world's nations have no adequate laws controlling disposal, while the annual current rate of e-waster generation is 44 trillion metric tonnes, or about 6 kilograms per person on earth. [35, 36]

Then there is the energy cost; a consideration often overlooked. Running 5G networks can consume four times the energy required for 4G. Fossil fuel usage will spike, not decrease, should there be full 5G implementation. Consider that China, which is a leader in 5G development through Huawei, has already had to revert to 4G networks in regions where energy supply could not service the 5G infrastructure it had installed. [37] Businesses do see IoT as the way of the future, but not always with enthusiasm. In a survey of 34 project management firms across America, not one single firm expressed confidence in their ability to navigate a transition to an IoT business model. [38] In fact, a study by Tang et. al., showed that while IoT configured businesses delivered productivity spikes of between 6.3% and 5.1%, it turned out that the debt taken on resulted in a negative impact of 14.9%. [39]

The value of IoT will ultimately be driven by its capacity to improve the value proposition of businesses, but also of its impact on society as a whole. A closing thought from Parise et. al., sums up how we ought to proceed:

> *"It is generally recognized that human society was born based in the social contract for which the individuals consent to submit some of their freedoms to defend their remaining human rights. The achievement of an ethic globalization of advanced IoT and the progress of its security and safety are mandatory."* [1]

IoT is an inevitability, but the benefits and the costs will be remains a matter for further research and discussion.

REFERENCES

1. Parise, G., L. Parise, and M. Parise. *Evolution of human society and of things assisted by IoT*. in *2018 IEEE International Symposium on Technology and Society (ISTAS)*. 2018. IEEE.
2. Ghimire, S., et al., *IoT based situational awareness framework for real-time project management.* International Journal of Computer Integrated Manufacturing, 2017. **30**(1): p. 74-83.
3. Hurtoi, V. and D. Avadanei, *IoT Project Management.* Informatica Economica, 2020. **24**(3): p. 75-80.
4. Ashton, T.S. and P. Hudson, *The Industrial Revolution*. 1998, Oxford, England: Oxford University Press.
5. Marx, K. and F. Engels, *The communist manifesto*. 2012: Yale University Press.
6. Vale, R., *Second industrial revolution: the technological revolution.* URL: https://richmondvale.org/en/blog/second-industrial-revolution-thetechnological-revolution (4.8. 2020.), 2016.
7. Perera, S. and P. Das, *Industry 4.0 will usher in a gamut of opportunities for project management professionals*. 2019, Australian Institute of Project Management: Sydney.
8. Al-Wazzan, H. *Transformation of project management in industry 4.0*. in *HVAC Expo Saudi*. 2019. Riyadh International Convention and Exhibition Center: DMG.
9. Vermesan, O., et al., *Internet of things strategic research roadmap.* Internet of things-global technological and societal trends, 2011. **1**(2011): p. 9-52.
10. Anderson, R.N. *'Petroleum Analytics Learning Machine'for optimizing the Internet of Things of today's digital oil field-to-refinery petroleum system*. in *2017 IEEE International Conference on Big Data (Big Data)*. 2017. IEEE.

11. Wanasinghe, T.R., et al., *Digital twin for the oil and gas industry: Overview, research trends, opportunities, and challenges.* IEEE Access, 2020. **8**: p. 104175-104197.
12. AlBar, A., et al. *Combining the power of IoT and big data to unleash the potential of digital oil field*. in *International Petroleum Technology Conference*. 2019. OnePetro.
13. Lu, Y. and L. Da Xu, *Internet of Things (IoT) cybersecurity research: A review of current research topics.* IEEE Internet of Things Journal, 2018. **6**(2): p. 2103-2115.
14. Saragih, L.R., M. Dachyar, and T.Y.M. Zagloel, *Implementation of telecommunications cross-industry collaboration through agile project management.* Heliyon, 2021. **7**(5).
15. Affia, I., L.P.E. Yani, and A. Aamer. *Factors affecting IoT adoption in food supply chain management*. in *9th International Conference on Operations and Supply Chain Management*. 2019.
16. Almeida, R.B., et al., *A distributed event-driven architectural model based on situational awareness applied on internet of things.* Information and Software Technology, 2019. **111**: p. 144-158.
17. Abdel-Basset, M., G. Manogaran, and M. Mohamed, *Internet of Things (IoT) and its impact on supply chain: A framework for building smart, secure and efficient systems.* Future Generation Computer Systems, 2018. **86**: p. 614-628.
18. Ben-Daya, M., E. Hassini, and Z. Bahroun, *Internet of things and supply chain management: a literature review.* International Journal of Production Research, 2019. **57**(15-16): p. 4719-4742.
19. Hendrik Sebastian, B. and H. Evi, *Impact of IoT challenges and risks for SCM.* Supply Chain Management: An International Journal, 2019. **24**(1): p. 39-61.
20. Gerami, M. and S. Sarihi, *The impacts of Internet of Things (IOT) in Supply Chain Management.* JOURNAL OF MANAGEMENT AND ACCOUNTING STUDIES, 2020. **8**(3).
21. Wegener, D., *Industry 4.0–vision and mission at the same time. Industry 4.0–Opportunities and challenges of the industrial internet.* Industrie, 2015. **4**: p. 343-358.
22. Shah, S. and A. Ververi. *Evaluation of Internet of Things (IoT) and its Impacts on Global Supply Chains*. in *2018 IEEE International Conference on Technology Management, Operations and Decisions (ICTMOD)*. 2018. IEEE.
23. Marnewick, A.L. and C. Marnewick, *The Ability of Project Managers to Implement Industry 4.0-Related Projects.* IEEE Access, 2020. **8**.
24. Hirman, M., et al. *Project management during the industry 4.0 implementation with risk factor analysis*. in *29th International Conference on Flexible Automation and Intelligent Manufacturing*. 2019. Limerick, Ireland.
25. Whitmore, D., et al., *Are megaprojects ready for the Fourth Industrial Revolution?*, in *Proceedings of the institution of Civil Engineers*. 2020, ICE Publishing.
26. Bolick, C., *How can project managers prepare for the fourth industrial revolution?* 2019, Northeastern University.
27. Thee, Z.W. and S.M.K. Nang. *Transformation of project management in industry 4.0*. in *12th International Conference on Project Management*. 2018. The Society of Project Management.
28. Clarkson, I., *Project management and the fourth industrial revolution*. 2019, PM Today.
29. Reja, V.K. and K. Varghese. *Impact of 5G technology on IoT applications in construction project management*. in *ISARC. Proc. Int. Symp. Autom. Robot. Constr*. 2019.
30. Prasher, V.S., *Internet of Things (IoT) and Changing Face of Project Management.* 2018.
31. TW Project. *Project Management in Industry 4.0*. Project Management 2019; Available from: https://twproject.com/blog/project-management-industry-4-0/.
32. López-Robles, J.-R., et al., *The relationship between project management and industry 4.0: Bibliometric analysis of main research areas through Scopus.* 2020.
33. Cakmakci, M. *Interaction in project management approach within industry 4.0*. in *International Scientific-Technical Conference MANUFACTURING*. 2019. Springer.

34. Brous, P., M. Janssen, and P. Herder, *The dual effects of the Internet of Things (IoT): A systematic review of the benefits and risks of IoT adoption by organizations.* International Journal of Information Management, 2020. **51**: p. 101952.
35. Nižetić, S., et al., *Internet of Things (IoT): Opportunities, issues and challenges towards a smart and sustainable future.* Journal of Cleaner Production, 2020. **274**: p. 122877.
36. Penke, M. *Toxic and radioactive: The damage from mining rare elements*. 2021; Available from: https://www.dw.com/en/toxic-and-radioactive-the-damage-from-mining-rare-elements/a-57148185.
37. Morris, I. *Bill Shock: Orange, China Telecom fret about 5G energy costs*. 2018; Available from: https://www.lightreading.com/mobile/5g/bill-shock-orange-china-telecom-fret-about-5g-energy-costs/d/d-id/747781.
38. Prasher, V.S., *Internet of things (IoT) and changing face of project management*. 2018, Harrisburg University.
39. Tang, C.-P., T.C.-K. Huang, and S.-T. Wang, *The impact of Internet of things implementation on firm performance.* Telematics and Informatics, 2018. **35**(7): p. 2038-2053.