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INTEGRATING INTERNET OF THINGS (IoT) INTO ENTERPRISES: SOCIO-TECHNICAL ISSUES AND GUIDELINES

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ABSTRACT

Internet of Things (IoT) devices are cyber-physical devices that can operate in any context by its sensing, communicating and processing capability. The increase in the use of IoT devices and internet of things started to revolutionize our daily life. Use of IoT devices in enterprises may help increase business effectiveness. However, organizations face many challenges in integration of these devices into the legacy ecosystems. In this study, we conducted a broad literature review to identify the socio-technical issues related to integrating IoT into enterprise information systems. We provide guidelines, strategies, and best practices for IT staff and managers to integrate IoT devices into the enterprise information systems successfully.

Keywords: Internet of Things, IoT, Business Processes, Enterprise Information Systems, Management of Information Systems

KURUMSAL ORGANİZASYONLARDA NESNELERİN İNTERNETİNE GEÇİŞ: SOSYOTEKNİK KONULAR VE TAVSİYELER

ÖZET

Nesnelerin interneti cihazları, kendilerinde bulunan algılama, iletişim ve bilgi işleme kapasiteleri sayesinde çok çeşitli ağlara bağlanarak çalışabilen siber fiziksel cihazlardır. Bu tip cihazların sayısının hızla artması ile nesnelerin interneti günlük hayatımızda şimdiden devrim yaratmaya başlamıştır. Son tüketicilerin kullanımının yanında kurumsal kullanımı da işletme verimliliğini artırmaya yardımcı olmaktadır. Ancak, bu yeni tip cihazların mevcut kurumsal bilgi sistemlerine entegrasyonu çözülmesi gereken çeşitli problemleri de beraberinde getirir. Bu araştırmada, nesnelerin interneti cihazlarının yönetim bilişim sistemlerine bütünleştirilmesinde karşılaşılan sosyal ve teknik konular detaylı bir literatür taraması sonucu tespit edilmiştir. Bununla beraber, nesnelerin interneti cihazlarının yönetim bilişim sistemlerine entegrasyonunda ve teknoloji geçişinde dikkat edilmesi gereken konular ve çözüm stratejileri belirlenmiştir. Araştırma kapsamında belirlenen konular ve stratejiler, başta bilgi teknolojileri personeli olmak üzere üst düzey yöneticilere nesnelerin interneti teknolojilerine geçişte sosyoteknik konularda karar almalarına yardımcı olacaktır.

Anahtar Kelimeler: Nesnelerin İnterneti, IoT, İş Süreçleri, Kurumsal Sistemler, Yönetim Bilişim Sistemleri

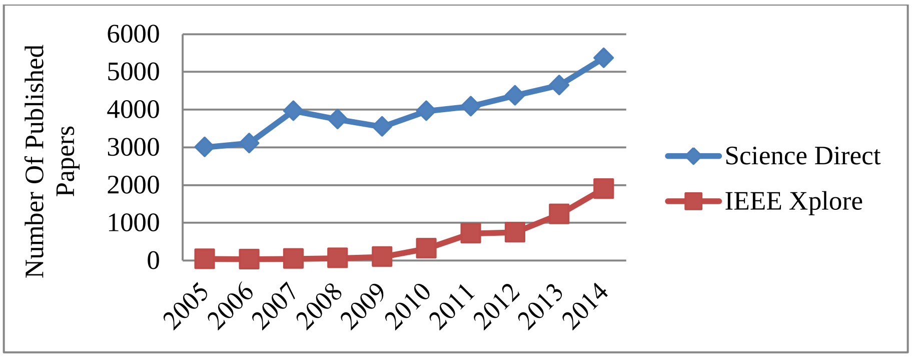
INTRODUCTION

Internet of Things (IoT) devices are cyber-physical devices that can operate in any context by its sensing, communicating and processing capabilities. Gartner estimated that in 2015 there would be 4.9 billion connected "things" in use (Gartner, 2014). Therefore, IoT domain has a significant impact not only on the consumer market but also on the enterprises. IoT have a great potential to increase organizational effectiveness and productivity by its enhanced capability.

The evolutions in the technology led to Industry 4.0. A key capability of the Industry 4.0 is collecting data directly from production steps. Managers believe that they can achieve operational and business excellence in their companies using this technical capability (Davenport, 2013). IoT devices enable technologies required for data collection from production steps. This data is analyzed using knowledge extraction techniques or big data analytics to improve the business efficiency. However, integrating IoT technology into enterprises naturally creates many challenges and problems related to communication, management, security, and social issues. Therefore, managers should develop various strategies in the integration of these devices into the new and legacy systems. In this study, we identified the current problems and challenges related to IoT transformations in enterprises. Furthermore, for overcoming each challenge or problem, we identified various solutions, strategies, best practices, or guidelines for managers.

In our study, we conducted a survey using “IoT” keyword in two different databases. The survey results show an increasing trend in IoT research. Figure 1 presents the result of our keyword search.

Figure 1. IoT Related Papers per Year



Most IoT related studies focus on technical challenges of integrating IoT technology into enterprises. However, the number of studies related to management and socio-technical issues in IoT domain is limited. We believe more research is needed focusing on resolving management and socio-technical issues in the integration of IoT devices into business processes. This study aims to contribute to the current literature by providing a set of solutions, strategies, best practices, and guidelines related to management and socio-technical aspects of IoT transition.

In the next section, we present a summary of our literature review. Then, we list the socio-technical aspects related to IoT transition. For each aspect, we provide a recommendation based on our literature review. In the last section, we present our conclusions.

LITERATURE REVIEW

We conducted a keyword search on papers published between 2010 and 2015. The keywords used are listed in Table 1. Based on citation counts and relevance, we selected several studies reporting research on IoT use in enterprises.

Table 1. IoT Related Papers in Databases

Database	Keyword 1	Keyword 2	Number of Papers
Science Direct	Internet of things	Enterprise information systems	5232
		Legacy Systems	1884
		Enterprise systems	5457
IEEE Xplore	Internet of things	Enterprise information systems	95
		Legacy Systems	37
		Enterprise systems	153
Google Scholar	Internet of things	Enterprise information systems	>100.000 for each row
		Enterprise systems	
		Legacy Systems	

Spiess et al. (2009) proposed an architecture to integrate IoT systems into enterprise services. In the study, the authors emphasized that the industry is moving from stand-alone systems to integrated systems. Therefore, a service-oriented architecture (SOA) would be the best solution to enhance industrial processes. The proposed architecture consists of six layers. These layers are application interface, service management, security, device management, platform abstraction, and devices. The study also presented a proof of concept showing that IoT devices can handle integrated enterprise services using the proposed architecture.

Haller et al. (2009) investigated publishing of services in a domain composed of legacy and IoT systems. Similar to other studies, the authors emphasize that SOA is a good solution for integrating IoT devices with large-scale systems in enterprises.

Thoma et al. (2012) presented a classification for IoT services based on the lifecycle and physical interaction of the device. They argue that SOA-based solutions may provide an integrated service composed of enterprise resource planning systems, cyber-physical systems, and other business process tools.

Meyer et al. (2013) conducted a study to extend business process model and notation (BPMN 2.0). BPMN has two representation methods: a graphic and a machine-readable method. Authors update both methods in the standard and use the updated version of the standard to present a proof of concept. They show how to utilize IoT devices and its novice services as process resources in an ERP system. Authors propose to use IoT devices in a process flow as resources both for documentation and automation purposes.

Thoma et al. (2013) presented a study that enables high-level interoperability between wireless sensor networks and enterprise information systems using the methodology of semantic web technologies. They abstracted the real world cyber-physical systems and called these systems as “Semantic Physical Business Entities (SPBE)”. Therefore, enterprise information systems can communicate with these systems with the help of semantic services and semantic knowledge repositories.

Karadimas et al. (2014) enhanced a business process architecture enabling Web-of-Things using web service technologies. They implemented the architecture and demonstrated the enhancement with an example. The example show how to trace a supply chain in a document management system.

Bi et al. (2014) gave an overview on the effects of IoT devices on enterprise information systems in manufacturing. They point out the gap between IoT devices and enterprise information systems. They conducted a detailed analysis on the new features of next generation enterprises and possible applications of these new features. Their study includes well-defined solutions using IoT-based technologies for various business problems.

Da Xu et al. (2014) focus on key enabling technologies and major industrial applications of IoT. They propose a four-layer service-oriented architecture. The authors claim that a SOA-based IoT architecture helps to achieve interoperability between different types of

IoT devices. In addition, integrating IoT-related technologies into production processes will enable the manufacturers to achieve process and product quality in production. Using IoT devices, manufacturers are able to monitor the production steps closely.

He and Da Xu (2014) reported their latest work on enterprise service integration of distributed systems composed of mobile devices, embedded devices, and wireless sensors. They assert that SOAs and service description languages are key technologies to enhance the interoperability between IoT devices. In addition, they emphasize that integration of IoT devices into legacy systems will be a challenge.

Priller et al. (2014) studied secure and reliable communications between different types of IoT devices and web services. They proposed SOA as a solution.

Repta et al. (2014) introduced a novel concept: a "Cyber Intelligent Enterprise". The authors proposed a generic system architecture. They investigated the applicability of physical and cyber world solutions in future enterprise information systems. They implemented a three-layer architecture enabling a standard communication methodology to access system resources. In addition, they introduce an ontology that stores the state and the structure of the system. The ontology facilitates the information exchange between components of the system.

Lee and Lee (2015) classify IoT applications into three categories. These are monitoring and control, big data and business analytics, and information sharing and collaboration. They provide examples for each category. They also list key IoT technologies chronologically as shown in Table-2. The researchers expect challenges in the areas of data management, data mining, privacy, and security in the IoT domain.

Table 2. Key IoT Technologies (Lee and Lee, 2015)

	Before 2010	2010–2015	2015–2020	Beyond 2020
Network	• Sensor networks	• Self-aware and self-organizing networks • Sensor network location transparency • Delay-tolerant networks • Storage networks and power networks • Hybrid networking technologies	• Network context awareness	• Network cognition • Self-learning, self-repairing networks
Software and Algorithms	• Relational database integration • IoT-oriented RDBMS • Event-based platforms • Sensor middleware • Sensor networks middleware • Proximity/ Localization algorithms	• Large-scale, open semantic software modules • Composable algorithms • Next generation IoT-based social software • Next generation IoT-based enterprise applications	• Goal-oriented software • Distributed intelligence, problem solving • Things-to-Things collaboration environments	• User-oriented software • The invisible IoT • Easy-to-deploy IoT software • Things-to-Humans collaboration • IoT 4 All
Hardware	• RFID tags and some sensors • Sensors built into mobile devices • NFC in mobile phones • Smaller and cheaper MEMs technology	• Multiprotocol, multistandards readers • More sensors and actuators • Secure, low-cost tags (e.g., Silent Tags)	• Smart sensors (biochemical) • More sensors and actuators (tiny sensors)	• Nanotechnology and new materials
Data Processing	• Serial data processing • Parallel data processing • Quality of services	• Energy, frequency spectrum-aware data processing • Data processing context adaptable	• Context-aware data processing and data responses	• Cognitive processing and optimization

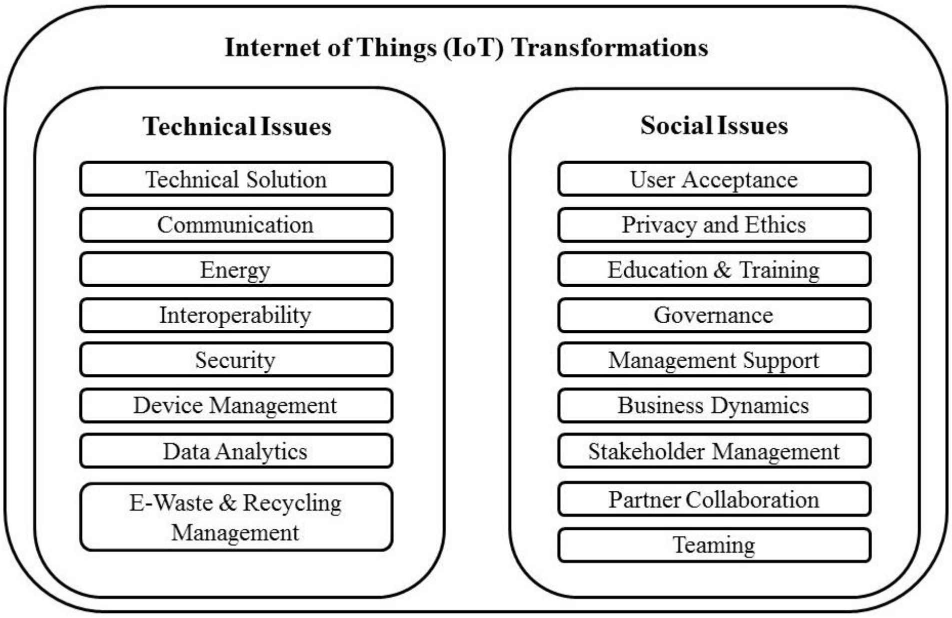
Zimmermann et al. (2015) propose a metamodel-based approach for integrating IoT architectural objects into enterprise architectures. The authors state that the approach is high scalable for Digital Enterprise Architectures composed of microarchitectures of distributed IoT devices and related services.

We briefly presented a sample of studies related to IoT domain. Currently, most of the studies deal with the technical problems encountered during the integration of IoT devices into enterprise information systems. These studies generally focus on interoperability between enterprise information systems and the cyber-pyhsical devices such as IoT and Wireless Sensors. They propose new architectures to integrate various heterogeneous devices and technologies. Many researchers propose SOA as the best solution for IoT integration. However, none of the studies provides a clear roadmap on how to integrate IoT devices into enterprises. Our study aims to fill this gap by providing a set of guidelines to deal with both technical and social challenges.

INTERNET OF THINGS TRANSFORMATION GUIDELINES

Manufacturing companies need to perform an IoT transformation to reduce cost, increase profit, and increase competitiveness. These transformations will be inevitable for most companies in the near future. During IoT transformations, managers need to deal with not only technical issues but also social issues. Therefore, we prepared guidelines including recommendations for both technical and social issues. Figure 2 shows the technical and social issues of IoT transformations. These recommendations are for decision makers managing a large-scale IoT transformation.

Figure 2. Technical and Social Issues in IoT Transformations



Technical Issues

In this section, we summarize the technical issues. Furthermore, we present our recommendation for each issue. These issues are generally handled by medium-level IT managers and IT staff.

Technical Solution

First, managers should analyze their business processes. Then, they need to identify areas to improve using IoT technologies. They have to take their time and be careful in choosing a viable IoT technology solution. Managers shall conduct various analyses using multi-criteria decision-making techniques with the help of IoT transformation project stakeholders. Especially the inputs from employees are valuable for such a transformation. Being an early majority would be less risky compared to being an early adopter (Rogers, 2003). Our first recommendation is as follows:

“Take your time and seek the best IoT solution aligned with your business dynamics.”

Communication

There are many studies addressing communication methods and related problems. Therefore, in this section we only focus on the issues related to deploying IoT devices. As stated previously, IoT devices are able to collect data from all production steps and locations in the company. Some of these data should be processed in real time for several services to take preventive and corrective actions. Offline data is useless in some cases (SAP, 2014). Improved communication devices and enhanced techniques may solve many existing real-time data transmission problems. (Soyturk et al., 2010). Therefore, IT managers should modernize the communication infrastructure based on the latency and speed requirements in data transmission.

“Modernize your network infrastructure to enable large amount of real-time data transmission.”

Energy

Batteries, fuel cells, solar technologies, and public electricity are the current energy resources for IoT devices. Chipsets and sensors embedded in recently introduced IoT devices have low power consumption requirements. In addition, various technologies, such as push-based, increase the standby durations of these devices. However, power management technologies are driven by specific needs and requirements. Therefore, enterprises should choose a suitable technology that best satisfy their specific needs and environmental requirements.

“Analyze the current power capacity and improve it based on the current and future requirements of IoT devices to be deployed.”

Interoperability

Although interoperability is a multi-dimensional aspect, in this study, we only focus on service publishing methods. Many studies in the current literature recommend service-oriented architectures (SOA) for the integration of IoT devices into current and legacy systems. Therefore, managers should seek SOA-based solutions in the acquisition of new enterprise information systems. Furthermore, they should investigate methods to enable their legacy systems work with SOA-based systems.

“Provide interoperability between existing systems and new IoT systems by implementing SOA-based solutions.

Security

According to a report by Gartner (2014), there will be 50 billion connected devices by 2020 and two-third of these devices will be sensor-based. We believe that most of these devices will be utilized for production and business processes. IoT technology bring many business advantages. However, it also brings many security related challenges. The use of IoT devices should not completely compromise security. The key point is to balance the security and usability in the use of IoT devices. Since there is an inherent tradeoff between security and usability (Cranor and Garfinkel, 2005).

“Balance security and usability in the use of IoT devices.”

Device Management

Organizations should be able to manage different types and brands of IoT devices from a single console. Central management of connected devices helps to provide an uninterrupted business service. In addition, central device management enables IT departments to install, monitor, and update the devices remotely (SAP, 2014). Therefore, central management of heterogonous IoT devices helps to achieve business efficiency.

"Automate management of different types and brands of IoT devices."

Data analytics

Deployed sensors started to collect a significant amount of data. For example, the Oracle-sponsored catamaran equipped with 300 sensors and video cameras generate data that contain 3000 variables per second and 200 gigabytes of video per day (Burkitt, 2014). As the data collected increase, improved servers and storage systems will be a necessity to process these data.

"Improve server and storage systems to analyze data produced by IoT devices."

Electronic Waste (e-Waste) and Recycling Management

As the number of IoT devices increase, the pollution created by the disposal of these devices will be a serious threat to our environment. The ultimate goal should be 100% recycling. However, achieving this goal will not be easy. For example, at the end of their lifetime, collecting devices deployed in humanless areas such as nuclear power plants or volcanic areas would not be an easy task. There are some regulations on e-waste (Zhang et al., 2012). However, the current initiatives are not enough for preventing pollution. As a result, organizations should develop maintenance and disposal plans for each type of devices. Then, they need to follow the proper recycling procedures. A detailed overview on e-waste management is presented in (Kiddee et al.,2013).

"Develop an e-waste and recycling management program."

SOCIAL ISSUES

In this section, we summarize the social issues. Handling these issues successfully help to achieve effectiveness in the transformation process.

User Acceptance

The studies show that the main barrier in technology acceptance is user resistance. Therefore, managers should seek user acceptance during information technology transformations. In general, employees do not instantly accept the changes due to technology transformations. Studies indicate that the percentage of early adopters in enterprise level technological improvements is low. Employees have the fear of losing their jobs during new technology deployments. The managers should be open about the expected results of these technology transformations. If there will be a downsizing, then the managers should be fair in choosing the employees facing layoffs. Not all technology transformations lead to downsizing. If that is the case, the managers shall create an organizational climate in which employees trust their managers. The managers shall prepare conferences, briefings, trainings, and other forms of information sharing activities. Adequate and on-time user training ease the IoT transformation process. These activities help to achieve the intended organizational change and technological transformation. Demir and Ozkan hypothesized that utilizing social hubs is an effective method for achieving organizational change (Demir and Ozkan, 2015).

"Seek ways to achieve user acceptance. Pay special attention to conferences, trainings, and other types of information sharing activities."

Privacy and Ethics

IoT devices are capable of collecting data from machines, systems, products, employees, and even from customers. All collected data are sent to servers or data centers. Some of the data collected may include sensitive or private data (Bassi and Horn, 2008). This data collection may create ethical and privacy issues. There are two methods to ensure privacy during data collection. In the first method, IoT device users set the permissions. This approach is similar to the privacy language definition introduced in (Dehghantanha et al., 2010). Moreover, users are used to this approach since it is commonly used in smart phones. In the second method, users are informed about this data collection with a message indicating that it is to serve business needs. There are various technologies to implement the second method (Weber, 2010).

"Inform users and let them adjust privacy settings for private data collections using IoT devices."

Education and Training

Education and information are two central aspects for achieving success in IoT (Bassi and Horn, 2008). Education and training is vital in any type of technology transformation programs. Education and training will prevent misuse of devices and equip users with the necessary knowledge to benefit from IoT technology with its full potential. Creating a help-desk department for user problems and maintenance of IoT devices will be a smart move for organizations. In addition, education and training will help to achieve user acceptance.

"Develop and conduct an effective training program for the users."

Governance

Absence of governance is a major problem in the IoT domain. Although there are some initiatives, currently, we do not have a central governing body to develop international standards and regulate the IoT use. Furthermore, we need proper legislations as well (Bassi and Horn, 2008). Organizations may fill these gaps with organizational procedures and standards. Well-prepared procedures help to eliminate many problems during and after IoT transformations. Standardization of IoT use with adequate procedures and standards will help governance of IoT.

"Develop organizational procedures and standards to achieve IoT governance."

Management Support

In an IT transformation process, each member of the organization has a responsibility and part in the change (Markus and Benjamin, 1997). In addition to IT staff, managers are required to support the IT-enabling transition. Good leadership, sharing a common vision, following a viable strategy, and taking responsibility are important in achieving an effective IT transition. Furthermore, these factors increase the speed of the transition. Managers have the power to influence other members of the organization (Thong et al., 1997; Thong et al., 1996; Keen, 1981). Management support is crucial in securing adequate funding and necessary human resources. In short, management support is a success factor in IT projects (Demir, 2008) including IoT transformations.

"Secure management support."

Business Dynamics

Business dynamics are categorized as interior and exterior dynamics. While interior dynamics focus on processes within the organization, external organizational relationships create the exterior dynamics. Before an IoT transformation, decision makers should know about the capabilities and limitations of their business. A scope of the IoT transformation should be defined based on these limitations and capabilities. This scope definition also reveals the necessary business resources required to achieve the transformation. Note that scope management is quite challenging in IT projects (Demir, 2009). To achieve competitive advantage, organizations are required to distinguish themselves from other organizations by implementing cutting-edge technologies that others have yet to implement.

"Study interior and exterior business dynamics and develop a transformation process based on organizational capabilities and limitations."

Stakeholder Management

Stakeholder management is important for any type of IT project (Demir, 2009). Identification of all internal and external stakeholders and their stakes is a first step in a successful technology transition. This is no different for IoT transformations. Management of both primary and secondary stakeholders during the transformations is a success factor.

"Identify all stakeholders and pay attention to stakeholder management."

Partner Collaboration

Development of an open and extendible ecosystem between business partners is important to integrate market applications and improve decision-making processes. Such an ecosystem increases revenue, improves operations, reduces operational risk, and enhances productivity (HP, 2015). Creating strategic alliances between business partners and supporting partners in IoT transformations may help to achieve competitive advantage.

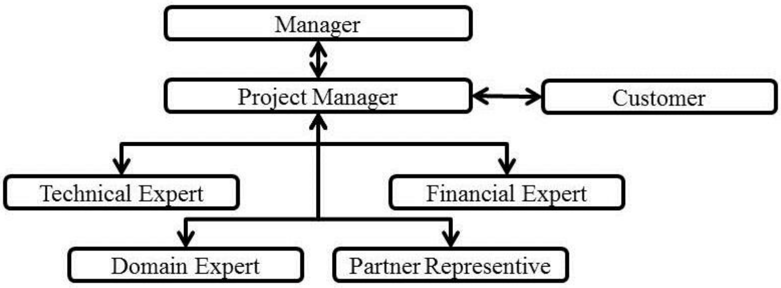
"Support your partners to initiate an IoT transformation process within their organizations."

Teaming

Teaming is one of most critical issue in an IoT transformation process. Without having a shared vision, such a transformation will not be a success. Creating a synergy within the team having different and necessary skills and expertise is a success factor. An organization for a management team responsible for the IoT transformation is shown in Figure 3. Arrows show the information flow between team members. Note that the project manager and the customer do not have a hierarchical relationship. The number and composition of team members may be determined based on the organizational needs and size.

"Build a management team responsible for IoT transformation process."

Figure 3. IoT Transformation Team



Source: Integrating IoT Sensor Technology into the Enterprise (Intel, 2015)

CONCLUSION

In this study, we developed guidelines for integrating internet of things (IoT) devices into the enterprise information systems. The guidelines covers recommendations related to technical and social issues in IoT transformations. We gathered these recommendations based on a broad review of literature consisting of academic and industrial studies. Following these recommendations help to achieve success in IoT transformations.

Our literature review shows that there are many studies dealing with technical issues of IoT transformations. However, the studies dealing with social issues are few compared to the number of studies focusing on technical issues. We believe, just solving the technical problems will not be enough to achieve success in IoT transformations. Therefore, investigating social aspects of IoT transformations is as important as solving technical problems. As future work, we plan to develop an IoT transformation model based on the recommendations gathered during this study.

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The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of any affiliated organization or government.

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