



The Industrial Internet of Things, Volume B01: Business Strategy and Innovation Framework

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1 OVERVIEW

1.1 INTRODUCTION

This document is a deliverable of the Business Strategy Task Group, within the Industrial Internet Consortium's (IIC) Business Strategy and Solution Lifecycle (BSSL) Working Group.

It provides a high-level identification and analysis of issues that an enterprise will need to address in exploiting Industrial Internet of Things (IIoT) concepts for commercial (or other) gain.

1.2 PURPOSE

Because uncertainly and flux characterize much of the IIoT market, the primary objective is to act as a reference document for any enterprise planning to engage with IIoT concepts. The adoption of frameworks and concepts documented herein accelerate gain by de-risking any decision to deploy IIoT technologies. Accordingly, this document provides a single-source compendium of the issues and challenges to consider before deployment of IIoT initiatives.

The secondary objective is to be a touchstone reference document that defines the scope of work and remit for the Business Strategy Task Group.

1.3 SCOPE

Of necessity, the scope of this document is wide ranging and high level. Subsequent documents to be published by the Industrial Internet Consortium over the coming months will build on this document incrementally. Specifically, they are likely to take one of two forms:

Detailed documents that unpick and analyze major business strategy to provide greater insight into topics identified within the scope of this document, while being consistent with the overall approach and framework.

Action-oriented documents that highlight 'next steps' for organizations considering deploying IIoT initiatives that build on the broader analysis here and in subsequent detailed publications.

1.4 STRUCTURE

While IIoT projects are in many ways quite similar to traditional systems integration projects, there are significant differences. We emphasize those differences here, including sections on:

- Market context,
- IIoT strategy,
- IIoT business model innovation and
- IIoT foundational capabilities.

1.5 AUDIENCE

The two prime audiences for this document are CxOs (or equivalent) actively engaged in specifying and deploying IIoT initiatives and CxO staff (or equivalent) in the early stages of considering the deployment of IIoT initiatives.

Subsequent publications may be more suitable for CxOs (or equivalent) that are in the early stages of contemplating IIoT initiatives, or other senior managers who may benefit from a more comprehensive analysis of pertinent issues.

1.6 USE

The document sets out a robust approach applicable for any company seeking to engage in IIoT. It is a comprehensive and relatively 'heavy' approach since we have taken the view that it is preferable to present a more-or-less complete view of 'best practice' and so allow the reader to draw inspiration from collective thinking among IIC membership.

Clearly, any executive drawing from this document is free to adopt an appropriate 'lighter touch' or existing internal project model, especially within smaller companies. Alternatively, and particularly in the case of larger companies, a range of project support processes will already be in place and the approach documented herein should be used to inspire the enhancement of existing infrastructures in order to efficiently address the IIoT opportunity.

Many of the techniques and approaches discussed in this document are also applicable to consumer IoT¹ initiatives and, where relevant, we welcome the application of IIoT concepts in consumer IoT environments.

1.7 TERMS & DEFINITIONS

This document introduces no significant new terms or definitions

1.8 SYMBOLS

This document introduces no significant new symbols

1.9 CONVENTIONS

Given that the document is non-normative, all 'must', 'may' and 'should' statements are to be interpreted as English language and not as in RFC 2119.

1.9.1 Typographical and Linguistic Conventions and Style

Terms that require definition are rendered in *italics*. (As the usage immediately preceding demonstrates, italics may also be used as example, or for emphasis.)

¹ Consumer IoT generally differs from industrial IoT due to the contrasting levels of emphasis typically placed on security, quality, cost and quality of service in these two environments.

Generally, only the first use of the term is italicized. However, when a term can be read in its usual English language mode, the first use of the term may be italicized as the discussion becomes technical. In the first example below, "safety" and "security" are used informally. In the second, it introduces a definition.

Example 1: "Among the key system characteristics that must be considered, safety is perhaps the most important, followed by security."

Example 2: "*Safety* is the condition of the system operating without causing unacceptable risk of physical injury or damage to the health of people, either directly, or indirectly as a result of damage to property or to the environment."

1.10 RELATIONSHIP WITH OTHER IIC DOCUMENTS



This document fits in the IIC Technical Publication Organization, see Figure 1-1.

Figure 1-1: IIC Technical Publication Organization

2 EXECUTIVE SUMMARY

The Industrial Internet of Things will create massive new opportunities across all lines of business, with the potential to generate trillions of dollars in economic value.

Much like the advent of the commercial internet, the IIoT is set to transform virtually every existing business model and vertical industry, creating new threats and opportunities for all players. Access to new data sources and analytics tools, all on a previously unimagined scale, will define the contours of the corporate IIoT roadmap.

Enterprises will need to broaden their overall market approach, adapting business and operational models through the integration of Information Technology (IT), Operational Technology (OT) and customer-outreach platforms. IIoT solutions will unify disparate organizational elements, processes and information sources, which will in turn enhance how goods and services are developed and delivered. In addition, IIoT solutions will increase the variety of business channels available to enterprises, creating more opportunity to add customer value and deliver wider societal benefits.

However, current expectations among businesses that stand to benefit from these opportunities are more guarded. Many leadership teams are unsure of what exactly IIoT means, how it differs from the competitive dynamics of the past and how to define new business strategies. They are beginning to recognize that the competitive landscape is changing in ways they do not fully understand, and that collaboration and mastery of new skills, such as those within IIoT, will be essential to business success. An organized, disciplined approach to moving forward with IIoT is essential to that success.

Firstly, businesses need to define their IIoT strategy and goals. Doing so will determine how quickly they need to move and how they balance the risks associated with market leadership against the risks for followers and late adopters.

No single enterprise will possess the full range of skills required to address the challenges associated with IIoT. As a result, effective IIoT strategies will necessarily involve some degree of participation in alliances and business partnerships. Many enterprises will participate in multiple IIoT applications, making it necessary to formalize IIoT portfolio management and place initiatives in the context of a corporate roadmap and budgeting process.

Secondly, businesses need a structured framework to target and select the right IIoT opportunities. A framework for determining beneficial opportunities comprises four stages:

Opportunity ideation identifies IIoT application opportunities through an iterative process, motivated by two drivers: using IIoT technologies to optimize current products, services and business operations, and; launching solutions based on innovative business models. Success in IIoT requires addressing both elements.

Opportunity preparation details the ideas the business determines are worth pursuing. The aim is to analyze and document them in detail to sharpen focus, derive underlying assumptions and assign actions to various team members to validate these assumptions.

Opportunity evaluation develops an acceptable business case and implementation risk profile. This step considers adapting investment decisions to handle a first wave of IIoT applications, followed by a flow of second- and subsequent-generation application opportunities.

Opportunity initiation addresses the challenge of structuring internal execution capabilities in a way that allows deploying IIoT hardware, and software and service delivery specialists as effectively as possible. This stage considers takes account of the cultural implications of multidisciplinary project teams.

This overall process of transitioning from strategy and IIoT project selection to execution rests on two foundational elements: an IIoT Center of Excellence (CoE) and an IIoT platform.

Businesses will find IIoT concepts different from 'business as usual' activities, forcing them to make use of new pools of expertise. To do this, some enterprises may augment internal skills with IIoT partner ecosystems formed by large industrial players. Others will see value in establishing their own COE to leverage expertise across multiple applications and business units, apply consistent change-management techniques, evaluate implementation projects both internally and among competitors and implement best practices.

The second element of the implementation framework is to acquire an IIoT platform capability. This corresponds to the technical systems that provide the enabling services necessary to deliver IIoT applications. Examples of such services include connectivity management, device management and IIoT application enablement.

Not all enterprises can justify the level of commitment in dedicated personnel and investment to own their own IIoT platform. Many will share infrastructure to benefit from economies of scale. Over time, enterprises will share application-enabler resources and data with the aim of driving IIoT service innovation through economies of scope. Technology and standardization choices play a greater role in IIoT platform selection where enterprises are making strategic investments as distinct from experimental or pilot evaluations.



Figure 2-1: IIC framework for identification and deployment of IIoT solutions

The IIoT innovation framework and elements described later will help companies to generate the maximum possible benefit from IIoT concepts.

3 MARKET CONTEXT



This section discusses the market drivers and opportunities presented by IIoT and the factors influencing them. It also explores business model transformation and the important intersection between IT and OT.

3.1 THE OPPORTUNITY FOR THE INDUSTRIAL IOT

IIoT is reshaping virtually every existing business model and vertical industry, and is creating significant new opportunities across all markets.

The promise of access to new and unified data sources in the IIoT age will require a platform for improved decision-making by humans and machines. This data will come from a wide variety of sources, including traditional internal business sources, IT and related systems, sensors, devices connected to the internet, external social media sources, and other structured and unstructured data elements such as audio, video and digital images.

Bringing these sources together for analysis within the context of IIoT will provide a basis for more comprehensive business monitoring, insight and control, while also increasing efficiency.

Beyond business processes, IIoT has the potential to have a positive impact on society and human welfare. It will open up new opportunities for jobs and training, and new avenues for businesses by adding capabilities and revenue streams not previously considered within a given market.

3.1.1 BUSINESS AND MARKET DRIVERS

There are a number of internal and external business factors driving organizations toward IIoT adoption. These include:

- competitive pressures forcing accelerated planning and time to market,
- continuous reevaluation of business models, value chains and commercial relationships,
- accelerated Insight, adjustment and optimization of current operations,
- creation of additional and new value by the business and
- potential for societal benefit.

To stay competitive in markets where disruption and change occur quickly, enterprises must continually review and optimize their business strategy, planning and operational models. They must look for ways to compete within existing markets and create new market playing fields.

Doing so requires access to internal and external data sources that can better inform these decisions. These data will come from connected devices, traditional data sources, social media and more.

It is no longer enough to know how well operations performed last week; insight requires a view into past activities, real-time adjustments to make determinations and corrections now, and

predictive analysis to model future conditions. This past-present-future analytics approach will increasingly become a priority and competitive advantage across all elements of a business.

In this accelerated and competitive environment, the ability to enhance and create new customer value becomes key. Within any product or service, whether a website, a smartphone app, or a heart monitor, or factory floor device, cost and functionality must balance with customer sentiment and experience. This creates a situation in which enterprises must constantly look for ways to adapt business and operational models in real time, and to modify and add value to their products, services and customer experiences. Enterprises need to continuously aim to differentiate their offerings in existing markets and identify untapped opportunities in new markets.

This new environment also provides a plethora of opportunities for startups and small businesses that will have the potential to integrate into the production domains of large companies in a more agile way.

3.1.2 SOCIETAL DRIVERS

While the perceived value of IIoT relates primarily to business and operational optimization, it also has the potential to influence and impact society in a profound and positive way, including:

- creating new jobs and job markets,
- shortening time for and improving human and machine decisions,
- generating environmental benefits and
- producing benefits for public health, safety and quality of life.

The connected, collaborative world will lead to an almost innumerable range of connection points, applications, products, data sources, and software/integration needs. Due to growth in business startups and established enterprises, there will be an increased need for a skilled workforce to advance IIoT adoption. This will require the creation of new roles and skills to provide technical enablers and services for this new industry.

An equally impactful benefit will come from enhanced decision-making processes, integrating data from internal and external sources to enable more effective and timely decisions. For example, in the case of a hospital, the connection and integration of bedside medical devices alongside traditional hospital information systems and other patient-care data could have a profound impact on both immediate and longer-term patient-care decisions. Similar potential for societal benefits exists in other industries, particularly in the context of smart cities.

The use of IIoT and associated data in reporting, real-time analysis and predictive models will help improve local and global environmental conditions. This is especially true in scientific research and businesses directly focused on environmental resource utilization. Improvement may be seen using IIoT to help focus on more effective utilization and analysis of past, present and future conditions. These industries, as well as IIoT use cases directly related to public safety and health will enhance quality of life and experience.

3.2 THE TRANSFORMATION OF BUSINESS MODELS WITH THE INDUSTRIAL IOT

IIoT is set to transform business models in all markets in broadly similar ways:

- extending the overall business model and market approach with customers to incorporate new value-generating elements,
- providing a basis for unifying disparate internal organizational elements, processes and information,
- enhancing the development and production of goods and services and
- increasing the variety of avenues for enhancing customer value and experience.

3.2.1 GENERAL BUSINESS MODEL AND MARKET TRANSFORMATION

Many current business models place strong emphasis on the effectiveness of internal production processes. The focus of these models will broaden considerably in the IIoT world to include more emphasis on customer relationship and value creation.

In the IIoT age, business models must still take account of traditional internal elements while simultaneously transforming themselves to take advantage of the new spectrum of possibilities. IIoT will affect operations, product development, marketing and the overall business value chain. Business models must adapt to accommodate and take advantage of these changes.

Beyond this more general development, a significant opportunity exists for technology developers to expand their business models into new markets, where they will function as IIoT enablers. Offering their products and technologies for use as stand-alone or embedded elements within other systems will open up new avenues for product distribution. These technologies may include software, devices, sensors or mechanical elements. This opportunity also exists for providers that offer services rather than products alone.

Enterprises that shift their business model as suggested here will realize increased market value from the deployment of IIoT concepts, provide greater value to their customers, become more agile and provide differentiating value to their customer base. Businesses that do not take advantage of IIoT will risk quickly losing market share to competitors that embrace it.

3.2.2 UNIFICATION OF DISPARATE BUSINESS ELEMENTS

Depending on the market segment, the new 'factory floor' can be almost anything: an equipment-manufacturing plant, department store, airplane or even a hospital room. Any one of these locations has the potential to produce a massive amount of data. In contrast to today, IIoT will provide the opportunity to connect different parts of a business and unify its data, from device to IT. This integration can lead to improved analytics and improved human and machine decisions. Bringing these disparate sources together will require a new paradigm of how organizational elements operate together.

New business models will have to take data connection, collection and analytics into account. They must also consider the implications of bringing together data sources across all levels of the organization (including from outside of the organization), where analytical capability needs to reside (at machine level, at the edge, or in IT), the security of systems, resources, and data, and likely changes to business organization models or operational processes.

These elements will evolve over time, which means that enterprises implementing IIoT methodologies must put governance structures in place that factor in the IIoT impact across the entire business. This system of governance must focus on determining the value of IIoT within the enterprise at strategic and operational levels, and ensure a consistent implementation approach in affected areas. See section 6.1.6 for additional discussion of this topic.

3.2.3 ENHANCED DEVELOPMENT AND PRODUCTION

To ensure the continued evolution of its product and service offerings, and strengthen its competitive position, an enterprise must gain an understanding of customer needs, market needs and usage behavior. Today, in all market segments, this cycle has accelerated. Enterprises must transform their business models to reflect the way in which IIoT will enhance product development and production processes.

Within service industries, a combination of connected devices, data collection from numerous sources, and analytics will provide business insight into areas not previously considered. In the railroad industry, for example, the monitoring of railroad track and train conditions, signals, customer travel patterns and fuel consumption can produce insights that enable new or improved service offerings, enhanced safety and more efficient operations. Incorporating this potential into the business model help enterprises develop new services.

In manufacturing environments, the collection and analysis of data from connected internal devices and internal systems, and the integration of these sources, can provide similar insight to increase production efficiency and operational effectiveness. This is especially true in combining manufacturing data from connected devices with business data (from sales, services, or supply chain contexts, for example) to provide real-time and historical insight. Factoring this back into operations, whether historical, real-time or predictive, helps optimize production.

3.2.4 INCREASING CUSTOMER VALUE

While many advantages of IIoT solutions relate to enhancing operational efficiency and enabling new product development, a significant transformational value of IIoT lies in gaining insight that will improve overall consumer value in terms of service and product usage and overall customer experience. Those companies looking to implement IIoT projects should consider both the operational benefits and strategic value such projects bring to their business. This requires thinking outside the operational context into a view of the business and its exposure to the customer.

As an example, consider an application on a tractor. Operationally, sensors could provide information to optimize operations. Coupling in data from external sources (such as weather, sensor data from fields, predictive yield calculations, infestation, pricing, data from local farmers) can each add value. The combination could enhance the farmer's business and operations giving a more complete and even predictive picture of how, when, what the farmer does for planting, harvesting, impacting the environment and other farm activities.

This same potential for operational and added value in business products, services and customer experience exists for all market segments and industries.

3.3 OPPORTUNITY AT THE IT/OT INTERSECTION

IIoT is creating the potential benefit from the connection and integration of data from information technology (IT) systems and the data center with data from operational technology (OT) on the factory floor and connected devices. The IT side of business focuses on resources that process data for business-related functions such as payroll, databases, customer access, various business analysis, reporting tools, and inventory. The OT side targets systems and elements that build, execute, control, and monitor industrial or service processes.

At present, operating models for many larger 'traditional' industrial enterprises include at least some IT and OT assets. As the IIoT becomes more prevalent, the intersection of these elements has the potential for both disruption and benefit within the enterprise.

While there is generally some integration between the IT and OT domains in most companies, the degree of integration varies considerably by market segment. Many enterprises have different processes, organizational structures and systems in place for each domain. Much of the integration between the two is manual, loosely connected, or in silos.

With IIoT comes a significant opportunity, and a necessity, to bring these two operating worlds together to the benefit of the entire business model. Indeed, the intersection between these two domains and the potential for data integration across the business is one of the most significant motivations and benefits of IIoT adoption.

3.3.1 THE NEW INTERSECTION AND OPPORTUNITY POINT

Until the advent of IIoT, there was limited collaboration or cross-linkage between the disciplines of IT and OT, as Figure 3-1 illustrates. Such 'islands' of execution fostered organizational models that, while individually effective, caused IT and OT to operate in relatively independent ways. This is partly because IT and OT require different processes, systems, and measures, and even a different operational 'language.'

The net impact of this situation has been the inability to make use of broader business insight and learning to benefit production operations. Likewise, IT saw limited benefit from physicalworld and real-time analysis or trends that might increase business insight and allow for faster adjustment of business models (further insight into this can be found in the IIC Reference Architecture or IIRA [IIC1], section entitled 'Functional Approach').



Figure 3-1: Current IT/OT state and transformation potential

In the IIoT space, there is a significant business and operational opportunity to be explored in the intersection between the IT and OT silos. While the two domains can continue to operate as separate entities, enhanced integration of operational and business data, historical, real-time and predictive analytics, control, interaction, and insight may lead to more integrated IT and OT infrastructures, yielding benefits both vertically within both domains and horizontally across the entire organization.

As an example, consider an airline whose IT department manages the business systems (reservations, administration, planning systems, inventory, etc.), while the OT department manages processes for ground-based and in-flight monitoring and operations.

During each flight, an aircraft generates extensive amounts of data. Using these data in flight can help operate the aircraft more safely and efficiently. Summary data from the aircraft—combined with ground-based maintenance data and even external information such as weather data—could enable the airline's IT department to create better predictive maintenance and flight analysis. Over time, this would help to optimize the business, reduce costs, create new customer value and enhance operational safety.

Likewise, summary data from predictive, optimization, and business analyses can impact real time activities of the pilots and crew who are operating the aircraft. This data, when coupled with onboard aggregation and analysis, offers an opportunity to improve the safety and profitability of operations and to provide an enhanced customer experience.

The goal of IIoT in this context is not simply to enable connectivity, but to provide access to data and create information assets that provide value across the enterprise from both business and operational perspectives. These information assets will serve to enhance current operations and business outcomes, and will open up new opportunities that were not previously possible. Such opportunities are not limited to a B2B context alone: B2C propositions will lead to increased benefits for consumers, and B2B2C solutions have additional potential to transform value chains.

3.3.2 HARNESSING OPPORTUNITIES AT THE IT/OT BOUNDARY

Beyond the technical integration of IT and OT elements (e.g. connection, data source integration), the central strategic challenge for companies will be to combine and gather insight from data across all aspects of the enterprise to make informed and integrated business and operational decisions, whether in real-time or predictively.

An organization studying the integration of the IT and OT environments needs to study both how data will be analyzed and where it should be analyzed (at the cloud, in a private data center, or closer to OT assets) in both raw and more refined forms.

To harness this opportunity, companies will need an ordered governance approach to planning and connecting all elements of data and analysis gained across the business. This governance must consider IT and OT operational objectives, overall business and market strategy, physical systems, connectivity and utilization of insights gained from, and back into, both elements. See further detail in section 6.1.6.

4 INDUSTRIAL IOT STRATEGY



years?

An enterprise must define its vision and overall IIoT strategy before embarking on an IIoT journey. Are the motivations for engaging in the IIoT purely economic, or are there broader imperative in terms of societal benefits (in the case of smart cities applications, for example)? What is the overall market and competitive environment in which the enterprise plans to engage? How is this likely to change in the coming

The strategy should reflect the extent to which the enterprise it plans to shift toward IIoT and the speed at which this shift is to take place. Should the enterprise become a pioneer and attempt to gain rapid market share, accepting a higher risk of failure? Or should it become a follower, only implementing a new IIoT solution if certain that its customers will accept it and buy into its new product or service? Some enterprises regard IIoT as just one of several important paradigm shifts occurring today, and are willing to invest only limited resources in IIoT adoption. Others see it as *the* paradigm shift of the next decade, and have already invested significantly in IIoT programs and established far-reaching internal change-management processes. Each strategy must set out a vision, goals, and guiding principles appropriate to the enterprise's viewpoint to shape its overall approach to IIoT.

When the strategy is perceived to be important, or its effects likely to be wide ranging, it can be beneficial to appoint a senior stakeholder from within the enterprise's management team to lead and coordinate IIoT initiatives across the enterprise. This approach can ensure consistency between different IIoT initiatives and minimize the chances of pursuing conflicting goals or investing in less-than-optimal supporting infrastructure. Areas within which the senior stakeholder could facilitate cohesion include the management team's understanding of market potential and approaches to new technologies and standards. The stakeholder would also help to define corporate strategy with regard to alliances and partnerships, as well as overall governance frameworks that apply to IIoT initiatives.

Enterprises will also need to define an appropriate guiding set of principles for collaborating with partners and working within the overall IIoT ecosystem. In parallel, they will need to identify, at a high level, the capabilities that they are likely to need to engage in IIoT projects.

Adopting a well-defined and clear approach to IIoT and appointing a dedicated leader to navigate the IIoT journey on their behalf, enterprises will significantly improve their chances of achieving successful outcomes.

4.1 INITIATING THE INDUSTRIAL IOT JOURNEY

Although the IIoT journey resembles the traditional planning and implementation approaches seen in IT and machine-to-machine (M2M) projects in a number of ways, one important difference is the emphasis placed on adding IIoT concepts to the strategic agenda (a change-management effort) and on establishing partnerships (need for a collaborative approach).

The recommended approach is first to include IIoT as an item on executive-level agendas. The move to adopt IIoT technologies is a CxO-driven initiative, not merely another IT or product development project. It will significantly transform the nature of the business—either by improving operational processes by means of new insights, by enabling new business models based on real-time data, or by delivering new customer experiences and engagement models through connected devices and services.

The first questions to answer are, 'How compelling to our business is the IIoT hype? Is this really the single most important disruptive force set to change our business in the coming years? Or is it just one of several change areas, or something that's not relevant to our business at all?'

In a large, highly diversified organization, the answer to these questions may differ from one business segment to the next. What's more, it may not relate explicitly to the IIoT. For an automotive OEM, the question might instead be, 'How important will the connected vehicle be to me, and when will it impact my business?' An industrial equipment company looking to design new products with integrated services might ask, 'What is the strategic importance of connected devices in the context of our overall servitization strategy?' Some CEOs might prefer to hire a management consultancy firm to answer these questions, while others will decide this together with their inner management circle based on internal business knowledge and experience.

Many large organizations will already have corporate strategy and portfolio management processes in place, alongside different types of CoEs and shared IT platforms. It is important to stress the articulation for questions outlined above, and the answers to these questions. This will form a solid basis from which the management team can derive a vision, goals, and guiding principles for its IIoT activities.

4.2 Systematic Management of Industrial IoT Portfolio

A particularly beneficial course of action involves implementing frameworks and processes for tracking IIoT projects from conception through to live operations, including validation of results, to ascertain whether individual IIoT projects have achieved what they set out to achieve.

This kind of tracking should ideally include portfolio management and progress tracking, and budget tracking and overall roadmap. We discuss these two elements in turn.

4.2.1 PORTFOLIO MANAGEMENT AND PROGRESS TRACKING

Accurate IIoT project portfolio tracking is needed to support sales and marketing activities, and for overall business management. It is also an important input for corporate budget planning and iterative refinements of corporate strategy.

As project portfolios and timelines are subject to updates and refinement as organizations discover barriers or restrictions to deployment, it is essential that this type of information make its way to some kind of corporate overview dashboard.

The best way to achieve oversight capability is by establishing a traditional 'program office,' supported by both technical experts (embedded in the wider business) and dedicated business analysts. One of its tasks is to ensure that IIoT initiatives are refined and rescheduled when

roadblocks or other limiting events occur, and to support the ongoing optimization of the strategy. Consolidating these activities into a single office assists with the spread of knowledge and best practices within the enterprise.

Within large organizations, multiple IIoT business opportunities and ongoing projects may have to compete for resources such as developers and subject-matter experts. When implementing IIoT solutions, it is important to plan and track both the portfolio of opportunities and the underlying IoT services enabling them.

IT capabilities will also affect business model development. In enterprises whose strategy follows a resource-based view that leverages specific capabilities to develop new opportunities, the IT roadmap will affect the assessment and further evaluation of business models. Enterprises whose strategy follows a more market-based view will require development of new capabilities based on their targeted business models. In both cases, IT portfolio managers should be included in business model development to ensure alignment between the various IIoT solutions. This guarantees that all parties share a common understanding of the business value of each solution.

Techniques such as value-benefit analysis or the analytic hierarchy process can be applied in the business model evaluation phase. Both use weighted scores to evaluate how alternatives perform with regard to quantitative and qualitative goals. Evaluation criteria for IIoT applications include market potential, technological feasibility, and statutory regulations in different environments. For more detailed analysis of both value-benefit analysis and analytic hierarchy process, see Kim and Kim (2016) [SK1].

Portfolio management should span the entire lifecycle of IIoT solutions, with different management techniques required for each phase. While the techniques mentioned above are relevant for the business modeling phase, it is still important to track the performance of products and solutions once established. KPIs must be continuously tracked and adjustments made where necessary.

Figure 4-1 below summarizes the central process within enterprises of identifying, selecting, and prioritizing IIoT opportunities and developing a roadmap with an optimized portfolio. Reassessing existing opportunities and identifying new ones are important elements in the process of continuous innovation.



Figure 4-1: The identification, selection, and management process for IIoT opportunities (Source: Machina Research, 2016)

4.2.2 BUDGET TRACKING AND OVERALL ROADMAP

A closely related issue is the need for budgetary tracking and overall roadmap management for IIoT initiatives. IIoT projects can often encounter unexpected roadblocks or limitations as they evolve from idea to commercial reality. This is due to three main reasons:

- IIoT is new and few widely adopted standards exist,
- the need to work with partners and a wider ecosystem of providers in an more way and
- many IIoT applications represent radical shifts from generally accepted ways of doing business, and so in themselves might significantly influence end-market dynamics.

In many cases, there is a temptation for project teams to push for increased budgets, delayed timeframes or reduced functionality. Any current-day IT development project is subject to the same kinds of stresses, but, the risk and materiality of such effects is likely to be greater in an IIoT environment due to its relatively nascent stage of development.

For these reasons, it is particularly important to establish an effective budget tracking and overall roadmap function to ensure that IIoT projects deliver the returns that were envisaged at sign-off (unless these goals have subsequently changed). Such monitoring should extend through the project lifecycle and into the commercial deployment phase, so that the actual results achieved by IIoT initiatives can be tracked and demonstrated. Additionally, any 'lessons learned' can be factored into future planning cycles.

A corollary to this is that many companies may find it advantageous to 'start small,' to increase the overall level of knowledge within the organization, before tackling bigger, more complex, or more risky projects. This approach will effectively de-risk an overall IIoT strategy by increasing awareness of concepts such as the potential OT impacts of IIoT projects, data movement, storage and security, and the complex dynamics of collaborating to support IIoT solution deployment.

5 INDUSTRIAL IOT BUSINESS MODEL INNOVATION



Once an enterprise has established an IIoT strategy and corresponding goals, it should put robust systems in place to actively identify, assess and initiate IIoT opportunities.

The best approach to generating ideas and managing new opportunities includes optimization measures and business model innovation. We use here Alexander Osterwalder and Yves Pigneur's definition of a business model, in which "a business model defines the rationale of how an organization creates, delivers, and captures value." [AO1]

With increased digitization, we observe a shift from linear value chains to value creation within a network of stakeholders, both internal and external. As a result, multiple interested parties will need to streamline their efforts to maximize value for the target customer and end user. It is therefore crucial to think in terms of 'value networks' when defining business models. The following diagram illustrates the specific nature of an IIoT business model:



Figure 5-1: The specific nature of IIoT business models (Source: Bosch Software Innovations, 2016)

Because of the prominent role of IT in the IIoT, it will be even more important to close any gaps or adjust any misalignments that exist between business and IT groups within an organization. In the following sections, we will present a number of common methodologies and techniques that will help enterprises to align these domains.

One approach that enterprises may find helpful when pursuing ideas and designing business models is the IoT Business Model Builder developed by the University of St. Gallen and Bosch Software Innovations [BSI1]. Although this procedure model relates to the wider IoT in general,

rather than the IIoT specifically, it is relevant to both types of project. The model covers the entire process from the initial idea through to business model evaluation, and provides a number of useful tools.



Figure 5-2: IoT Business Model Builder (adapted from [BSI1])

This network-centric approach is based on the premise that each stakeholder contributing to the IoT solution has a specific business model and business case for its own organization. Any joint business model encompassing multiple stakeholders must unite all relevant aspects in a joint business case that captures the costs of each partner. The IoT Business Model Builder provides a list of helpful techniques for designing business models within partner networks.

5.1 IDEATION



Enterprises will typically identify IIoT application opportunities through an iterative process that starts and ends with the generation and refinement of ideas. Two drivers motivate this process: the first involves exploiting IIoT technologies to optimize production; the second involves the creation of solutions based on innovative business models. We examine each of these elements in more detail.

IIoT applications can unlock a wide variety of benefits, including (but not limited to) the following:

- cost and revenue optimization,
- operational efficiency,

- real-time business insight (decision-making),
- new market and customer experience improvement,
- new services and
- societal improvements.

When initiating the IIoT opportunity discovery process, there are two fundamentally different objectives to consider:

- leveraging IIoT technology for production optimization and
- investigating new IIoT business model opportunities.

Compared to product optimization, new IIoT business model opportunities are generally at an earlier stage and have the potential to be more disruptive to current business practices. The specific objectives of the enterprise in question will formulate techniques used to identify IIoT opportunities, as described below.

Like all projects, IIoT projects must start with an idea. The difficulty is that the potential of the IIoT is vast and as not yet fully understood, meaning almost all IIoT projects are ground-breaking to some extent. Clear development paths to follow are not yet commonly available, and ideas can emerge from any part of the organization. Enterprises seeking to engage in the IIoT should therefore draw on as wide a pool of talent and knowledge as possible when identifying potential projects. For instance, analogies drawn from IIC use cases, best-practice implementations, and lessons learned from IIC testbeds or other enterprises might serve as good starting points. Benchmarks with competitors or other industries may also offer inspiration in this early phase of innovation. An outward view should be taken, by conducting interviews with, for example, industry experts, clients and suppliers.

The overall objectives underpinning any specific IIoT initiative (whether the aim is to optimize production or to explore new business models) will determine which analysis techniques to apply.

5.1.1 **PRODUCTION OPTIMIZATION**

Where the objective is optimization, the most effective technique for idea generation is to follow a structured approach deriving ideas from a specific context. Examples include analyzing the enterprise's overall value chain, value streams on the shop floor, processes and value drivers for important performance indicators (KPIs). Classic Business Process Management (BPM) applies techniques to assess the optimization potential of each idea and the process should start by focusing on the current portfolio of products and services provided to existing customers.

5.1.2 New IIOT BUSINESS MODEL IDEATION TOOLS

In the context of new IIoT business models, an open process for generating innovative ideas for IIoT solutions should draw on the potential of employees, customers and developers.

Tools that support the idea generation process include traditional creativity methods such as random input (confronting the idea with random items), brainstorming (formulating ideas for

specific questions), brainwriting (also known as 6-3-5 method, where ideas are generated filling out a sheet by 6 persons, changing the sheet 3 times limiting the working time to 5 minutes). More IIoT-specific exercises, like confronting the idea with business model patterns involving "sensors as a service" or "digitally charged products" are also worth considering as part of the process of identifying new opportunities [EF1].

The five IIoT Layers (physical thing, sensor/actuator, connectivity, analytics and, digital service) help determine on which specific value-creation layer the opportunity should focus. It illustrates the range from product focus up to digital services [EF1].

After formulating an initial idea, a pre-evaluation step should be carried out. Capturing the essence of potential ideas in a structured manner¹ allows enterprises to compare and pre-evaluate the various ideas generated.

At this early stage, promising IIoT ideas are usually selected by means of a vote or other informal method that captures the consensus among the innovation teams. At a later stage, after developing the candidate ideas in more detail, more formalized evaluation methods can be used (decision support tools such as scorecards based on internal enterprise standards).

5.2 PREPARATION



Selected ideas should then be analyzed and documented in detail to sharpen focus, derive underlying assumptions (market attractiveness, value proposition, or technical implications, etc.), and assign actions to various team members to validate these assumptions.

After describing the IIoT solution, mapping techniques should be applied to help to break down the value proposition into features that correspond to stakeholder's perceived benefits. This is a highly iterative process, as the early-stage nature of IIoT dictates that some ideas will turn out to be less promising than expected, while other new, more innovative ideas may emerge along the way. Again, validating assumptions, for example by collecting early user feedback helps to prioritize value drivers. The targeted solution should then be described in a holistic way: Sketching the solution from the user's perspective by describing the customer's journey with all relevant touch points and activities delivers insights about the required capabilities (in terms of technology, know-how and resources). The capability assessment helps to differentiate which parts of value creation the focal company can perform and which parts performed by partners.

With a number of different parties contributing to any IIoT solution (including sensor providers, production plants, telecommunications providers, etc.), it is crucial to involve each of these parties in the refinement stage of the planning cycle. These players will need to coordinate their efforts to create maximum value for the target group(s).

¹ One possibility is to use the 'IoT Shamrock'; see the IoT Business Model Builder [BSI1].

At this point in the process, value propositions should be devised for all relevant stakeholders in the value creation network. When designing a network-centric joint business model, a good starting point can be to document value streams and analyze potential stakeholder roles. Figure 5-3 below illustrates a value-creation network centered on a product manufacturer.



Figure 5-3: Value-creation network for an IIoT solution

As the business model matures, the business roles adopted by each stakeholder become more apparent. In the example above, the product manufacturer acts as the business owner (the party coordinating the business model). Partners such as the telco operator are participants in the value-network and are exposed to a higher degree of risk than suppliers who deliver products or services under contractually predefined conditions.

Depending on the value proposition devised for each stakeholder, different levels of engagement can be identified. This determines how active each stakeholder should be in the business modeling phase (for example, partners should be involved at an early stage, suppliers later). Each stakeholder has their own business model in mind and must be aware that relevant aspects need to be brought together with inputs from different stakeholders for the joint business model and business case. Data access and the potential for different network partners to share customer, usage and other information within the network is a key consideration.

Coordinating such value networks comes with high transaction costs and requires a cultural shift within organizations toward increased openness and collaboration. Nevertheless, business models with a well-balanced network of partners are likely to prove more robust in the long term. In the future, as cross-domain IIoT solutions emerge, partnering capabilities will play an even greater role in achieving business success.

5.3 EVALUATION



The range of opportunities associated with IIoT is so vast that one of the most important tasks facing enterprises is to assess and prioritize the potential opportunities in an effective way.

This section examines three methods to narrow the list of candidates: business case calculation, business case challenges and impact and risk assessment

5.3.1 BUSINESS CASE CALCULATION

After calculating the total cost of ownership of the solution for all parties in the network, allocate the expected returns among the various stakeholders appropriately. This may require an extreme degree of openness and cost transparency between the parties, which underlines the importance of trust and strategic partnerships within the ecosystem.

Historically, most IT business cases were analyzed on a standalone basis, not in the context of an overall enterprise strategy. For an IIoT business case, an enterprise must consider how its business might perform should it decide not to adopt IIoT concepts. It must also 'share' the costs of developing generic IIoT capabilities among current and future IIoT projects. Often, the business cases that underpin IIoT projects are more analyses of existential questions than simple analyses of costs and revenues.

One consequence of this is that business cases for IIoT initiatives should account for two elements: first, the 'local' ROI based on direct costs and revenues (including the impact of selling into new markets, an enhanced customer experience and new services); second, the wider business impact in terms of overall business continuity and operations, market reach, and competitiveness (see Figure 5-4 below). In many cases, it will be necessary to adopt IIoT initiatives to maintain competitive positioning, rather than to generate significant new returns.



Figure 5-4: Business case context (Source: Enterprise-IoT.org)

Use a range of real options for both 'local' and 'overall' business cases to assess the benefits of a candidate concept in the context of various specific market development scenarios. Then assign probability values to them to gain insight into expected benefits and potential downside risks.

Assess the potential for 'local' business models enabling subsequent ones. Reusing assets such as infrastructure and data is common in the IIoT world. For example, combining data generated

by connected devices to create new value-adding information can lead to the creation of new services. Any investment decision must consider this potential.

5.3.2 BUSINESS CASE CHALLENGES

Organizations developing an IIoT business case are likely to encounter several challenges that may not be obvious at first glance.

Firstly, enterprises should not underestimate the fixed costs for hardware development. Many assume that recent advances in low-budget hardware such as Arduino and Raspberry Pi have changed the laws and economics of hardware development, but the costs of creating reliable hardware for deployment are still high. They include the initial design, prototyping, testing, and certification phases, as well as integrating IoT capabilities into existing hardware. Many IIoT business cases require significant initial investment before any revenue generation, and business models often rely on economies of scale to achieve acceptable unit costs. This is risky.

Secondly, IIoT-enabled connected products require a backend infrastructure that has ongoing operating costs. One option for covering them is to introduce pay-per-use or subscription-based models, but these models usually encounter severe customer acceptance challenges, especially when hardware is involved. A more attractive option is to build the operating costs into the sales price and implement a variety of risk insurance tactics, such as planned obsolescence.¹

These are just two examples of the complexity of IIoT business cases, yet they illustrate the effectiveness of a structured process for business case development, and clarify why these business cases take time to reach a certain level of maturity.

5.3.3 IMPACT & RISK ASSESSMENT

Business cases are a good starting point for sensitivity analyses, which generally involve the systematic modification of important quantitative assumptions to assess their effect on the outcome [BD1]. Since future value streams are subject to uncertainty, the assumptions underpinning the business case should be documented clearly and linked to the business case calculation. This allows the impact of any changes to the parameters to be reflected in the ROI.

IIoT business cases typically follow the same procedure as traditional business cases for sensitivity analysis. Assumptions that have a high impact on business success can include technology risks like device errors, risk that partners will change their minds, that may not be in the business case calculation. As such, enterprises should invest significant time in identifying and profiling a more extensive list of risks. This should include operational, technology, execution, implementation and security risks and identify any pitfalls or lessons learned from previous projects, potential suppliers and ecosystem partners. There is a wide range of recognized risk management frameworks available to support this kind of analysis.

¹ For further information and specific examples, please refer to Felix Wortmann on Enterprise-IoT.org [FW1].

As the overall project progresses, those involved will gain a deeper understanding of the initial idea, which will necessarily undergo a process of refinement. The objective of this refinement phase may be to hit specific budget targets in light of clearer operational constraints, ensure compliance with statutory regulations or accommodate partners' technical limitations.

The key to impact analysis is to discern the degree of elasticity in a technical specification, and the extent of compromise needed to meet budgetary constraints, particularly in the face of change. For instance, it may transpire that data sovereignty regulations limit the scope of potential solutions in ways that were not envisaged when the initial business case was developed, or that certain planned Quality of Service (QoS) levels may not be achievable (due to limited connectivity, for example). It's difficult to conceive of all the potential problems that can crop up and blow an IIoT project off its budgetary course—and that's precisely the point: IIoT business cases need to be structured in a way that allows analyses of the best way to achieve compromise between technical constraints and available budgets. Business planners need sufficient detail within the overall context. This allows them to discuss descoping possibilities with downstream project managers.

A related issue is security: the level of security deployed as part of an IIoT solution should be subjected to a specific risk- and scenario-based analysis. The transformation of business systems that will take place under a new IIoT regime will bring new types of risk that have not been previously considered in the context of more traditional IT projects.

Lastly, there is significant potential for new or different business models to materialize once a foundational IIoT infrastructure has been put in place. For instance, a manufacturing company that has set up a fully connected, automated production line might consider a new business model that brings the customer into the production process as a decision-maker, with the ability to adjust their preferences at the time of production. These post-investment opportunities for business models should be analyzed using standard evaluation tools, for instance by extending net present value calculation to include real-option approaches. Scenario planning can elaborate on future possibilities and develop a business model roadmap.

Scenario planning can also serve as a helpful tool for reducing risk. Based on the assumptions underlying the business model (such as the target group, timeframe), determine various future scenarios and the most effective business model response. It is particularly important to explore those elements of the business model that have impact and value, both in the context of a specific scenario and the overall strategy. Engaging in this level of rigorous strategy planning and scenario analysis enables enterprises to develop a future-proof business model.

5.4 INITIATION



IIoT opportunity initiation involves restructuring the enterprise's internal execution capabilities in a way that enables deployment of IIoT hardware and software specialists as effectively as possible.

The cultural challenges associated with multidisciplinary project teams are an important facet of this process, as discussed below.

5.4.1 INTERNAL ORGANIZATIONAL SETUP

The ideal organizational setup and execution strategy for any given IIoT project (or wider IIoT strategy) must be considered in parallel with development of the business plan.

While time-to-market factors are important here, it is also necessary to look critically at internal execution capabilities. Given the trend of software companies migrating into hardware, and hardware companies migrating into software, most organizations are unlikely to already have sufficient hardware *and* software specialists available in house to provide adequate support for their IIoT project portfolio. In addition, there may be a negotiated cultural shift, whereby software companies implementing IIoT projects are faced with longer project implementation times than normally experienced. The reverse also applies to hardware companies. Furthermore, constraints specific to standard hardware and software projects still apply.

Typical deployment options include setting up an internal project, acquiring an external company, or establishing a spin-off company. It is also common to see a mixture of these models, whereby the enterprise sets up an entity comprising people with roots in the wider organization (ideally from both IT and OT) and those that have come in through acquisitions. Recently, the term 'acqui-hiring' has become popular to describe a strategy of acquiring companies for their team and talent, rather than their products and customer base.

Organizational setup is an area that requires careful attention, especially for IIoT opportunities that developed from existing internal organizational capabilities. In particular, it is essential to maintain the interfaces and relationships between the solution team and members of the existing asset organization, which may be a potential source of friction.

A number of enterprises in similar situations are experimenting with 'podular' organizational structures that allow for ongoing engagement in a project concept as it progresses from 'idea' to commercial reality and gains traction across the organization.

5.4.2 INORGANIC TECHNIQUES

Where there is a need to compensate for shortfalls in organizational capability, enterprises can take tactical approaches such as 'acqui-hiring' or the more 'standard' acquisition process.¹

¹ We do not discuss acquisition approaches further here, since these have been comprehensively documented elsewhere in a wide range of business texts.

Another approach that has come to characterize the IIoT space is 'partnership.' It is generally recognized that the opportunities associated with IIoT are so vast and diverse that few enterprises today have the breadth and depth of expertise required to exploit the opportunities available fully. Realizing the IIoT opportunity depends on effective use of internal assets, and integration with external assets controlled by third parties. The partnership approach allows enterprises to share capabilities in a relatively flexible way, yet with a level of commitment that falls short of full acquisition.

Third-party companies may enter into partnering arrangements for a variety of reasons:

- enterprises that are already working in close cooperation may perceive they have no choice other than to become IIoT partners, as there is too much to lose in not doing so.
- enterprises may align with each other on the strategic basis of a shared vision,
- enterprises may engage in partnerships simply to capitalize on a standalone opportunity that neither can readily execute without the other,
- partnering arrangements may de-risk a deployment, leading to better alignment of risks and rewards,
- capability shortfalls; these are particularly common as hardware companies increasingly seek to develop software, and vice-versa,
- a partnership arrangement may be necessary to compensate for a resource shortfall in capability or volume
- the improved information flows inherent in a partnership arrangement may afford opportunities for increased efficiency, flexibility and responsiveness and
- improved information flows between partners lead to increased transparency between enterprises, potentially allowing for the development of better products and services in the medium term.

As is evident from the list above, 'IIoT partnering' where companies execute and go to market together is significantly different from the more traditional vendor-supplier partnership model.

Notwithstanding these motivations, partnership arrangements can also be more effectively realized in the form of mergers or acquisitions, albeit at significantly higher levels of risk (for one of the partners, at least).

6 INDUSTRIAL IOT FOUNDATIONAL CAPABILITIES



The process of business model innovation relies on investing in capabilities across multiple initiatives with synergy effects.

The two foundational blocks are an IIoT Center of Excellence (CoE) and an IIoT platform.

6.1 INDUSTRIAL IOT CENTER OF EXCELLENCE

While not strictly required to launch IIoT projects on an *individual* scale, many enterprises will find it beneficial to develop an IIoT Center of Excellence (CoE). The goal is to create and govern a unified IIoT strategy within the organization and to ensure that knowledge of best practices can be effectively shared and leveraged across the entire organization. The scope of this CoE can encompass a wide range of activities, including:

- identifying and applying IIoT best practices,
- enabling change management,
- re-thinking business models,
- managing human resources,
- IIoT maturity assessment and
- IIoT governance.

6.1.1 IDENTIFYING AND APPLYING HOT BEST PRACTICES

Given that IIoT concepts are sufficiently new and different from 'business as usual,' enterprises may find it beneficial to implement or expand initiatives to track IIoT best practices. This should be configured as an internal CoE staffed with experts who 'live and breathe' IIoT concepts and are capable of guiding their peers in the wider enterprise. Typical functions could include:

Support: A CoE should support business lines in realizing opportunities through the provision of IIoT-specific consulting services. These services may include business case creation, project setup and IIoT project execution coaching.

Guidance: An CoE should help define the range of standards, methodologies, tools, and knowledge repositories required to support an enterprise's overall corporate strategy. A number of these elements will be highly vertical-specific; some of the more horizontal aspects could be standardized.

Shared learning: Training, certifications, skill assessments, team building and the formalization of roles are all established methods that can be applied to the development of IoT capabilities.

Measurements: An CoE should create IIoT-specific metrics and maturity models that help make the progress of the enterprise's transformation more transparent.

Governance: The CoE should coordinate across projects and perform detailed governance tasks. In the connected IIoT world, there is always a high degree of cross-dependency between projects that should be managed carefully.

Clearly, establishing and maintaining a dedicated IIoT CoE will involve a significant investment, and several enterprises have reported mixed results from CoE initiatives. It is important to ensure that project teams view the CoE as a means of adding value, and not as a disturbance. There are usually two options for setting up an internal CoE: either appoint a team of dedicated CoE resources, or opt for a 'virtual' CoE with members embedded in operational teams, spending a certain percentage of their time supporting the CoE's activities (or some hybrid blend of these two approaches). The advantage of the latter option is that the CoE members are experts from a hands-on project background with a great deal of relevant experience. A potential drawback is that these highly respected experts could treat project work as a priority, which may compromise their ability to meet their part-time CoE obligations.

6.1.2 ENABLING CHANGE MANAGEMENT

IIoT has the potential to bring transformational change to a significant portion of the business model, including decision-making, business processes, employee roles, staffing, operations, strategy, customer value, customer experience and even the overall enterprise architecture.

Many of these changes will be disruptive to traditional business execution, but all have the potential to exert a positive impact on the business. Understanding the changes, thinking about each one in both traditional and new ways, and finding ways to adapt and capitalize on them is essential to an enterprise's ongoing business operations, competitiveness, and longevity.

6.1.3 RE-THINKING BUSINESS MODELS

IIoT requires enterprises to rethink their current business models. This is necessary regardless of whether they actually adopt IIoT solutions internally: industry is moving toward IIoT adoption, and enterprises that keep pace with this trend will undoubtedly have a strong competitive advantage.

In operational terms, connection and integration of factory-floor elements yields production efficiencies. Timely, enhanced decision-making at all levels of production lays the foundation for improvements in the broader production process. In the longer term, IIoT opens the door to greater integration between organizational, system, process and data elements. This will have an impact across the entire enterprise, from the factory floor to the overall IT infrastructure. Business models must consider this end-to-end impact.

Industries with a more service-based approach, such as healthcare, education and retail, will benefit from the integration of data from a wide range of devices, both internal and external. Enterprises will need to adjust their business models to expand their focus from operations to offering new services or improving current ones. While operational factors will continue to inform a significant part of the business model, it is beneficial to add a strategic 'what is possible' view.
For example, a business model for a retail company could be adjusted to reflect current and potential data sources, new technologies such as location services and radio-frequency identification (RFID), integration with customer devices such as cellular phones, movement of customers within stores, and the role of social media. By exploiting IIoT to create new services and experiences, the retail store of the future will become a place to add value.

This new business model could result in improved day-to-day operations, improvements in customer service, a reshaped store experience, a more expedient checkout process, or the possibility of targeting customers with customized product offers and marketing in real time, both within the physical store and at home.

In strategic terms, while traditional business model considerations will still be pertinent as IIoT takes hold, enterprises must also think of new ways to add value as part of their business development strategy. No longer constrained by what *is* possible, they must now embrace transformational change and consider a business model that includes what *might be* possible. Connected and intelligent devices allow just about anything to be connected, offering both a potential source of business insight and a chance to develop new products and services that can lead to improved opportunities for the enterprise within the relevant market segment.

IIoT is set to affect all business segments in similar ways.

6.1.4 MANAGING HUMAN RESOURCES

IIoT creates a need for both deeper and entirely new skill sets in technology and services. Enterprises can obtain these skill sets by providing professional development and retraining opportunities for current staff, or by hiring externally. Enterprises that are not large enough to have dedicated development staff, or that want this expertise outside of the organization, can engage the services of outsourcing companies specializing in IIoT development or implementation. Hybrid situations are also possible, providing some elements in-house with others supplied externally.

If enterprises require new technology and service expertise within their organization, they will also need to consider modifying existing employee roles or adding new ones. Enterprises that wish to have internal resources in place for IIoT development and implementation will need to attach greater importance to aspects such as specific technology considerations (networking and security, for instance), project skills, software development, analytics, and business modeling when training and hiring personnel. There is a need for employee retraining as initiatives develop within an organization, particularly at the operational level (such as the factory floor), once systems, devices, and machines can make real-time decisions.

At a societal level, IIoT and consumer IoT creates a need for more advanced technical education to support these roles.

6.1.5 IIOT MATURITY ASSESSMENT

An IIoT maturity assessment is a valuable tool with a variety of uses. It comprises a framework for rigorous and comprehensive determination of the overall level of adoption. It may include a

parallel analysis to identify best practices for the deployment of IIoT concepts among competitors and the wider industry as a whole.

Ideally, the scope of an IIoT maturity assessment should not be restricted to the industry in which the enterprise operates. It should include within its remit the identification of best practices from other industries, in particular adjacent and broadly comparable industries.

A context in which an IIoT maturity assessment is particularly useful is the CoE. It provides input for several different areas within the organization, including:

- strategy planning,
- IIoT project portfolio planning and ideation,
- business case and scenario planning,
- achieving internal stakeholder and third-party buy-in,
- internal change management and
- a range of specific overall corporate development and project-based issues.

The CoE is best positioned to develop and 'own' the maturity assessment tool. Internal consultants in particular, and other CoE staff in general, are ideally placed to analyze the overall level of IIoT development prevailing within their industry, and the degree to which it might apply to their own organization.

In particular, members of the IIoT consulting group should devote part of their time to analyzing the wider industry in which their enterprise operates. They should seek to identify best practices and assess the overall maturity of IIoT concepts within the industry, with a view to outlining a long-term IIoT scenario for their industry.

6.1.6 IIOT GOVERNANCE

To embrace the shift toward IIoT, enterprises must harness the combined value of IT and OT. Necessary considerations include appropriate governance and common methodologies.

In practice, enterprises may well continue to plan for IT and OT separately to account for the specific day-to-day objectives of each domain. Governance structures should optimize using elements in both. These elements include:

- operational objectives and data,
- overall business strategy and market objectives and data,
- more specific objectives for lines of businesses (LOBs) within the company,
- existing and developing standards for OT, IT and IIoT within the company,
- IIoT strategy and objectives and
- any internal program development.

This approach is particularly relevant and necessary for data that might flow to and from both IT and OT domains, and may provide a unified view of all data across the organization.

The governance structures put in place within an enterprise should include both IT and OT representatives within the IIoT solution team. Input from the various lines of business (LoBs)

within the enterprise is also important to direct the specific requirements and applications of IIoT solutions, and ensure that all parts of the overall organization work together to define how this should benefit all elements of the business. This collaboration also provides for proper budgeting of resources and development and ensures an equitable and effective use of resources.

This governance approach ensures representation of all elements of the business and that all elements are working together within the enterprise toward a unified view of IIoT introduction and implementation. It also ensures data and insight are used to benefit the entire business end-to-end.

6.2 INDUSTRIAL IOT PLATFORM

The second foundational block underpinning the IIoT implementation framework is the IIoT industrial platform. In this section, we address three IIoT platform implementation issues.

- What is an IIoT platform?
- IIoT platform selection parameters
- Standards in the IIoT

6.2.1 WHAT IS AN IIOT PLATFORM?

From a functional perspective, an IIoT platform is a technical system that provides a range of enabling services to support the delivery of IIoT applications.

In the context of the IIC's testbed initiative, individual (vertical) applications such as asset efficiency management, micro-grid controllers, and factory operations rely on IIoT platform services to deliver robust, scalable, and secure applications to end users.

Figure 6-1 below illustrates the platform support requirements of an IIoT solution in relation to four applications, Apps #1 to #4. Each IIoT application communicates with its respective devices and sensors, via an enabling IIoT platform. Thus, App #1 communicates with Device A and Device B.

Many IIoT systems operate on common infrastructure in the form of wide-area communications networks and cloud-computing platforms. However, while App #1 and App #2 share common infrastructure and services on Platform A, they do not interoperate. The term 'silo solution' is a common characterization of the combination of elements that constitute such an IIoT application stack.



(Source: Adapted from IIC Open Horizontal testbed program [IIC2])

Each IIoT application depends on a platform foundation and a set of platform services.

The *platform foundation* provides the basic processor, network and system software needed to host the IIoT platform services. From an application perspective, the platform may involve an Infrastructure-as-a-Service solution (IaaS) or a hosted solution (public/private cloud, self-managed/third-party-managed, on-site/remote cloud, etc.).

IIoT platform services comprise two service groups.

Connectivity-management services include the functions needed to connect a device or sensor to a network and then manage its communications behavior once in operation. Device lifecycle management is an important support function and includes pre-provisioning (for device testing), service provisioning, activation, ongoing device management, in-operation status monitoring and decommissioning activities. User tools, such as management dashboards, visualization aids and services for remote troubleshooting are another important aspect of connectivity-management services.

Application-enablement services provide an environment for developers and users to develop, deploy, and manage IIoT applications. Developer environments provide services for managing data feeds and performing quality-control checks. Application-enablement services help users implement the application logic and business rules that enable a connected device to fulfill control-action and alarm-notification objectives.

Together, these two categories of platform service offer a wide range of capabilities comprising the items in Figure 6-2:



Figure 6-2: Inventory of IIoT platform service functions

These IIoT platform services are common to many IIoT applications. There are standardization advantages to reusing these services to support multiple applications. Furthermore, their inclusion in a horizontal platform architecture helps to break down silo boundaries and enables interoperability¹ across applications.,

Consider a scenario where different platforms support multiple applications. Clearly, there are economic benefits from sharing common infrastructure. More importantly, shared services allow applications to share data as well as security and identity management credentials.

In practical terms, this would enable the owner of App #1 in Figure 6-1 above to deliver a better application by incorporating data from one of the devices associated with App #4, for example. Similarly, an application provider on Platform A could create a completely new application by combining sensors and other data sources from Apps 1#, #2 and #3. The presence of common service functions in a horizontal IIoT platform architecture makes this possible. These examples illustrate the case where a horizontal platform supports multiple interoperable vertical applications. In a market where several vertical and horizontal platforms exist, horizontal platforms also enable cross-platform interoperability.

Interoperability is particularly relevant in industrial environments. Construction sites, farms, manufacturing plants and transport hubs all offer significant opportunities for sharing sensors, data and computing resources.

¹ For the purposes of this discussion, we do not distinguish between interoperability and interworking.

Interoperability is also a driver for the development of new and innovative applications across clusters of stand-alone silo applications.

6.2.2 IIOT PLATFORM SELECTION PARAMETERS

When designing IIoT applications, the IIC's IIRA [IIC1] recommends that industrial users should consider business, usage, functional and implementation perspectives.

In the case of IIoT platforms, each of these perspectives has a tactical and strategic component. An operational solution intended for a rapid market launch might require a customized IIoT platform (e.g. for a one-off, capital-intensive machine in a factory environment). Over the medium to long term, this approach is not ideal if the platform requires customization to support new IIoT applications, such as interoperating with other machines or an entire assembly cell in the same factory environment. The table below highlights the main tactical and strategic platform selection considerations from each of the IIRA's main viewpoints.

| Platform supports immediate IIoT application requirements Platform demonstrates implementation track record Adequacy of duty-cycle loading Dynamic response capabilities (i.e. from non-time-critical responses to real-time | Platform offers resource re-use capabilities Visibility in terms of platform roadmap (new capabilities, protocols, and support for interoperability) Extensibility to support use-case evolution (IT/OT integration) as the boundaries of an |
|---|---|
| Dynamic response capabilities (i.e. from | |
| responses) Support for highly automated (rules engines, protective overrides) and human-operated (visualization, intervention controls) usage environments | IIoT application expand Support for new business models (from B2B to B2B2C, for example) |
| Functional alignment between platform feature set and usage priorities | Roadmap for next-generation features and composable value-added services (analytics, data monetization, etc.) Scope for interoperability across different layers of the IIoT value stack |
| Infrastructure choices (on-premise, hosted, virtual environment, etc.) Solution choices (in-house, managed service, etc.) Solution provider expertise and viability | IIoT application expansion requirements for hybrid platforms (multi-provider cloud computing, geographic diversity, etc.) Solution multi-sourcing to increase bargaining leverage |
| | Support for highly automated (rules engines, protective overrides) and human-operated (visualization, intervention controls) usage environments Functional alignment between platform feature set and usage priorities Infrastructure choices (on-premise, hosted, virtual environment, etc.) Solution choices (in-house, managed service, etc.) |

Organizations will base their platform investment decisions on their specific requirements. Some enterprises may want to invest in a platform to explore the various opportunities presented by IIoT; others may have a well-defined, long-term roadmap in place. In both cases, enterprises must be clear on how best to internalize the experience they have gained and simplify its dissemination

Enterprises will often collaborate with specialist service providers in designing and launching their IIoT applications. It is therefore important to balance business and technology

to other business units.

considerations, on issues such as adherence to standards-based technologies and membership of industry ecosystems, when selecting IIoT platforms and service providers.

6.2.3 STANDARDS IN THE INDUSTRIAL IOT

The internet and mobile industries have demonstrated the importance of widely adopted open standards. They both benefit from a competitive supplier base that encourages innovation and economies of scale. As a result, business and consumer users have enjoyed affordable prices for communications products and services that have led to near-universal adoption. Standardization will play an equally important role in securing the long-term success of IIoT.

The number of standards that claim to support IoT runs to many dozens if not hundreds. Often they apply to specific industries or relate to different layers of the IIoT stack. OPC-UA, for example, is a specific communications protocol for process control applications, whereas CoAP (IETF and OASIS) and DDS (OMG) are general-purpose standards for communications and data management. Both CoAP and DDS were produced by recognized standards development organizations (SDOs).

Enterprise and industry alliances represent a less formal approach to standardization, achieving this through *de facto* solutions or individual certifications. In the smart home domain, examples include Google's Thread solution and the approach proposed by the Open Connectivity Foundation (OCF).¹ In the healthcare sector, the Continua Alliance² has published an open implementation framework for interoperability between personalized, connected healthcare devices and solutions. This framework draws explicitly on communications and healthcare standards produced by SDOs. The Continua Alliance enforces this framework through a certification process.

CoAP, DDS, Google Thread and OCF are examples of standardization that build up from the networking protocol layer. To ensure end-to-end service quality, IIoT platforms must be able to operate across multiple devices and sensors using different networking protocols and application technologies.

The SDO community has begun to address this integration challenge through new IoT architecture and horizontal platform initiatives. The first step in this standardization process is usually a review of the market and existing standards. The following timeline maps the activities of several SDOs in terms of the three main milestones associated with initiating a new standard— opportunity discovery, IoT program launch, and release of a first deliverable.

¹ Merger of AllSeen Alliance (Qualcomm) and OIC (Intel, Samsung) initiatives targeting the home and small-office segments.

² The Continua Alliance recently merged with the mHealth Summit and HIMSS to form the Personal Connected Health Alliance (PCHA), which operates as a membership association.



Business Strategy and Innovation Framework

Figure 6-3: Timeline of standardization efforts by IoT service enablers [SDO1]¹, Source: more-with-mobile.com (2016)

oneM2M[™], one of a number of bodies focused specifically on common platform services, launched a market review in 2012 and issued its oneM2M[™] cross-industry standard in early 2015. Other initiatives have delivered formal standards focusing on IoT communications (IETF/CoAP) and data exchange (OMG/DDS) capabilities.

When enterprises decide to work to a standard, they are making a technical and strategic commitment. The technical dimension comes from determining whether a given standard is appropriate for the enterprise's IIoT application requirements. The strategic element relates to the credibility of the relevant SDO and its ability to manage, maintain and deliver regular enhancements to the core standard over time. Without this, the promised economies of scale and long-term, features roadmap will not materialize.

Over time, many of the standardization initiatives in the market will converge or find common ground for collaboration. By way of example, the *de facto* standards initiatives launched by the AllSeen Alliance and the Open Interconnect Consortium (OIC) recently agreed to come together under the Open Connectivity Foundation (OCF). Since then, Google Thread has joined the OCF to form an IoT alliance to advance the adoption of connected home products and make their respective technologies fully compatible.

Mirroring the industry alliance sector, collaboration also occurs between SDO bodies. In the internet domain, for example, the W3C developed the specifications for HTML and other application-level technologies. It has also worked closely with the IETF on interface issues as W3C standards (such as HTML for web page formatting) run directly on IETF protocols (such as HTTP,

¹ Refer to the appendix for descriptions of various SDOs. The graphic encompasses internationally recognised standardisation bodies that have launched IoT-related initiatives.

which carries web page information between client and server). Thus, while the W3C and IETF work closely together, each SDO specifies its own standards.

This collaborative model is likely to prevail for IIoT through a standard for a family of horizontal, service enablers. These will integrate lower level, communications protocols and standards to create a clean interface that IIoT application developers and systems integrators can use.

Over time, standardization will move up the layers of the application stack in areas related to analytics and semantics, for example, as businesses place more value in application interoperability. Individual organizations should factor this evolution into their IIoT platform strategies.

Annex A REVISION HISTORY

| Revision | Date | Editor | Changes Made |
|----------|------------|--------|--|
| V0.1 | 2016-03-16 | | Released for comment |
| V0.2 | 2016-09-07 | | First full draft, released for comment |
| V0.3 | 2016-10-07 | | Revised full draft, released for comment |

Annex B ACRONYMS

Industrial Internet of Things (IIoT) Application

describes an instance of an IIoT system deployed for a specific identified purpose

Annex C GLOSSARY

Industrial Internet Consortium (IIC)

an open membership, international not-for-profit consortium that is setting the architectural framework and direction for the Industrial Internet. Founded by AT&T, Cisco, GE, IBM and Intel in March 2014, the consortium's mission is to coordinate vast ecosystem initiatives to connect and integrate objects with people, processes and data using common architectures, interoperability and open standards.

Industrial Internet of Things (IIoT)

describes systems that connect and integrate industrial control systems with enterprise systems, business processes and analytics. Note 1: Industrial control systems contain sensors and actuators.

Note 2: Typically, these are large and complicated systems.

Industrial Internet of Things (IIoT) Application

describes an instance of an IIoT system deployed for a specific identified purpose

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