An Overview of IoT Readiness Assessment Methods

Dejan Arsenijević[*], Stevan Stankovski[**], Gordana Ostojić[***], Igor Baranovski[****] and Dragana Oros[*****]
[*] Student Center Novi Sad, Novi Sad, Serbia, moonsoft@neobee.net
[**] Faculty of Technical Sciences, University of Novi Sad, Novi Sad, stevan@uns.ac.rs
[***] Faculty of Technical Sciences, University of Novi Sad, Novi Sad, goca@uns.ac.rs
[****] Faculty of Technical Sciences, University of Novi Sad, Novi Sad, baranovski@uns.ac.rs
[*****] Faculty of Technical Sciences, University of Novi Sad, Novi Sad, spawn@uns.ac.rs

***Abstract*— In the next decade significant influence of IoT technologies over all areas of human society is expected. Most research show that IoT implementation is in early phase in majority of companies, IoT application is partial, at starting point, through pilot projects (HCL Global Systems' "Global IoT Report 2017" reports that 6 out of 10 surveyed are in early phases of exploration and defining IoT strategy). Potential benefits and necessity of application are not in question, but ways how to implement IoT efficiently and effectively are not enough explored and known yet. In defining IoT strategy it is necessary to assess current organization state from IoT perspective, IoT readiness assessment methods provide structured approach to do that. A number of typical IoT readiness assessment methods are presented in this paper.**

I. INTRODUCTION

In the next decade significant influence of IoT technologies over all areas of human society is expected [1], [2]. Lessons learned and development of IT infrastructure will enable IoT application in a number of new areas that could result with significant cost reduction and improved life conditions. Most research show that IoT implementation is in early phase in majority of companies, IoT application is partial, at starting point, through pilot projects (HCL Global Systems' "Global IoT Report 2017" reports that 6 out of 10 surveyed are in early phases of exploration and defining IoT strategy [3], in May 2017. Cisco announced results from comprehensive IoT survey that reveals that close to three-fourths of IoT projects are failing [4]).

Potential benefits and necessity of application are not in question, but ways how to implement IoT efficiently and effectively are not enough explored and known yet. There is not a single way of developing an IoT strategy, and key challenges include the following: 1) Setting end goals for an Internet of Things (IoT) strategy may seem challenging, as many of the technologies, business models and standards are nascent; 2) organizations embark on IoT strategy with very different starting points based on previous experiences, such as M2M initiatives, as well as how well the IoT vision is articulated; 3) Working through the IoT vision can be challenging and often involves getting the participants in the process up to speed with the opportunities offered by IoT technology and how it can be used to enhance products and/or create services; 4) A separate IoT strategy can add value, but maximum value is derived when IoT is regarded as part of a companywide digital business strategy initiative [2].

All strategies need to address demand (what are the requirements from the organization), supply (how to satisfy demand), governance (how to prioritize and fund the initiatives) and security. What makes IoT more challenging than putting together any other IT strategy is that the demand side is usually not well understood inside the organization and, for most organizations, it is reasonable to expect that it will take several iterations of refining the vision before demand solidifies. The same goes for the supply side of the strategy. Technology advances rapidly while standards and business models remain largely immature, hence the supply side will also take several iterations before it solidifies. IoT strategy work is no different than other strategy work in that you need to know the current state or position in order to assess the gap to the future, desired state or position [2].

Based on previous statement, logical first step in IoT application would be organization's current position assessment from the IoT perspective. IoT readiness assessment methods provide a structured IoT implementation approach, and they are subject of great interest for consulting companies (TDWI, Gartner, McKinsey etc.), IoT technology and equipment manufacturing companies (Intel, IBM, Cisco etc.), professional committees and academic institutions. Some of mentioned organizations have developed tools which enable companies to understand their current position concerning IoT.

Readiness assessment methods (or closely related maturity assessment) are very helpful in assessing current organization's position concerning observed characteristic's, in this case IoT's, point of view on its evolution path. A Readiness assessment method consists of a sequence of maturity levels for a class of objects. The bottom stage stands for an initial state that can be, for instance, characterized by an organization having little capabilities in the domain under consideration. In contrast, the highest stage represents a conception of total maturity. Advancing on the evolution path between the two extremes involves a continuous progression regarding the organization's capabilities or process performance [5].

Knowledge base in methods provides criteria and characteristics that need to be fulfilled to reach a particular maturity level. During a maturity appraisal, a snap-shot of the organization regarding the given criteria is made. The characteristics found are evaluated to identify the

appropriate organization-individual maturity level. The application of maturity models can be supported by predetermined procedures, e. g. by questionnaires. Based on the results of the as-is analysis, recommendations for improvement measures can be derived and prioritized in order to reach higher maturity levels [5].

In this paper one of the several types of literature review is used – narrative literature review. Although systematic quantitative approach provides more systematic and objective results, as well as provides structured review process [6], a number of founded papers that fulfill requests were so small that according to suggestion provided in [6], narrative literature review was chosen.

In the next sections a few typical IoT readiness assessment methods are presented.

II. GARTNER'S IOT MATURITY ASSESSMENT

To achieve your goal, understand your starting point. Based on that statement Gartner developed method for quick IoT self-assessment along the two relevant axes: technical capabilities and vision. Both are divided in three levels: basic, intermediate and advanced.

Levels for technical capabilities are defined as follows: 1) Basic - The organization has no prior experience when it comes to procure or operating IoT or M2M solutions; 2) Intermediate - The organization has been operating or procuring M2M or IoT solutions for more than two years. Some of this experience may be in the area of OT, for example, telemetry solutions to remotely monitor assets like pumps, transformers, compressors, etc.; 3) Advanced - The organization has been involved in large-scale IoT or M2M projects for more than five years, probably in more than one area/division and IT has been a partner in the development of the solutions.

Vision is defined as follows: 1) Basic - The organization has assigned responsibility for ideation around IoT and vision formulation is in early stages; 2) Intermediate - LOB has been educated about the potential IoT and has an understanding of the technological capabilities. A first version of an IoT strategy has been developed and accepted by relevant stakeholders; 3) Advanced - The organization already is shipping products/services in operations that leverage IoT or M2M technologies and are now working on the second or subsequent iterations of an IoT vision. All relevant stakeholders have an understanding of how the current initiatives have impacted the organization.

IoT implementation is realized in following steps:

1. IoT Readiness identification by Performing an IoT Maturity Assessment;

2. Refine IoT strategy component iteratively - Depending on type of organization and LOB requirements, the vision could be focused on enhancing existing products and/or processes or be much more radical and aim to establish new products or business models.

3. Assess where organization need to be in matrix - Depending on which one of the nine quadrants you are currently in, only adjacent quadrants could be considered realistic targets for advancement. It is important to understand that this is an iterative process, as requirements on either axis grow and certain activities need to take place to evolve the overall position. In many situations, it is difficult to plan more than one move ahead, and each move can take anywhere from six months to 18 months.

4. Invest in ideation to further develop the IoT vision - the IoT vision needs to be continually enhanced to stay relevant.

5. Produce an IoT roadmap based on current IoT maturity and vision - depending on which one of the nine quadrants and one box best reflects your current capabilities and vision, different components will be of different importance to your organization moving forward.

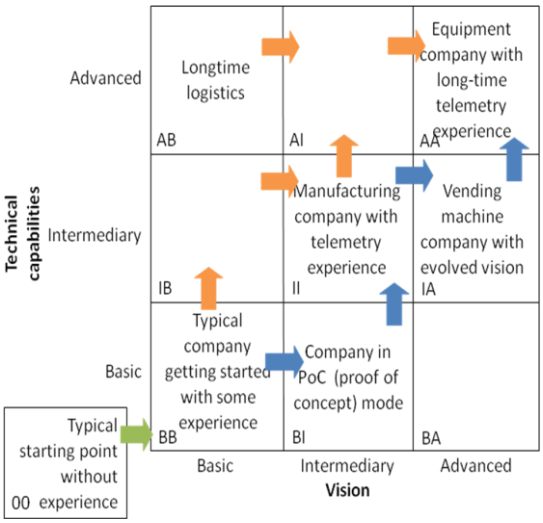

Figure 1. Sample IoT Assessment Matrix [2]

Gartner suggests list of activities that should be concerned when moving along the two axes are as follows - not all activities may be relevant depending on target architecture and priorities may be different for different organizations.

Finally, Gartner's experts recommend that IoT strategy should not be stand alone strategy, but part of global company's digital strategy. IoT in and of itself rarely generates any tangible business benefit unless it is monetized by being an integral part of another product that is sold at a premium, or if the data collected by the IoT initiative generates transactions that are fed into a back-end system to generate billable events. A stand-alone IoT strategy adds considerable value initially but even more value is extracted over time when the IoT work is part of a companywide digital business strategy that helps organizations meet threats and opportunities in an increasingly digital world as part of the business strategy.

III. SCHUMACHER'S INDUSTRY 4.0 MATURITY MODEL

The term Industry 4.0 symbolize the concept of a Fourth Industrial Revolution. Industry 4.0 refers to recent technological advances where the internet and supporting technologies (e.g. embedded systems) serve as a backbone to integrate physical objects, human actors, intelligent machines, production lines and processes across organizational boundaries to form a new kind of intelligent, networked and agile value chain [7]. Similar or the same definitions have recent terms Industrial internet, Cloud-based Manufacturing, Smart Manufacturing, and the subject of this paper IoT. In this subsection a readiness assessment method for Industry 4.0 developed by A. Schumacher, S. Erolb and W. Sihn.

Model has been developed in three distinct phases: an initial phase to create complete understanding of the domain of Industry 4.0, a core development phase to design and architect the model's structure as well as a practically applicable tool and an implementation phase to validate the resulting tool in real life application.

Developed model include 62 maturity items which are grouped into nine dimensions that helps in readiness assessment, as it is shown in Table I.

TABLE I.
DIMENSIONS AND MATURITY ITEMS OF INDUSTRY 4.0 MATURITY MODEL [7]

Dimension	Exemplary maturity item
Strategy	Implementation I4.0 roadmap, Available resources for realization, Adaption of business models, …
Leadership	Willingness of leaders, Management competences and methods, Existence of central coordination for I40, …
Customers	Utilization of customer data, Digitalization of sales/services, Costumer's Digital media competence,
Products	Individualization of products, Digitalization of products, Product integration into other systems, …
Operations	Decentralization of processes, Modelling and simulation, Interdisciplinary, interdepartmental collaboration, …
Culture	Knowledge sharing, Open-innovation and cross company collaboration, Value of ICT in company, …
People	ICT competences of employees, openness of employees to new technology, autonomy of employees, …
Governance	Labour regulations for I40, Suitability of technological standards, Protection of intellectual property, …
Technology	Existence of modern ICT, Utilization of mobile devices, Utilization of machine-to-machine communication,

The evolution path each item undergoes five maturity levels where level 1 describes a complete lack of attributes supporting the concepts of Industry 4.0 and level 5 represents the state-of-the-art of required attributes.

Measuring, determining and representing the enterprise's maturity follow a three-step procedure (Figure 2) which we integrated in an easy-to-handle, software-supported tool.

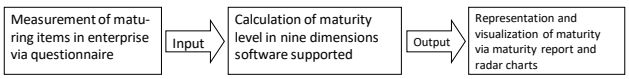

Figure 2. Three step procedure to assess Industry 4.0 maturity [7]

Evaluation of maturity through the maturity items within an enterprise is conducted by using a standardized questionnaire consisting of one closed-ended question per item. Each question requires an answer to a Likert-scale reaching from 1- "not distinct" to 5- "very distinct". As authors stress, the questionnaire can only be answered properly, if all respondents have a basic understanding of the concepts of Industry 4.0. External consulting or group sessions can therefore increase the questionnaire's representability and the maturity model's accuracy. Responses to the questionnaire then serve as data input for the software tool to calculate and represent the maturity level.

IV. TDWI READINESS MODEL FOR IOT

TDWI Research provides online questionnaire for IoT readiness assessment with which users can test their organizations on quick and simple way. Although model behind the quick self-assessment tool is primarily focused on IoT data and analysis, all IoT relevant areas are included in questionnaire. TDWI's Readiness Model for IoT assesses IoT readiness across five dimensions (see Table 2) most of which map to specific business or technical analytic functions. Within each function, there are multiple processes, team structures, and levels of experience that can affect IoT success. These are represented in the model as metrics. At the highest maturity of IoT, these functions are closely aligned to each other and, ultimately, to the strategic direction of the company. This ensures investments in IoT and analytics deliver the outcomes the enterprise needs.

TABLE II.
IOT READINESS MODEL CONSISTING OF DIMENSIONS AND METRICS [8]

Dimensions	Organizational Readiness	Data Readiness	Infrastructure Readiness	Analytics Readiness	IT, Dev. & Op. Readiness
Metrics quantified by responses to the questionnaire	Business use cases	IoT data production	Architecture	Team expertise	Business process change
	Leadership	Data properties	IoT network technologies	Data integration	Team experience
	Strategy (business models, processes)	Data understanding	Data quality	Embedded and actionable	Team readiness
	Culture	Data management	Storage technologies	Delivery & deployment	
	Governance	Data sources	Security	Techniques	

General description of each dimension with a few examples of the questions that the assessment tool asks for each dimension and its metrics follows.

Organizational readiness: This dimension consists of five key success areas. The first is that an enterprise must define a use case for IoT that makes business sense. This is critical because often organizations start an IoT project without including all relevant stakeholders in early discussions. For instance, some organizations are worried about what competitors are doing. They want to get started on a project but have not necessarily thought about the data needed, its frequency, the processes impacted, or how they will take action on IoT analytics.

Second, ideally upper management is committed to analyzing IoT data, has a vision for it, and is willing to fund it. This can be important, especially if outside expertise is needed to help with the deployment.

Other success factors include a culture that supports IoT, the beginnings of a strategy, and governance[1] for IoT.

Data readiness: Questions in the online assessment tool test the presence of IoT data and whether the organization has the experience and skills to source, manage, and process IoT data, or big data in general (although not all IoT data is necessarily big data). In this section, respondents answer questions about IoT data sources and data management. They are also asked about data frequency.

Infrastructure readiness: The assessment tool tests whether your organization has thought through architectural issues related to IoT and IoT analytics. It looks at where analytics will occur in the IoT deployment, what data storage will be put in place, and how security will be handled. Data quality is also examined here. In this section, questions about where data is processed (e.g., at the edge or in the cloud) are also addressed.

Analytics readiness: Collecting IoT data is important, but analyzing and acting on it is where the largest value lies. That analysis might include techniques such as predictive analytics, stream analytics, or query and reporting. This section examines the composition of the analytics team and its experience with different analytics techniques. It also looks at whether your organization is set up to take action on analytics, and the deployment and delivery models for doing so. For example, it asks questions about data scientists and how your organization currently acts on analytics.

IT/Dev/Ops readiness: IoT projects often include other parts of the enterprise. For example, development teams might be involved as well as engineering and operations. IT may be involved in the data management and processing portion of an IoT deployment, but operations may need to be included in the rollout as well. The assessment tool tests how ready the technical team is to deploy and manage IoT. To further quantify readiness, the tool collects information about how the organization will address changes to systems or processes brought about by IoT. This might involve developing workarounds to legacy systems.

After answering to questions in the Readiness Assessment Tool, the score for particular dimensions is calculated. The greatest score for each single dimension is 20. Multiplying 20 by the five dimensions yields 100 as the greatest possible score overall.

At the end of the assessment, the Readiness Assessment Tool displays your scores per dimension (out of 20) and overall score (out of 100), plus the average dimensional and overall scores of all respondents from an organization. Also the average for organization's industry and size is given. That way, one has a context for determining whether his/hers organization is ahead of or behind the curve. Results are also shown graphically via radar chart.

After self-assessment is done few typical organizations scenarios concerning results are given, their strengths and weakness are analyzed. In the end, recommendations how successfully implement IoT are given.

[1] IoT governance refers to the development and application by Governments, the private sector and civil society of shared principles, norms, rules, decision-making procedures, and programmes that shape the evolution and use of the Internet of Things in a direction that addresses policy concerns and ensures that the maximum benefits are reaped [9].

V. AXEDA'S CONNECTED PRODUCT MATURITY MODEL

Axeda Corporation, a part of PTC company, which is one of the IoT platform market leaders, has developed their own Connected Product Maturity Model. The model is primarily suitable for production companies, and is based on their own experiences with IoT customers. The Connected Product Maturity Model has six levels (Fig. 3). The level of maturity relates to the degree of integration of business processes and functions - from initial connection to differentiated services and solutions. According to authors, the purpose of the model is to understand organization's current IoT capabilities along a continuum of value. It can also serve as a benchmarking tool against competitors who are providing differentiation. Below is a more detailed explanation of each level as well as the action steps your organization can take to move forward to the next level of the model.

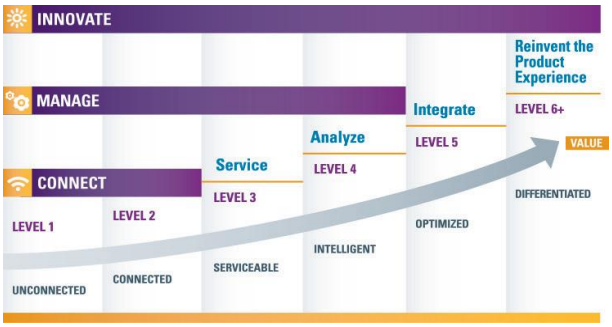

Figure 3. Connected Product Maturity Model [10]

Level 1 - Unconnected. An unconnected organization is looking to make existing processes more efficient and drive higher levels of intelligence from the connected world. There are IoT opportunities in every industry because virtually all electronic and electro-mechanical products can be designed to automatically transmit information about status, performance, and usage, and can interact with people and other devices in real time.

Requirements. At this level, understanding what's possible and the underlying technologies is critical. Embedded software, network communications, device protocols, provisioning, and real-time data processing technologies combine with advanced Web Services, security, and data management to strain the skills of most IT organizations and development teams. Few companies have all these specialized people on staff, so IoT projects can get stalled or off track - if they are ever started at all. Increasingly, companies are coming to the conclusion that they should focus on their core competency, dismiss the idea of the internal "build," and conduct an educated "buy" with faster, short-term ROI and time to market.

Implementation. Level 1 starts with planning. The first step is "Getting connected" which is a broad term with different meanings depending upon the environment of the product and the economics of the solution. And while IoT isn't new, the fundamentals of a connected product initiative are incredibly complex. Basic enablement, network connectivity, security, middleware services, cloud services, application development, and other device management functions are all needs that must be

addressed when organizations seek to launch a connected product initiative.

Level 2 - Connected. Once connected, organizations begin to realize a new means to generate growth and achieve a sustainable service position. Connected product services typically generate a recurring revenue stream, require less fixed capital, and provide potentially higher margins.

Requirements. Keeping up with device proliferation and the numbers and types of devices produced by manufacturers continues to grow rapidly. Here, the focus should be on developing a solution that is resilient to change and allows applications to capitalize on, rather than be hindered by, product differences.

Implementation. Reaching Level 2 is accomplished by connecting a product to a network (internet, cellular or satellite) and enabling data transmission back to an enterprise server or system for processing.

Level 3 - Serviceable. Each and every product requires some level of service and support. Service organizations are increasingly adopting remote service solutions to identify, diagnose, and resolve issues remotely.

Requirements. Organizations require a cloud-based application platform and suite of tools to monitor assets remotely login and manage remote content. The solution would handle hosting, security, scalability and have flexible APIs, so that they are unencumbered by infrastructure and can focus on the value of the solution.

Implementation. Reaching Level 3 is accomplished by enabling remote access and service.

Level 4 - Intelligent. Here, the focus quickly turns to analyzing the data and developing user-facing tools and applications that facilitate data analysis, provide insights and improve business functions. With the right IoT reporting and BI solution, a company can run reports, query the data, create dashboards, or feed the data into your data warehouse and BI environments.

Requirements. Many organizations including Service, Engineering, Finance, Compliance, QA, Product Management, and Sales need visibility into product usage, performance and behavior. The data from the connected products needs to organized and stored in a way that makes it is easy to report on and analyze.

Implementation. Reaching Level 4 is accomplished by enabling reporting and analytics.

Level 5 - Optimized. Organizations who were early in bringing their products online are now realizing that the real "gold" in IoT is taking that data and integrating with enterprise systems such as CRM, ERP, PLM or data warehouses — optimizing critical business processes and essentially "IoT-izing" their business.

Requirements. IoT data must be made available to integrate with other systems. The IoT data must deliver additional value by combining information from connected products with information from other complementary sources and systems to enable people and processes to collaborate and extract even more value. For example, product data flowing through a CRM system can be sent to billing or into a supply chain management system — eliminating error-prone manual steps and providing new sales opportunities for consumable replenishment or warranty renewals. Quality assurance or product management can help enhance product features based on real world data that shows usage patterns or equipment issues - improving customer satisfaction and streamlining beta programs. The valuable IoT product data - now unlocked - can also guide engineering efforts in building more reliable products with differentiating features driven by customer demand.

Implementation. A middleware to integrate with business systems by feeding IoT data into CRM/ERP/PLM systems to optimize business processes by enhancing service, billing, sales, inventory management, and product development.

Level 6 - Differentiated. The ultimate goal for product manufacturers is to reach Level 6 - Differentiation. This is where connected capabilities have the capacity to transform company business and increase customer loyalty. Innovation is achieved by enabling end-users and customers to reinvent their user experience through connected products.

Requirements. There are many types of custom applications that can enhance the utility of a product. For example, organizations can present data from the connected product to users and end-customers via portals that they can view while using equipment in real time. This enables application leaders and developers to receive real-time technical and industry information and develop a culture of innovation that motivates and rewards end-user feedback. Mobile applications for smart phone and tablets are also emerging as a way to put applications that interact with products in the hands of field personnel and end-users who need remote access from anywhere.

Implementation. A platform that includes a rules engine, scripting engine, robust APIs including RESTful and SOAP-based web services.

VI. CONSLUSION

Recent surveys show that there are significant obstacles in IoT project implementation [3], [4]. Reasons could be found in [2]: many of the technologies, business models and standards are nascent; organizations embark on IoT strategy with very different starting points based on previous experiences concerning IoT technologies, as well as how well the IoT vision is articulated.

IoT readiness assessment methods provide a structured IoT implementation approach, and they are subject of great interest for consulting companies, IoT technology and equipment manufacturing companies, professional committees and academic institutions. Some of mentioned organizations have developed tools which enable companies to understand their current position concerning IoT. However, different background and motivation of this organizations (often motivated by marketing, or influenced by big commercial alliances that are interested in their own products or technologies promotion) results in diversity of available solutions for IoT implementation methodologies and IoT readiness assessment tools. Such diversification confuses potential users raising concerns like: will selected method would be appropriate for certain type of company and its business domain, in what extent company will become dependant of certain provider, what will be extent of interoperability with partners, etc.

Significance of IoT solution application in order to improve financial, organizational, productional and other organization's performances, as well as necessity of organization's adoption of these new technological trends,

and required interoperability of IoT systems, raise the need to develop universal methodology for IoT implementation, which will make that complex process easier and more predictive.

In the last few years a lot of efforts are made in development of common standards that concern implementation of IoT in organizations, one of which is Standard for an Architectural Framework for the Internet of Things conducted by IEEE, and which is expected to be finished in the next few years. In the meantime, users can chose among existing or newly developed solutions. It could be expected that lessons learned in the process of IoT implementation will be included in currently developing standards.

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