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THE INTERNET OF THINGS (IOT) UPHEAVAL:

OVERCOMING MANAGEMENT CHALLENGES

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Abstract: Products based on the Internet of Things (IoT) concept use a combination of physical devices embedded with sensors, other electronic hardware, software and the Internet to utilize meaningful data. Recently there has been a boom in IoT projects, but many of these projects are failing. One of the major reasons for this failure is a lack of specific project management methodologies that appropriately deal with the complexity and interdisciplinary nature of IoT projects. This article looks at the existing literature to find business, management and technical issues with these projects. In order to find solutions to these issues, various IoT stakeholders were surveyed and asked about which tools, processes and management strategies they find most useful. Ultimately, the goal of this article is to provide detailed knowledge about the existing IoT management philosophies, tools and their challenges, pros and cons, and how to scale these to improve the success rate of such projects.

Keywords: Internet of Things, Project management, Agile, Big Data, Cloud computing, Sensors

1. Introduction

The Internet of Things is a well-established computing approach which uses everyday physical objects, electronics, sensors, software, and Internet connectivity to acquire, transfer, store and use meaningful data (Whitmore, Agarwal, & Da Xu, 2015) (Gubbi, Buyya, Marusic, & Palaniswami, 2013) (Atzori, Iera, & Morabito, 2010). An IoT project uses many different kinds of hardware and software at the same time. It uses small, portable, low-cost computing chips embedded in devices (Huang, Eleftheriou, Kudithipudi, Tapson, & Yu, 2019). It also uses emerging high-speed network technologies and vendor-driven data storage and management platforms which take in enormous volumes of data from IoT devices (Rossi, de Souza, dos Santos Marques, Calheiros, & da Cunha Rodrigues, 2019) (Xu, Aung, Zhu, & Yong, 2018) (Oteafy & Hassanein, 2018). IoT projects also use artificial intelligence technologies to automate real-time data analysis and visualization (Al-Turjman, 2019). And IoT projects have been growing in popularity because of the advancement of the technologies listed above (Hosseinian-Far, Ramachandran, & Slack, 2018).

Many industries (transportation, construction, mining, education, medical, healthcare, and many others) have already made significant strides in transforming their businesses by utilizing IoT technology (Hopkins & Hawking, 2018) (Abdel-Basset, Manogaran, Mohamed, & Rushdy, 2018) (Saheb & Izadi, 2019) They have integrated sensors with tools and machines on the shop floor, and they have used cloud-based real-time tracking systems to reduce downtime and to increase manufacturing productivity (Firouzi, et al., 2018) (Habte, Saleh, Mohammad, & Ismail, 2019) (Sullivan, 2016). These undertakings employ many different tools, depending on the industry and the purpose of the IoT project. Some examples include the use of CCTV, beacon, manufacturing robots, RFID tags, point-of-sale terminals, and remote access control systems (Ding & Jiang, 2018) (Muñoz, et al., 2018). Consumer products, household objects, and personal devices such as entertainment systems, home security systems, lighting, thermostats, wearable devices and smartphones embedded with sensors and network connectivity have also been integrated into IoT projects.

IoT projects are growing in popularity. McKinsey Global Institute researchers predict that the economic impact of IoT projects is expected to increase from $3.9 trillion a year to $11.1 trillion a year by 2025 (Manyika, et al., 2015). This boom in IoT projects, coupled with the fundamentally interdisciplinary nature of IoT designs, has led to the creation of many job and research opportunities. Many people are currently working on IoT projects such as smart cities, precision farming and use of unmanned aerial vehicles (UAVs) for remote sensing or geospatial mapping (Bruneo, et al., 2019) (Chatterjee, Kar, & Gupta, 2018) (Zamora-Izquierdo, Santa, Martínez, Martínez, & Skarmeta, 2019) (Motlagh, Bagaa, & Taleb, 2017). Despite this apparent success, there are still many limiting factors and challenges faced by those managing IoT projects. A number of regulatory and legal issues as well as interoperability, privacy, and security challenges, pose major roadblocks to the success of IoT projects (Conti, Dehghantanha, Franke, & Watson, 2018) (Frustaci, Pace, Aloi, & Fortino, 2018) (Singh, Millard, Reed, Cobbe, & Crowcroft, 2018) (Voas, Kuhn, Laplante, & Applebaum, 2018). According to a 2017 Cisco survey, which involved more than 1,800 IT leaders in the USA, UK, and India about 75% of IoT projects are failing and 60% of such initiatives launched by respondents got shut-down at the proof of concept phase (NA, 2017). Many reasons for these failures were cited. The culture, organization and structure of these companies were not conducive to the creation of IoT projects. Other reasons that were cited were a lack of internal expertise, an inability to integrate, low-quality data, budget overruns and problems with time to completion.

If so many IoT projects are failing, we need to adjust our current project creation and management strategies in order to increase their success rate. In the coming Literature Review and Approach sections, key issues with the successful deployment of IoT-based products and services are discussed. A strong case is built for investing more time and research efforts into the management aspects of such projects. In addition, current challenges, and various reasons for the failure or success of IoT projects are also discussed. In order to support these claims, a survey was carried out among the professionals in the field about their experiences with IoT projects. The Results section presents the data gathered, which sheds light on ways that management strategies can be changed to work better with these hi-tech, intricate, collaborative, and cutting edge projects. The Discussions and Conclusion sections detail how what must be done now is using bottom-up approaches to align the technology with the current business objectives. It also argues that IoT project managers need to create effective cultures, philosophies, processes, and trends that will facilitate effective project planning and implementation for the success of such projects.

2. Literature review

This literature review explores what causes the failure of IoT projects, with a particular focus on the managerial aspects of these projects.

2.1 Current IoT Methodologies

Because each IoT project is unique, it is difficult to find one managerial method that will work across the board. For example, for some projects a method with no artifacts can work very well. In other cases, a detailed set of artifacts over the whole lifecycle of the project will work better. The management frameworks used in the software and systems development world are not one-size-fits-all. The common practices like Dynamic System Development Methodology (DSDM), Extreme Programming (XP), Test Driven Development, Feature Driven Development, Lean Development, Agile Modeling, DevOps and Use-Case Essential could work for any project in that industry. But, because of the complexity and variance in needs for IoT projects, there is no clearly defined guide (yet) for how to run an IoT project (Giray, Tekinerdogan, & Tüzün, 2018).

The existing literature shows that, for IoT projects, methods based on Waterfall or Agile are used depending on the IoT project need. The existing methods such as Scaled Agile Framework (SAFe) and RUP (Rational Unified Process), and practices such as use cases, Kanban, Scrum, and user stories are helpful when developing either small applications (apps) or for complex systems development (Hoda, Salleh, & Grundy, 2018). They can also be used to create methods for systems engineering, which is critical for the development of systems with integrated hardware and software tools.

Literature regarding methods for the IoT is extremely sparse, but there are two methods that can provide some insight into the emerging trends: Ignite and IoT Methodology (Jacobson, Spence, & Ng, 2017). Ignite is a methodology with Strategy Execution, and Solution Delivery practices at its core. Ignite is based on real-world experience. It was created with this experience in mind, and it is a well thought out and comprehensive methodology. Where per- Strategy Execution agreements are drawn as what to build (that is, the solution) and involves the practices of opportunity identification, opportunity management, and initiation. And under Solution Delivery is how to deliver the solution to users, and it has a life cycle consisting of planning, building, and running (that is, operating the solution) (Slama, Puhlmann, Morrish, & Bhatnagar, 2015).

Like Ignite, IoT Methodology is a very generic method at a high level. It uses an IoT Canvas and an IoT Open Systems Interconnection Prototype (OSI) reference architecture. The IoT Canvas is a modification of a lean business model used to validate a minimal viable product (MVP) requirement for IoT projects by using brainstorming and discussions. The IoT OSI reference model is a version of the seven-layer ISO/OSI reference model designed specifically for IoT solutions. IoT project stakeholders and developers can use the MVP and IoT OSI reference 'model's five layers (endpoints at the bottom, connectivity, middleware, IoT services, and, finally, applications at the top) information to jointly create and define an end-solution definition before prototyping (Collins, 2017).

Ignite has its benefits, and the IoT Methodology provides a lightweight method that is highly inspired by lean startup and design thinking. IoT Methodology also follows iterative steps to question, ideate and co-create, to map-out IoT OSI. But both of these methods reuse many existing generic practices. Also, the other existing IoT system development methods (SDM) provide guidance on the steps necessary for development of IoT systems but these do not incorporate or consider the situational needs of such projects. New innovative practices specifically for the IoT product development should be explored (Jacobson, Spence, & Ng, 2017).

2.2 Managerial challenges of the IoT projects

Over the last decade, new approaches such as: Disciplined Agile Delivery (DAD), Extreme Programming (XP), and other various Agile techniques have been implemented to accommodate product development for projects that include Big Data, Cloud Computing and Service Oriented Architecture (SOA) (Larson & Chang, 2016) (Franková, Drahošová, & Balco, 2016) (Sachdeva & Chung, 2017). These methods have been tested on ordinary software development projects, but have not been extensively tested on large-scale, interdisciplinary IoT projects that include more than just software. If these methods do not work on complex IoT projects, then we will need to develop a new managerial approach. Because IoT projects are relatively new, there is a lack of data, use cases and focused research on how to improve our management strategies for IoT projects.

Because of this lack of data, there is no clear management framework for such projects, despite a huge boom in the IoT industry. In recent years, various domains ranging from healthcare to agriculture have been exploring IoT projects and their benefits. As proposed by R.M. Dijkmana et al. (2015) in their study, which was based on numerous interviews and literature surveys among the practitioners, the building blocks (along with types of options) of any IoT management framework can help developers with IoT application building (Dijkman, Sprenkels, Peeters, & Janssen, 2015). Based on qualitative and quantitative survey analysis, this study suggested that the ""value proposition"" will play the central role among all the building blocks for creating an IoT business model.

A similar study by S. Madakam et al. (2015) walks one through the timeline of origin of IoT concepts, their initial usage and how rapidly these technologies are becoming a part of our daily lives. The authors of this study also note that because IoT projects have such complicated infrastructure both physically and digitally, keeping their various parts in sync is extremely difficult. The key message from this study though, and one of the biggest problems facing IoT projects and their management, is a lack of ""universalized"" jargon, processes and practices for IoT projects. This study calls for standard definitions around the

world, a universally recognized architectural level, and technology interoperability standard protocols for global governance in order to create a better future for the IoT world (Madakam, Ramaswamy, & Tripathi, 2015).
This study has a plethora of ideas about the technical and management aspects of an IoT project, and suggests these aspects need to be worked on from both the enterprise and the project level. This study suggests that each layer of IoT infrastructure would need a management plan, be it to cope with the issues or to take care of the risks.

2.3 Technical challenges of the IoT projects

Currently, creating an IoT project can be extremely expensive. As the practices and technology become more common, the price will go down, but as it stands, an IoT project is a heavy investment. Beyond just the monetary difficulties that IoT projects face, issues like data security, sensor setup and interconnectivity, managing overload, and Artificial Intelligence and Machine Learning application are adding to the complexity in IoT Solution Development.
For successful deployment of IoT-based products and services, the top five technologies that are essential are radio frequency identification (RFID), wireless sensor networks (WSN), middleware, cloud computing and IoT application software. A literature review by In Lee et al. (2015) focuses on the technical and managerial challenges in putting these five components together. To address problems of cost, they propose a net present value option to justify the investment in such projects. Also, this work emphasizes the need for more studies that deal with the economic, social, behavioral and project management aspects of IoT projects (Lee & Lee, 2015). In addition, this article introduces to a conceptual model of IoT applications where challenges in implementing IoT projects for enterprises are highlighted. Some of these challenges include: information sharing and collaboration, monitoring and control, and large data sets.

2.4 Summary of Key Points

To summarize, here are a few key points gathered from the above literature review:

- Techniques like Ignite, IoT Methodology, and variations of Waterfall and Agile are currently used.
- There is a lack of data about which techniques work best for IoT projects.
- There is no clear IoT management framework that can be applied to every project. Right now, we are building project plans on a case-by-case basis.
- Universalizing jargon and management processes for IoT projects would be extremely helpful for project development.
- IoT projects are expensive. A net present value option is suggested as a way to justify their cost.
- IoT projects are difficult to manage because of their complexity. More research needs to be done in order to understand the best way to manage these projects.

In conclusion, a 'manager's role and responsibilities will be changing in the IoT world as their role will broaden from advocate to specialist. And they will need to have new management philosophies.

3. Approach

In order to explore how IoT project management could be improved, IoT professionals who have worked or are currently working with top well-established as well as startup companies that are poised to make a mark in the IoT world were surveyed. The questionnaire covered following aspects of IoT projects:

- What management frameworks they use
- What challenges they face while developing a project charter
- What challenges they face while developing a team
- Who they thought (stakeholder) was most involved in the success of their projects
- What their preferred project management software was
- What project process groups are more prone to be limited or restricted by the constraints
- What factors they think are important for the management of such projects.

These questions were developed with several main knowledge areas, as defined by PMBOK-6, in mind (PMBOK® Guide - Sixth Edition, 2017) (Prasher, 2018). Knowledge areas such as Project Integration, Scope, Schedule, Cost, Quality, Resource, Communications, Risk, Procurement, and Stakeholders Management were all explored in these questions and the following subsections sums-up the related concepts.
Data was collected via LinkedIn and other social networking sites. We surveyed a total of 60 individuals. Their industry, role and level of experience is detailed in Table 1. The survey was distributed via personal email with a link to the survey. In 58 cases the questionnaire was filled out completely. Two respondents were excluded from further analysis because of partial responses. A total of 58 survey responses were deemed as valid for further analysis and detailed trends are presented in Results section.

3.1 Project Management Frameworks

Historically, project management methodologies were framed around the system development life cycle. A Waterfall-like one dimensional model was used. The steps for this model are: defining, designing, developing, testing and then deploying the end project. Now Agile philosophies are more popular than Waterfall methods. Agile

philosophies are built around performing all steps of traditional project phases at the same time. These two frameworks worked for smaller scale projects, but with the advent of IoT technology new methods may have to be developed to handle the massive scale of IoT projects.
This segment of the survey was used to gather responses for a statistical comparison between the methodologies that are currently being used by IoT professionals.

3.2 IoT Business Case Development

The biggest benefit of IoT projects is their ability to increase business efficiency. Increased efficiency means reducing costs and saving money for the business. But if a business case for an IoT and M2M (machine to machine) project is not clear about how it is going to be beneficial for business then the project is less likely to achieve the end goals or objectives.
This section of the survey was deployed to determine what challenges IoT professionals faced in developing their business cases.

3.3 Building IoT Teams

Building a good team for any project is essential for better communication, better relationships, and ultimately an increase in productivity. For many startups and businesses IoT is still an uncharted territory, so they are not sure where to start when it comes to building a team for an IoT project. To keep up with the fast pace of industry change, IoT project teams and developers would be required to constantly learn on the job, cross-train to survive, and actively seek training and mentorship to expand their skills. All of these things can pose challenges and create conflicts. Also, for globally dispersed IoT teams, culture clashes between different disciplines can be inevitable. Successful team building can help solve many of these challenges and conflicts.
This section of the survey asked IoT managers and development teams which factors affect overall organizational morale, smooth team collaboration and other aspects of team building for IoT projects.

3.4 Stakeholder Management

To adopt IoT, companies conduct stakeholder analysis. This is a process of identifying and selecting consumers who have an interest in the new products that this project will create. This process also involves finding the people who will create the products to the 'company's specifications. Other stakeholders include; anyone who may have any influence on the 'project's outcomes, anyone who may be affected by the product, or anyone who may have any knowledge needed to understand the requirements to build these products.
This section of the survey asked IoT managers and development teams to assess the engagement of the following groups of stakeholders in IoT projects: Steering Committee or Leadership, Program Manager, Project Sponsor, Project development team, Business/Product analysts, End customer or client, and local communities and regulators. The Stakeholder Engagement Levels were classified in the following ways: Unaware (Unaware of the project and potential impacts), Resistant (Aware of the project and potential impacts and resistant to change), Neutral (Aware of the project yet neither supportive nor resistant), Supportive (Aware of the project and potential impacts and supportive of changing), and Leading (Aware of the project and potential impacts and actively engaged in ensuring project success).

3.5 Project Management Tools

A trouble-free management software can play a significant role in a 'project's success, especially for the Internet of Things industry, where a large number of devices are working in tandem through the use of software tools and third-party resources, tools, and platform technologies. In the last decade, project management tools for both software and non-software applications have tremendously evolved to cater to the needs of the industry, and available choices have grown significantly. Many project management tools and software are being developed every day to help managers automate the administration of individual projects, groups of projects, or to manage extremely complex IoT, cloud computing, and big data projects.

INDUSTRY	#	ROLE	#	EXPERIENCE	#
Agriculture, Forestry, Fishing, and Hunting	4	Intern	1	Less than 1 year	23
Utilities	1	Entry Level	1	1-2 years	11
Computer and Electronics Manufacturing	6	Analyst/ Associate	26	2-5 years	14
Software	19	Manager/Administrator	12	5 and more	10
Hotel and Food Services	1	Senior Manager	2		
Health care and Social Assistance	9	Director	4		
Scientific or Technical Services	6	Vice President	1		
Government and Public Administration	2	Sr. Vice President	1		
Information Services and Data Processing	7	President/CEO	3		
Supply and Chain Management	1	Owner	3		
Telecom	1	Software	2		
Trading and Exchange	1	Developer/Engineer	1		
		Quality Analyst	1		

Table 1: Demographic profile of survey respondents by what industry they belong to, their roles and experience in IoT field.

For example, a popular software project management tool Jira has in-built workflow to rapidly and efficiently workout the elimination of bugs in the software, which can play vital role in software development. Similar tools, like Asana and Smartsheet are advanced and institutive management platforms, which teams use to stay focused on the goals, projects, and daily tasks. They also increase productivity by utilizing the cloud, collaboration, and mobile technologies. Also, software like MS project can help in managing large software projects with applying principles of PERT and by creating Gantt charts for critical path calculation for large projects.

This section of the survey asked IoT managers and development teams which project management software they find helpful for IoT projects.

3.6 Project processes and related constraints

Phases are very important for any project to ensure that the deliverables produced at the end of each phase meet their purpose. Phases also ensure that project team members (or sub-teams) are properly prepared for the next phase. As developed by the Project Management Institute (PMI), the five phases of project management include Initiation, Planning, Execution, Monitoring and Control, and Closing. To strategize, develop, monitor and control a project and finally deliver a product, triple constraints (time, cost and scope, with quality occasionally included as fourth constraint) are used by project managers. This allows project managers to assess if one of those constraints becomes problematic so that they can make adjustments to fix the issues.

In order to understand project health, it is essential to examine factors like: risks associated with the project, team-conflicts, and issues with vendor management. For a project a range of acceptability can be defined and monitored. When the project goes outside of that range of acceptability it has entered problematic territory, and the team must assess what they can do to rectify that situation. This strategy can be used at all three planning levels of a project – the project as a whole, anyone stage or phase of the project, and at the detail work package level.

In this section of the survey, it was determined which of these project process groups (Initiation, Planning, Execution, Monitoring and Control, and Closing) are likely to increase the constraints or limiting factors (Cost, Schedule, Scope creep, Conflicts, Quality Control, Risks, and Vendor Management).

To conclude, survey takers were given a list of factors and were asked to select the ones they think are crucial for the management of IoT projects. The main results are presented in the next section, where quantitative analysis of data gathered is used to glean the key points that can be used to best handle these projects.

4. Results

The survey takers were asked how often (always, usually, sometimes, rarely or never) they follow Waterfall, Agile, Hybrid or Rapid Application Development (RAD) project management frameworks for IoT projects. As shown in Figure 1, the results point to responders mostly embracing Agile philosophies (higher Always, Usually and Sometimes responses). The next most common is Hybrid, followed by Waterfall. RAD framework was rarely or never used in their IoT projects.

Figure 2 shows response trends to challenges faced by survey takers while developing a project charter on an IoT projects. It is seen that concerns about realistically measuring the IoT 'project's success (or return on Investment (ROI)) and no clear link with overall organizational strategy are always top concerns for such projects. Also, the project statement of work is not clearly defined, concerns about the goals being realistic and attainable and no clear picture of the risks and assumptions related to the project, are usually or sometimes obstacles when working on project charter. Responders also thought that not able to clearly delineate roles and responsibilities can also pose a challenge.

As seen in Figure 3, the majority of responders tend to strongly agree that a teamwork skill set is an asset for an IoT project. Further, having undefined roles and responsibilities does not drastically affect team building for such projects.

Also, data trends point to that responders considered IoT team management in general a challenge. Some specific challenges they see in IoT management are interdisciplinary teams and teams that are spread out geographically. Despite this information, IoT projects may not be more conflict prone than other projects.

The trends from Figure 4 show that the Program Managers are leading in engagement. The Steering Committee/Leadership, Project Sponsor Project Development Team, Business/Product Analysts and End Customer or Client are considered Supportive. Also, Local Communities are Unaware of such efforts, and Regulators seem to be playing a Neutral role. A list of Stakeholder Types and their Engagement Level with response percentage is given in Table 2: A.

As shown in Figure 5, Jira, which is predominantly used for managing Agile projects, stood out as most preferable management software choice for IoT projects.

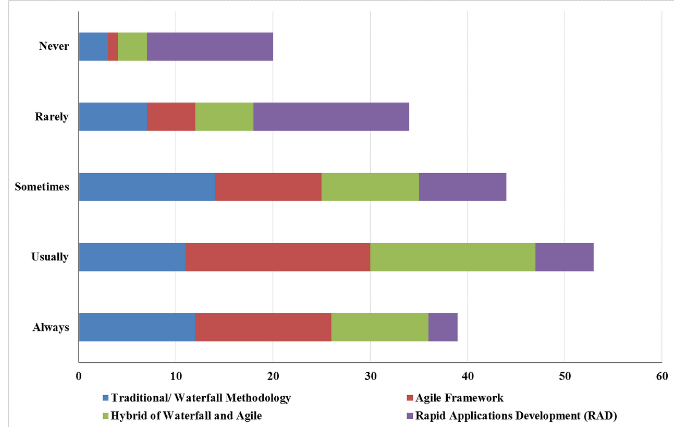

Figure 1: (Color online) Survey responses showing trend for project management frameworks being used in IoT projects.

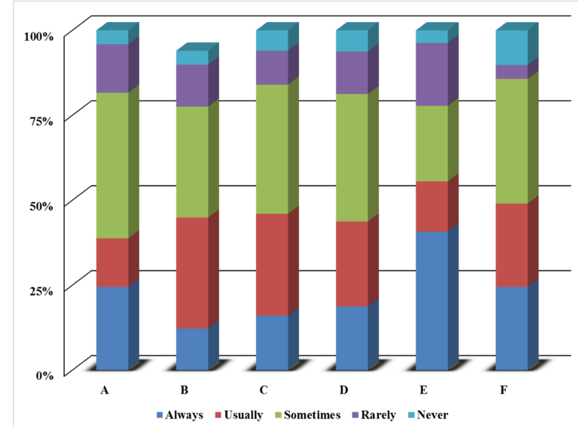

Figure 2: (Color online) Survey response trends for how often professionals in the IoT field face the following challenges: (A) there is no clear link with overall organizational strategy, (B) the project statement of work is not clearly defined, (C) there are concerns about the goals being realistic and attainable, (D) there is no clear picture of the risks and assumptions related to the project, (E) there are concerns about realistically measuring the project success (ROI), and (F) not able to clearly delineate roles and responsibilities.

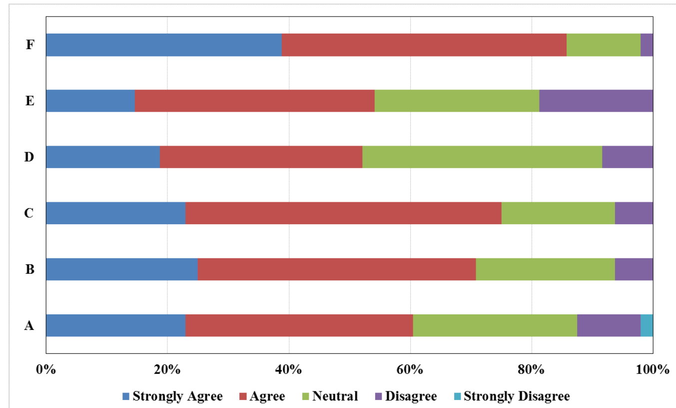

Figure 3: (Color online) Data trends showing ranking (strongly agree, agree, neutral, disagree and strongly disagree) of the following six challenges that survey takers may have faced while building a team on an IoT project: (A) IoT team management is a challenge, (B) IoT interdisciplinary teams are hard to manage, (C) team members being spread out geographically poses challenges, (D) roles and responsibilities are not well defined for such projects, (E) such projects are more conflict prone, and (F) teamwork skill set is an asset on any IoT project.

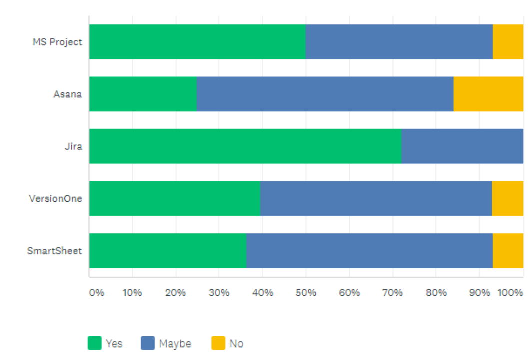

Figure 5: (Color online) Complied responses shows which project management tool (MS Project, Asana, Jira, VersionOne, or Smartsheet) would responders use for IoT projects.

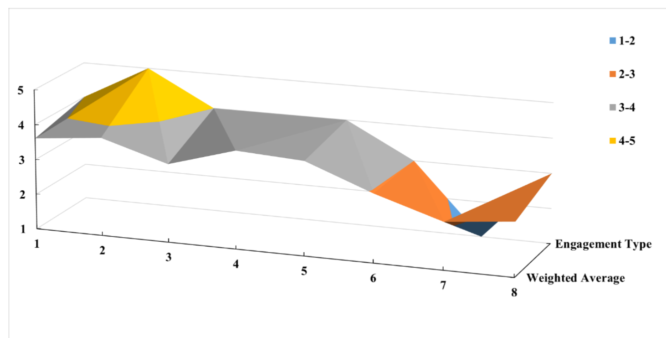

Figure 4: (Color online) Based on their experiences, survey responders rated stakeholder engagement for IoT projects: (1) Steering Committee/Leadership, (2) Program Manager, (3) Project Sponsors, (4) Project Development Team, (5) Business/Product Analysts, (6) End Customer or Client, (7) Local Communities, and (8) Regulators. The surface plot represents weighted average (x1w1 + x2w2 + x3w3 ... xnwn/Total response count, where w = weight of ranked position, x = response count for answer choice) and Engagement types (weighted rank) as: Leading (5), Supportive (4), Neutral (3), Resistant (2) and Unaware (1).

In Figure 6 the ""definitely would"" and ""probably would"" options were overwhelmingly selected for all categories. Factors like a Proof-of-Concept/Prototype before actual project begins (Weighted Average (Standard Deviation, Number of responses) = 1.82(0.77, 45)), and Project managers with interdisciplinary technical knowledge (1.89(0.90, 45)), stood out as factors that definitely would add value to IoT project management. Utilizing separate research and development phases (1.98(0.98, 45)), and use of hybrid of Waterfall and Agile methodologies (2.11(0.98, 44)) fell under ""probably would"" improve project management. And, universally defined business and technical jargon (2.24(0.94, 45)) factor ""might"" improve the project management.

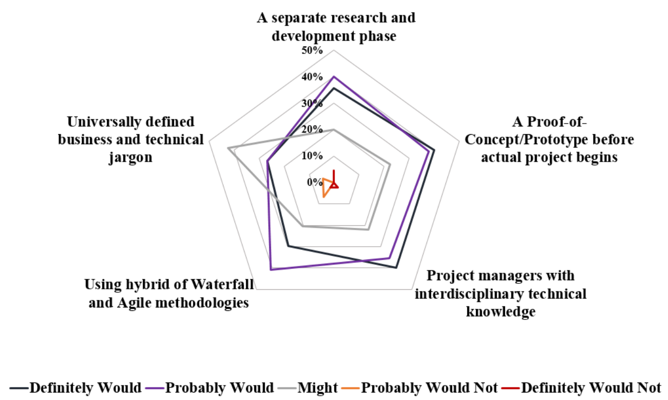

Figure 6: (Color online) A polar chart showing response percentage comparisons for factors that are likely to improve management for IoT projects (detail numbers are in Table 2: D).

Table 2: Survey response data: (A) Stakeholder types and their Engagement Level with response percentages, (B) Various factors and survey 'response's weighted average with standard deviation for Initiation, Planning, Execution, M&C and Closing phases, (C) Various factors and the respective phases in which they are likely to be more prominent, (D) Factors that Definitely Would, Probably Would, Might, Probably Would Not and/or Definitely Would Not impact IoT projects with percentage (number) of responses.

(A) Stakeholder Type	**Engagement Level (response %)**				
Steering Committee/Leadership	Supportive (36.36)				
Program Manager	Leading (34.09)				
Project Sponsor	Supportive (39.53)				
Project Development Team	Supportive (48.84)				
Business/Product Analysts	Supportive (45.45)				
End Customer or Client	Supportive (34.05)				
Local Communities	Unaware (39.53)				
Regulators	Neutral (43.18)				
(B) Factors	**Initiation**	**Planning**	**Execution**	**M&C**	**Closing**
Cost	3.29(1.43)	2.90(1.30)	4.00(0.87)	3.25(0.91)	2.42(1.61)
Schedule	2.81(1.45)	3.27(1.09)	3.59(1.16)	3.46(1.09)	2.70(1.63)
Scope Creep	2.62(1.45)	3.00(1.34)	3.45(1.19)	2.96(1.29)	2.32(1.46)
Team Conflicts	3.17(1.63)	3.27(1.29)	3.73(1.21)	3.21(1.24)	2.61(1.58)
Quality Control	2.71(1.44)	3.00(1.28)	3.29(1.10)	3.37(1.42)	2.83(1.49)
Risks	2.97(1.47)	3.13(1.38)	3.63(1.28)	3.33(1.22)	2.78(1.59)
Vendor Management	3.20(1.61)	3.41(1.22)	3.37(1.22)	3.22(1.40)	3.39(1.58)
(C) Factors	**Phase**				
Cost	Execution				
Schedule	Planning				
Scope Creep	Execution				
Conflicts	Planning				
Quality Control	Execution				
Risks	Execution				
Vendor Management	Initiation				
(D) Factors	**Definitely Would**	**Probably Would**	**Might**	**Probably Would Not**	**Definitely Would Not**
A separate research and development phase	35.56%(16)	40.00%(18)	20.00%(9)	0.00%(0)	4.44%(2)
A Proof-of-Concept/Prototype before actual project begins	40.00%(18)	37.78%(17)	22.22%(10)	0.00%(0)	0.00%(0)
Project managers with interdisciplinary technical knowledge	40.00%(18)	35.56%(16)	22.22%(10)	0.00%(0)	2.22%(1)
Using hybrid of Waterfall and Agile methodologies	29.55%(13)	40.91%(18)	20.45%(9)	6.82%(3)	2.27%(1)
Universally defined business and technical jargon	26.67%(12)	26.67%(12)	42.22%(19)	4.44%(2)	0.00%(0)

Listed in Table 2, the response statistics shows that the Execution phase would be more prone to Cost, Scope Creep, Quality Control and other Risks. In addition, concerns with Scheduling and Conflicts in Planning and Vendor Management are most likely to be the issues impacting the project Initiation phase (Table 2: B, C). All the key points gathered from survey responses will further be discussed in the next section.

5. Discussions

There are tremendous opportunities for developing in the market that are pushing many organizations into less explored IoT territory. Ranging from small startups to the big giants of the industry, all organizations across the globe are looking to adapt to IoT revolution and are evaluating how they can improve their products. The IoT concept is changing the world of embedded systems, where software development plays a significant role. The rapid outward advancement in this field is also changing the way hardware and software are being developed and released for connected/smart IoT devices. Specifically, because of increased end users expectations for connected devices, companies must develop frequent updates, upgrades, and efficient user experience. Implementing any new feature or business model change to an IoT project can require adjusting the hardware and software behind the project, which may impact the strategy behind the entire project. So, there is a need for us to find and adapt to a project management methodology that is well equipped for dealing with the demands of connected devices, where frequent updates are essentially a requirement.

Waterfall/traditional/serial methods, though they have been used for decades, are less effective in an environment where frequent updates are so essential. Aspects of Waterfall like ""the development process would stop with deployment, and, after the product has been released, the development or execution phase ends as well""won't be able to provide the flexibility that IoT development needs. Growing expectation for post-deployment content and frequent on-demand updates means the methodology need to embrace enhanced change and management solutions, with inbuilt features to test over smaller development cycles to quickly bring a product or its enhancement to the market.

Agile methodology and philosophies that espouse continuous delivery seem to be ideally positioned to address these increasing challenges and difficulties. Especially, for the following two reasons:

1. Agile framework focuses on rapid/time-bound development and a feedback loop where developers can more quickly fix bugs and contribute new code that has been tested and validated. This helps in parallelizing, scaling, and reconfiguring tasks as …needed, facilitating the developers and testers working in tandem to solve the issues at hand.
2. The Agile methodology removes silos and empowers collaboration between teams, resulting in faster overall development efficiency, and more product updates and releases.

With the tools and best practices of Agile, embedded engineers and software developers alike will be prepared to effectively contribute to the world of the Internet of Things. This will also satisfy the need to constantly add new features to make end customers happy, and will allow businesses to respond quickly to market needs. It will also help the developers/testers manage their development schedule. The rate of updates for the Internet of Things is increasing rapidly, so organizations should try to navigate the IoT sphere by using Agile development methodologies, or, if they prefer, a hybrid of both Waterfall and Agile methodologies.

While defining high-level strategic goals for organizing a business case or project charter for an IoT project, Return on Investment (ROI) analysis is an essential building block, as it helps in establishing baseline expectations for the project scope. The challenge with IoT ROI calculations is that the benefits are very difficult to quantify in the beginning, because companies lack a clear vision, concrete implementation strategy and a solid understanding of how it will eventually produce an ROI. To overcome this the following few steps are recommended:

1. IoT benefits come from data being collected from connected devices and sensors. This data can and should be used to make decisions to improve business processes, reduce costs or increase revenue. Predictive analytic results get better as the quality and amount of data increases, for which either mockup data or lessons learned from similar projects should be extrapolated to better estimate ROI.
2. It's easier to estimate the value of the data being collected if your project begins with a narrow, well-defined focus. This is one reason why experts say narrowing the initial scope of an IoT project is one way to establish a compelling ROI picture. Additionally, starting with an achievable project that has a defined return is a good way to set the stage for a larger, comprehensive IoT plan. Smaller projects not only make it easier to establish ROI, they give you a chance to test your technology, organize your data, establish your priorities and build a team of stakeholders.

As organizations advance into more sophisticated IoT projects, it will be necessary to look beyond cost reduction and evaluate other benefits that will deliver ROI. Streamlined business processes, faster problem resolution, reduced downtime, etc. can lower costs and boost profit margins. ROI calculations should also look at ways the IoT project is enhancing revenue. Predictive analytics and data-driven decisions can lead to new go-to market strategies, new services or products, and new customer acquisition. IoT success isn't automatic, but doing ROI analysis upfront to build a strong business case for such projects can be beneficial.

In general, an IoT design may look like Sensors > Gateway > IoT hub> Analytics> and BI. In this model product development tasks may be carried out in boardrooms, on manufacturing plant floors, in back-offices or in cloud architecture. Such projects involve multiple teams with various functions like management, the manufacturer's IT team, production control, etc. And these teams also need a multitude of skills e.g. Production Management, Operators, Shift leaders/Supervisors, Finance, Maintenance Teams, etc. Hence, IoT data flows across multiple domains and responsibilities, and to bring them together teamwork skills are essential. Things like good communication, being reliable and respectful, decision making, problem solving, and persuasion and influencing skills are more likely to result in a successful IoT project.

Project managers are taking the leading role in creating complex IoT products and platforms. They are also taking leading role in getting resources like hardware, software, platforms, and standards that cater to the connectivity of connected devices. Constant support is also given by steering committees/leadership, project sponsors, project development teams, business/product analysts, and end customers/clients. Internet of Things (IoT) has an internal impact on a company and socioeconomic impacts at large. Local communities should be made aware of upcoming IoT projects and how these projects can and will be changing their lives. Similarly, regulatory bodies should pass the right rules and participate more in such initiatives.

The IoT will overwhelmingly impact project management software tools because they will be required to be more interconnected, required to collect more data, and required to make that data available for any business decision. In the software world, for Agile project management, tools like Jira (Server and Cloud versions) from Atlassian are based on implementing requirements in the form of user stories/issues, and are successful as a requirements management tool as seen in the survey results.

Historically, the root cause for project failures has often been identified as poor requirements management and this is even more true when executing complex projects. IoT projects are intricate because of their use of cross-functional teams, technologies and infrastructure. Tools like Jira address these problems. They make full use of the Agile nature of user stories instead of carrying the baggage of legacy Waterfall approaches, where development was typically characterized by an upfront requirements gathering stage and fixed technology.

Jira has a customizable workflow engine that gives an admin the freedom to create a process workflow. This workflow can include documenting an issue, documenting a requirement, routing a requirement for approvals or even automated testing efforts. For an IoT project one can create a "Tech Story" type, a "Feature Request" type and also a "Risk" type, each having their own custom workflows. Jira has add-ons that connect to various APIs and tools so its functionality as far as market requirements management is very good. For IoT, Jira, and tools like, can allow stakeholders to have direct access to the requirements via the Cloud with configurable levels of access. Also, these tools can cater to key aspects of requirements management. They handle prioritization, auditing, dashboards, metrics, testing, modeling, project management and system definition for base-lining, release management and capabilities. This helps avoids spreadsheets and Gantt charts that were used by the Waterfall methods of the past. Thus, advanced project management tools which support the new wave of Lean/Agile approaches are required for IoT.

In the IoT project planning phase project managers should focus on schedules and conflicts among staff and external suppliers to ensure that the project is delivered on time without any constraints. In order to do this they should create plans to help guide teams through the execution and closure phases of the project by managing time, cost, quality, change, risk and issues.

Project execution is the longest and most demanding phase because the focus of the phase is on constructing deliverables and getting stakeholder approval. Project managers are trying to meet key project objectives and manage communication between all key stakeholders, sponsors and team members. For an IoT project they should be wary of factors like cost estimations, scope creep, quality-related issues and should navigate through by formulating a well-defined risk management plan.

A separate research and development phase should be used by IoT project managers. In this phase a team should produce a proof of concept (poc) that shows how an IoT solution can solve a problem or add value to a business segment. IoT project plan built around this poc model should be piloted.

Having a deeper understanding of the technical side of IoT will help project managers develop better IoT-ready products and increase the efficiency of processes. Every field has its own "lingo" that goes with the territory. The current tech industry is a prime example of this, with dozens of acronyms and complex software terms that may add to confusion and overall lower productivity. Having a common business and techy terms universally will broaden the IoT industry's knowledge base and will allow stakeholders to ask the right questions to get ahead. So, universally accepted business and technical jargon should be defined as to enhance IoT projects success rate at the global stage.

6. Conclusion

The Internet of Things as a concept has significantly impacted our daily lives. Smart appliances, smart cities and many other gadgets that utilize various technologies and applications are used to make our lives more comfortable.

The literature review points out that though scientists, engineers, and managers across the world are continuously working to create and exploit the benefits of IoT products, there are some flaws in the governance, management and implementation of such projects. Despite tremendous forward momentum in the field of information and other underlying technologies, IoT still remains a complex area and the problem of how IoT projects are managed still needs to be addressed. The literature review points out that IoT projects must be run differently than simple and traditional IT, manufacturing or construction projects. Because IoT projects have longer project timelines, a lack of skilled resources and several security/legal issues, there is a need for a new and specifically designed project processes.

In this study, via a quantitative data collection - survey technique, the following points are gathered and their relevance is discussed in detail:

- Agile or a Hybrid of methodology/framework is suitable for IoT projects
- Defining ROI upfront would help in creating a project charter
- While building an IoT team, Teamwork skill set can be game changer
- Jira and similar project management tools are best suited to IoT projects
- Among stakeholder, whereas Managers are most engaged, Regulators and End-users need to be actively involved
- Well defined Risk management, and Project management plan should be followed.

Based on analysis of the data gathered in this study, the following management techniques should improve the success rate of IoT projects:

- A separate research and development phase
- A Proof-of-Concept/Prototype before the actual project begins
- Project managers with interdisciplinary technical knowledge
- Universally defined business and technical jargon

In conclusion, this paper provides a standard comparative analytical study which is specifically aimed at bringing changes to the management of IoT projects to improve the success rates of such projects. This report also includes suggestions for how to streamline current project management philosophies to help ensure IoT projects deliver an end product. More focused and peer-reviewed studies should be conducted, especially in IoT- project management, to collect more data and uncover other trends.

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Dr. Vikram Prasher has 5 years of experience in Information Systems Engineering, Data Science and consulting in Project Management. His current research interests in technology are targeted at developing interdisciplinary advanced systems which deploy Big data analytics, Machine Learning, Artificial Intelligence, Cloud Computing and use of the agile/lean project management philosophies. His previous research experience includes radiation detection technology, fabrication of semiconductor devices and the skills required in scientific computation.

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References

Abdel-Basset, M., Manogaran, G., Mohamed, M., & Rushdy, E. (2018). Internet of things in smart education environment: Supportive framework in the decision-making process. Concurrency and Computation: Practice and Experience, e4515.

Al-Turjman, F. (2019). Artificial Intelligence in IoT. Springer.

Atzori, L., Iera, A., & Morabito, G. (2010). The internet of things: A survey. Computer networks, 54(15), 2787-2805.

Bruneo, D., Distefano, S., Giacobbe, M., Minnolo, A. L., Longo, F., Merlino, G., & Puliafito, C. (2019). An IoT service ecosystem for Smart Cities: The #SmartME project. Internet of Things, 5, 12-23.

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.

Collins, T. (2017). A methodology for building the Internet of Things. Retrieved 04 15, 2019, from http://www.iotmethodology.com/

Conti, M., Dehghantanha, A., Franke, K., & Watson, S. (2018). Internet of Things security and forensics: Challenges and opportunities. Future Generation Computer Systems, 78(2), 544-546.

Dijkman, R. M., Sprenkels, B., Peeters, T., & Janssen, A. (2015). Business models for the Internet of Things. International Journal of Information Management, 35(6), 672-678.

Ding, K., & Jiang, P. (2018). RFID-based production data analysis in an IoT-enabled smart job-shop. IEEE/CAA Journal of Automatica Sinica, 5(1), 128-138.

Firouzi, F., Rahmani, A. M., Mankodiya, K., Badaroglu, M., Merrett, G. V., Wong, P., & Farahani, B. (2018, January). Internet-of-Things and big data for smarter healthcare: from device to architecture, applications and analytics. Future Generation Computer Systems, 78(2), 583-586.

Franková, P., Drahošová, M., & Balco, P. (2016). Agile project management approach and its use in big data management. Procedia Computer Science, 83, 576-583.

Frustaci, M., Pace, P., Aloi, G., & Fortino, G. (2018). Evaluating critical security issues of the iot world: Present and future challenges. IEEE Internet of Things Journal, 5(4), 2483-2495.

Giray, G., Tekinerdogan, B., & Tüzün, E. (2018). IoT system development methods. In Internet of Things (pp. 141-159). CRC Press/Taylor & Francis.

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. Future generation computer systems, 29(7), 1645-1660.

Habte, T. T., Saleh, H., Mohammad, B., & Ismail, M. (2019). IoT for Healthcare. In Ultra Low Power ECG Processing System for IoT Devices (pp. 7-12). Springer, Cham.

Hoda, R., Salleh, N., & Grundy, J. (2018). The rise and evolution of agile software development. IEEE Software, 35(5), 58-63.

Hopkins, J., & Hawking, P. (2018). Big Data Analytics and IoT in logistics: a case study. The International Journal of Logistics Management, 29(2), 575-591.

Hosseinian-Far, A., Ramachandran, M., & Slack, C. L. (2018). Emerging trends in cloud computing, big data, fog computing, IoT and smart living. In Technology for Smart Futures (pp. 29-40). Springer, Cham.

Huang, G. B., Eleftheriou, E. S., Kudithipudi, D., Tapson, J., & Yu, H. (2019). Guest Editorial: Special Issue on New Trends in Smart Chips and Smart Hardware. IEEE Transactions on Emerging Topics in Computational Intelligence, 3(1), 1-3.

Jacobson, I., Spence, I., & Ng, P. W. (2017). Is there a single method for the Internet of Things? Communications of the ACM, 60(11), 46-53.

Larson, D., & Chang, V. (2016). A review and future direction of agile, business intelligence, analytics and data science. International Journal of Information Management, 36(5), 700-710.

Lee, I., & Lee, K. (2015). The Internet of Things (IoT): Applications, investments, and challenges for enterprises. Business Horizons, 58(4), 431-440.

Madakam, S., Ramaswamy, R., & Tripathi, S. (2015). Internet of Things (IoT): A Literature Review. Journal of Computer and Communications, 3(05), 164-173.

Manyika, J., Chui, M., Bisson, P., Woetzel, J., Dobbs, R., Bughin, J., & Ahron, D. (2015, June). The internet of things: mapping the value beyond the hype. McKinsey Global Institute, 144. Retrieved from www.mckinsey.com/business-functions/digital-mckinsey/our-insights/the-internet-of-things-the-value-of-digitizing-the-physical-world

Motlagh, N. H., Bagaa, M., & Taleb, T. (2017). UAV-based IoT platform: A crowd surveillance use case. IEEE Communications Magazine, 55(2), 128-134.

Muñoz, R., Vilalta, R., Yoshikane, N., Casellas, R., Martínez, R., Tsuritani, T., & Morita, I. (2018). Integration of IoT, transport SDN, and edge/cloud computing for dynamic distribution of IoT analytics and efficient use of network resources. Journal of Lightwave Technology, 36(7), 1420-1428.

NA. (2017, May 23). Cisco Survey Reveals Close to Three-Fourths of IoT Projects Are Failing. Retrieved April 2019, from https://newsroom.cisco.com: https://newsroom.cisco.com/press-release-content?articleId=1847422

Oteafy, S. M., & Hassanein, H. S. (2018). IoT in the fog: A roadmap for data-centric IoT development. IEEE Communications Magazine, 56(3), 157-163.

PMBOK® Guide - Sixth Edition. (2017).

Prasher, V. S. (2018). Internet of Things (IoT) and Changing Face of Project Management. Retrieved from https://digitalcommons.harrisburgu.edu/pmgt_dandt/49/

Rossi, F. D., de Souza, P. S., dos Santos Marques, W., **Calheiros, R. N., & da Cunha Rodrigues, G. (2019)**. Network Support for IoT Ecosystems. In Enabling Technologies and Architectures for Next-Generation Networking Capabilities (pp. 197-213). IGI Global.

Sachdeva, V., & Chung, L. (2017). Handling non-functional requirements for big data and IOT projects in scrum. In 2017 7th International Conference on Cloud Computing, Data Science & Engineering-Confluence (pp. 216-221). IEEE.

Saheb, T., & Izadi, L. (2019). Paradigm of IoT Big Data Analytics in Healthcare Industry: A Review of Scientific literature and Mapping of Research Trends. Telematics and Informatics. doi:https://doi.org/10.1016/j.tele.2019.03.005

Singh, J., Millard, C., Reed, C., Cobbe, J., & Crowcroft, J. (2018). Accountability in the IoT: Systems, Law, and Ways Forward. Computer, 51(7), 54-65.

Slama, D., Puhlmann, F., Morrish, J., & Bhatnagar, R. M. (2015). Enterprise IoT: Strategies and Best practices for connected products and services. O'Reilly Media, Inc.

Sullivan, C. J. (2016). Radioactive source localization in urban environments with sensor networks and the Internet of Things. In 2016 IEEE International Conference on Multisensor Fusion and Integration for Intelligent Systems (MFI) (pp. 384-388). IEEE.

Voas, J., Kuhn, R., Laplante, P., & Applebaum, S. (2018). Internet of Things (IoT) Trust Concerns (No. NIST Internal or Interagency Report (NISTIR) 8222 (Draft)). National Institute of Standards and Technology.

Whitmore, A., Agarwal, A., & Da Xu, L. (2015). The Internet of Things - A survey of topics and trends. Information Systems Frontiers, 17(2), 261-274.

Xu, Q., Aung, K. M., Zhu, Y., & Yong, K. L. (2018). A blockchain-based storage system for data analytics in the internet of things. In New Advances in the Internet of Things (pp. 119-138). Springer, Cham.

Zamora-Izquierdo, M. A., Santa, J., Martínez, J. A., Martínez, V., & Skarmeta, A. F. (2019). Smart farming IoT platform based on edge and cloud computing. Biosystems Engineering, 177, 4-17.