# A Digital Transformation Lab for Developing Countries and Small to Medium Enterprises

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***Abstract* - Digital transformation of small towns (population less than 100,000), small enterprises (employees less than 100) and small countries (population less than 10 million) especially in the developing nations is a challenging task. Besides financial and skillset shortages, a wide range of digital solutions are needed that are location and topic specific and must comply with regional government policies and industry guidelines. In addition, these solutions need to be produced quickly and at large scales to satisfy the needs of more than half of the world population. The needed solutions cannot be handcrafted individually and manully for such diverse populations. Based on the work with more thab 40 United Nations projects, a factory model has been developed that generates highly customized portals rapidly to meet the local requirements. Besides supporting UN Projects, this eFactory is being used to support graduate education in the Information Systems Engineering and Management Program at Harrisburg University. This paper explains how this eFactory can fuel a Digital Transformation Lab to support numerous humanitarian initiatives that may include some Metaverse experiments.**

***Keywords - SPACE Factory, Smart Cities and Communities, Strategic Planning, Enterprise Architectures, Metaverse***

## I. Introduction

Digital transformation, initially known as the eBusiness/eCommerce Revolution, has been around since the 1990s with major success stories such as GE, Amazon, Walmart and others [1]. But now it has become an essential part of the corporate toolkit for success in the post Covid era. However, digital transformation of small towns, small enterprises and small countries especially in the developing nations is a challenging task with reported failure rates in the 70% range [2] - [4]. The failure rates are mainly due to unclear goals and skillset shortages. But, production of needed solutions that address location and topic specific challenges and also comply with different government policies and industry guidelines is a non-trivial task. These solutions also need to be produced quickly and at large scales for more than half of the world population. The needed solutions cannot be handcrafted individually and manually due to these requirements. A factory model appears to be appropriate for this situation

Previous research on this topic by this author has produced a toolset that behaves as a factory to quickly generate location and topic specific digital solutions for developing countries [5]. Such factories have produced very large number of highly customized automobiles and other artifacts with integrated technologies and policies to satisfy needed regulations. This toolset, called *SPACE* (Strategic Planning, Architecture, Controls and Education), is being proposed as the key player of a Digital Transformation Lab for the developing countries and small to medium enterprises in this paper [6].

SPACE has evolved into a powerful computer aided planning, engineering and management platform due to a partnership with the United Nations initiative on Small Islands and Developing States. Specifically, a UN Partnership is utilizing the latest developments in digital technologies to accelerate the UN *Sustainable Development Goals* (SDGs) in more than 100 countries [7], [8]. These SDGs focus on humanitarian needs such as food, education, health, public safety and public welfare. SPACE has been architected as a 'factory' to address this challenge – it now quickly produces diverse smart hubs for different populations. SPACE is also being used to support graduate courses in Information Systems Engineering and Management [9] and has been extended to support Covid operational tasks [5]. SPACE and the Digital Transformation Lab will be explicated in Section II.

The proposed Digital Transformation Lab must address the following practical challenges to meet the needs of smart cities, communities and enterprises in developing countries:

- C1: Needed solutions (artifacts) must be generated quickly due to the aforementioned reasons
- C2: Artifacts must be customized and comply with topic and geographic considerations and guidelines
- C3: Collaborations between services for greater regional growth and creation of composites must be supported
- C4: SPACE Factory itself plus the generated solutions must be smart to detect, adjust and learn automatically
- C5: Lab must support research and education
- C6: Digital transformations must be supported by this Lab

Section II and III explain the research methodology that is being used to address these challenges and Section IV highlights the key results and outlines future research agenda of this long range partnership between UN, HU and a startup.

## II. RESEARCH METHODOLOGY - THE BIG PICTURE

Fig. 1 displays the vision of the Digital Transformation Lab and how it will address the stated research challenges by using the Design Science Research Methodology [10], [11]. The Lab capabilities are viewed in terms of the following layers:

- **SPACE Factory**, the top layer, provides an extensive array of capabilities for digital transformations. These include a patterns repository, planning tools and specialized gamifications and advisors to invoke different business scenarios. For details about SPACE, please see [12].
- **Agile Methodology** layer in the middle supports the preprocessing, production, post-processing and customer support activities of a typical factory [13]. As displayed in Fig.1, these phases invoke different capabilities of SPACE as needed (e.g., the Digital Transformation Advisor is invoked in Phase1 to initiate planning tasks).
- **Smart Collaborating Hubs** are the main products produced by the SPACE Factory. *A Hub is a center of activity that is supported by user specific smart artifacts such as a Citizen App, an Administrative Portal, Training Materials and location/topic specific Policies*. These hubs have pre-fabricated capabilities for collaboration with each other and can be combined into complex *"bundles"* that can represent smart enterprises or organizational units of different sizes in different sectors.
- **A Smart Global Village** is the final output of this Lab that is populated with several hubs and bundles being produced by the SPACE Factory. This Village at present is a large Sandbox with over 1100 hubs from more than 140 countries and represents more than 12 major sectors.

The Design Science Research Methodology is being used rigorously through iterative design and refinement of the Lab artifacts by using real life use cases based on UN and other small to medium business projects globally:

- The SPACE Toolset was initially designed to support the UN SDGs when they were announced in 2015 [12]. Specifically, the Patterns Repository was populated to support 10 SDGs that focused on health, education, public safety, public welfare and other vital sectors (support for the remaining 7 SDGs was added later).
- A Business Strategy Advisor was developed in 2018 to support ecommerce for small businesses globally.
- Smart cities, Blue economies, Covid, Manufacturing4.0 and Industry4.0 are currently being supported due to extensive and repeated upgrades of SPACE toolset and the methodology.
- The SPACE factory has also been used to populate a large sandbox, called the *Smart Global Village*, that houses more than 1100 'smart hubs' for more than 130 countries. This sandbox spans 12 sectors that include health, education, disaster management and others [14].
- The SPACE Factory and the resulting Smart Global Village have been used heavily since 2015 to support graduate education at Harrisburg University [9] and corporate training in the US, Africa and Asia.

In each iteration over the years, different users were involved and appropriate research tasks were initiated before implementation. So far, the three layers of the Lab have attempted to address challenges C1-C5 [15] - [17]. These layers are now being further extended to better support Digital Transformations (challenge C6) as explicated in the next Section. Details about the current results and future research agenda is presented in Section IV.

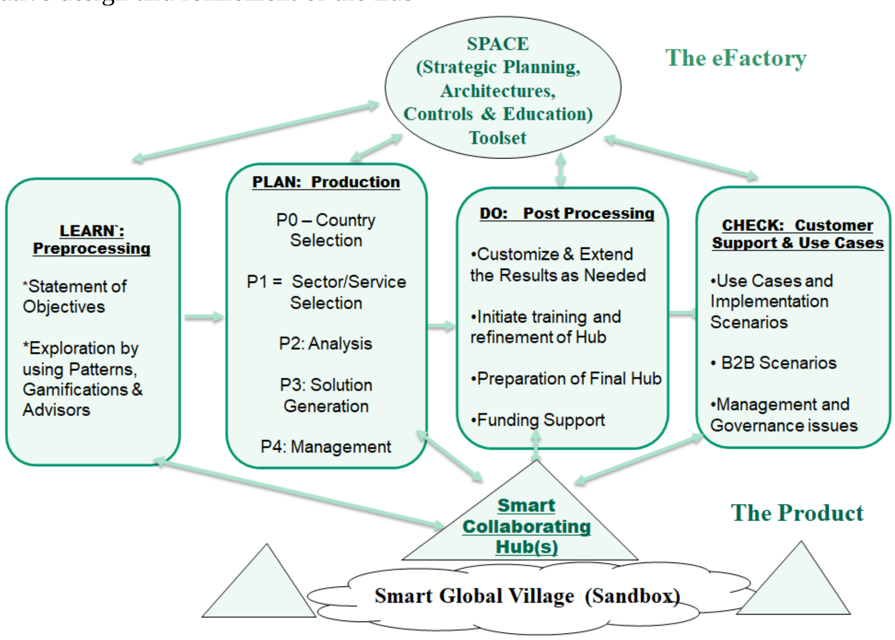


Fig. 1. Vision of the Digital Transformation Lab (The SPACE Toolset, the Learn-Plan-Do-Check Methodology and the Product).

## III. Details of The Digital Transformation Services

The SPACE factory has been extended to support digital transformations. In particular, a Digital Transformation Advisor (DTA) has been added to help formulation of a transformation strategy and a Planner has been extended to quickly implement this strategy and to show the detailed implications of launching this strategy. These two tools specifically address challenge C6 and are discussed below.

**The Digital Technologies Advisor** casts the evolution of digital technologies into approximate stages based on the following two dimensional model displayed in Fig. 2:

- X axis represents the use of Digital Technologies for Business Operations (eBusiness 0.0 to eBusiness 4.0)
- Y axis represents the use of Digital Technologies for Industry Operations (from Industry 0.0 to Industry 4.0)

Thus, different organizations can be represented in this diagram as different points in a scatter chart in terms of their use of digital technologies in their business and industry specific operations (e.g., manufacturing). Based on this, Stages 0 to 4 are introduced in this model to *roughly* represent an organization in any part of the world as it evolves. Thus Fig. 2 provides us with a simple framework to evaluate the progress of industrialization in different parts of the world, i.e., if most businesses in a country are in Stage 0 or 1, then it is lagging behind. Let us briefly describe these Stages:

- Stage 0: Brick and Mortar Enterprises. Organizations in this stage practically use no digital technologies. Many organizations in the rural areas of developing countries fall into this category.
- Stage 1: Simple Web sites for Advertising. The objective is to use the Web technologies to advertise and promote company products & services. For example, a restaurant can just display its menu on a website for advertisement.
- Stage 2: eCommerce sites. In this stage, the enterprises use digital technologies for online purchasing and other business operations such as supply chains/warehousing.
- Stage 3: Virtual Enterprises. In this stage, the enterprises use digital technologies heavily for most business operations and perform B2B operations over the Web as virtual enterprises. Digital technologies play a key role in integrating services across almost all organizational units in this stage.
- Stage 4: Next Generation Enterprises (NGEs). This stage fully exploits the latest digital technologies to quickly detect, adjust and learn in a highly competitive marketplace. The digital infrastructure *drives* all the company business and manufacturing operations in this model. NGEs are the ultimate in digital transformation and they push the limits of digital technologies in their sectors. The Smart Digital Enterprises and Manufacturing 4.0 easily fall into this category. In addition, *the very popular Metaverse Model could be viewed as an NGE because Metaverse pushes the limits of several technologies such as AI, Blockchains, Web and AR/VR [28].* More elaboration of this point later.

*The stage model is very useful in general classification but it does not explicitly include any digital technologies.* For that purpose, eight basic dimensions of digital technologies are proposed to represent a multidimensional space shown in Fig. 3. This model identifies eight specific digital technologies that help the enterprises to progress through the Stage Model. For each dimension, a set of values, {Low, Medium, High}, based on an informal estimation, indicate the adoption. In this model, enterprises conduct business by exploiting the following major digital technologies displayed in Fig. 3 (starting from Web and going clockwise):

- Web (W) dimension that indicates the use of Web technologies at three levels: Low (Basic Web usage for advertising), Medium (eCommerce), and High (Semantic Web, Internet of Things and Web3.0).
- Analytics (A) dimension represents the use of analytical techniques at three levels: Low (Descriptive Analytics for visualization), Medium (Predictive Analytics for forecasting), and High (Prescriptive Analytics for optimal investments and decision support).
- Smartness (S) dimension represents the use of AI techniques at three levels: Low (quickly detect events and trends), Medium (agility to respond to significant business events), and High (learn from the past experiences to improve the future operations by using Machine Learning and Deep Learning).
- Globalization (G) dimension deals with widely dispersed sites that are interconnected through the broadband global digital networks. Use of digital networks could be at three levels: Low for local businesses and small shops, Medium for regional businesses, and High for large

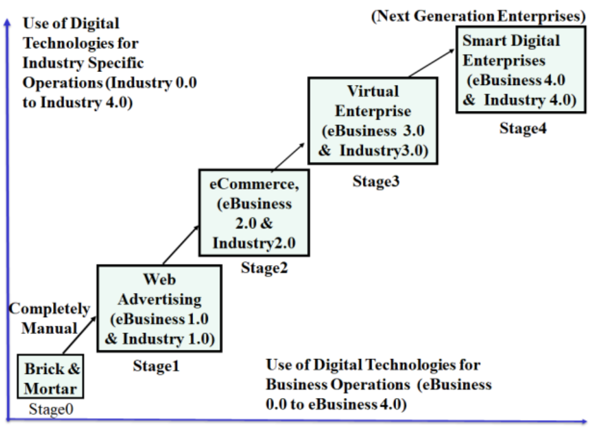


Fig. 2. Stage Model for Digital Transformations

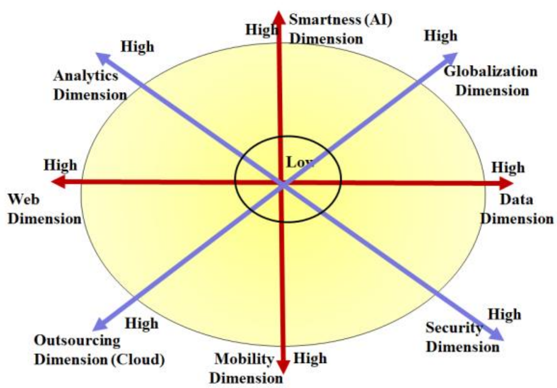


Fig. 3. Dimensional View of Digital Technologies.

global enterprises. Global businesses deal with many regulatory issues that arise due to international trade.

- Data (D) dimension represents the use of data technologies at three levels for improvement of business decisions: Low (Excel spreadsheets), Medium (Database Management Systems) and Large (Big Data Warehouses for business intelligence & decision support).
- Security (S) dimension, that also includes blockchains, represents the use of security technologies at three levels: Low (Basic Security with ID-PW), Medium (Enterprise Security packages from Microsoft, Norton and others), and High (Security Solutions with extremely high levels of security and accountability measures) -- blockchains could be very valuable in such organizations.
- Mobility (M) dimension represents the use of mobile devices and apps at three levels: Low (2G supported networks and mobile apps), Medium (3G supported networks and mobile apps that include short range wireless sensor networks and IoT (Internet of Thing) devices), and High (5G supported mobile apps that include augmented and virtual reality (AR/VR)).
- Outsourcing (O) dimension represents the use of cloud services for outsourcing at three levels: Low (only a few business operations are outsourced to the cloud), Medium (cloud providers are used extensively for outsourcing many business assets) and High (all business assets are outsourced and are in the cloud).

These eight technologies faithfully capture a very large number of digital enterprise models including smart cities and Industry4.0 initiatives that rely heavily on AI, security (with blockchains), analytics and outsourcing. The outermost circle of Fig. 3 also captures the spirit of NGEs and Metaverse. While more dimensions can be added, these 8 dimensions are good enough for representing the essence of most digital enterprises in a simple yet elegant manner [15].

The Stage and Dimensional Models are not perfect but have been used, with minor adjustments, very heavily by this author in a very large number of consulting/advisory assignments globally, academic and corporate training endeavors, and decision support tools since the early 2000s. These models were initially developed to categorize the ecommerce and ebusiness organizations in the Greater New York area around 2003 but now have evolved to capture the essence of Industry4.0 and even possibly the Metaverse model. These two models are also at the core of this Digital Transformation Advisor (DTA) that allows users to describe and analyze their digital transformation strategies completely. See [18] for a working version of this advisor.

**The Implementation Planner (PISA – Planning, Integration, Security & Administration):** Fig. 4 shows the IS planning model that is at the foundation of PISA and is used to *implement* the strategies recommended by DTA. PISA guides the users through major planning stages: enterprise modeling that captures the business processes and the organizational units where these processes are performed, application planning to automate the business processes, platform planning to determine the platforms to run the applications, network planning to interconnect these

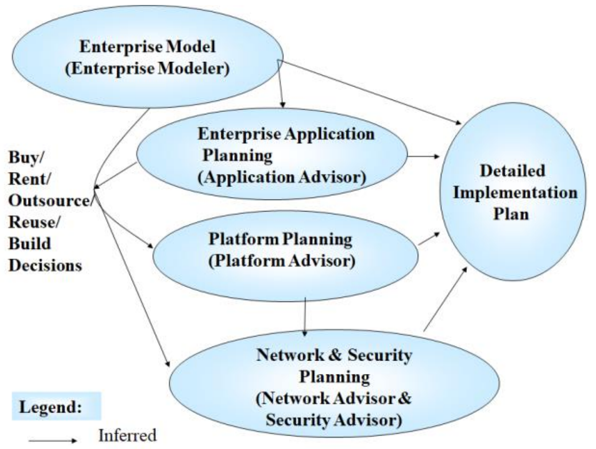

Fig. 4. PISA Planner Conceptual View

platforms with the end-user communities, and security planning to secure all of the above. The model presented in Fig. 4 serves as a foundation for PISA because it shows how the various advisors collaborate and infer from each other to quickly build solutions.

- Enterprise Modeler (EM): This Advisor captures the main attributes of an enterprise (i.e., the company type and size, company sites and type of business activities performed at those sites). This Advisor produces an enterprise map that shows what business processes are performed where to help in the workflow analysis.

- Application Advisor develops an application plan based on enterprise map produced by the Enterprise Modeler. This advisor allows a company to develop its automation strategy by determining what will be automated how (e.g., the buy, rent, outsource, develop and/or extend).

- The Platform Advisor suggests a computing platform plan that could "host" the applications selected by the Application Advisor. It recommends appropriate computing platforms based on the type of activities performed at a site and the needed applications.

- Network and Security Advisor first develops a network plan that interconnects the recommended computing platforms by using wireless and/or wired networks. This network information can be used in network planning and management initiatives. The Security Advisor then recommends security measures based on the network and other advisor outputs. This advisor uses attack trees and other risk analysis techniques.

Extensive information about PISA can be found at [19].

## IV. Key Results, Discussion and a Research Agenda

A large number of projects have populated our Digital Transformation Lab that houses more than 1100 *Smart Collaborating Hubs.* These smart hubs, generated by the users of the SPACE Factory mostly since 2018, offer location and industry topic specific services. They are being interconnected through a smart collaboration network with smart B2B Directory capabilities [20]. This Lab is growing rapidly at the time of this writing. Table suggests a quick walkthrough of this Lab through short videoclips and links to key resources for hands-on experiments. A sample use case is presented to highlight the practical use of this Lab, followed by an assessment of its current & future capabilities.

TABLE I. A QUICK WALKTHROUGH OF THE LAB

| *Short Videoclips (2 to 3 Minutes)* | *Websites - For experiments, please login as a guest* |
|---|---|
| • Digital Transformation Advisor, Video Clip [21]<br>• SPACE Factory: Video Clip [22]<br>• Smart Collaborating Hub: 3 Minute Video Clip [23]<br>• UN ICT4SIDS Partnership site video tour [24] | • The SPACE Website [6]<br>• United Nations ICT4SIDS Partnership Website [8]<br>• Smart Global Village Sandbox [14]<br>• Digital Transformation Advisor & Planner [18]<br>• Digital Transformation & Smart Cities Lab [26] |

**A Sample Use Case:** Fig. 5 displays how the Digital Transformation Lab can be, and is being, used in real life situations. It shows several highly specialized smart hubs in rural and urban locations in different parts of the world. Please note that these hubs are in different stages of digital transformation (Stage1 to Stage4), locations (Africa, Asia, USA) and provide services in different topics (education, health, smart towns, and disaster resilience & management - DRM). A Global Center supports and monitors the collaborations of this Village. The Digital Transformation Lab and the Smart Global Village are currently operating as part of our UN ICT4SIDS Partnership. The following discussion provides additional examples and insights:

- This Lab is supporting the Smart Solomons Education Project, a 3D Printing team in Nigeria for young entrepreneurs, a Blue Economy Center in Maldives, and an Agricultural Farm in Ghana that is interested in growing food and supplying leather to shoe manufacturers. Collaboration of such diverse groups is very interesting and an eye opening experience. All "hub masters" are automatically connected to the Smart Global Network and the Global Center.
- Stage0 and Stage1 hubs are mostly manual sites that are connected through 2G networks and exist in rural areas in least Developed Countries (LDCs). They are in the innermost circle of the eight dimensional technology model shown in Fig. 3.
- Stage2 and Stage3 hubs may exist in capital cities of LDCs or the rural areas in developing countries.
- Stage4 hubs fully exploit the eight dimensional technology model and are typically located in fully developed countries (e.g. OECD countries). However, many Stage4 hubs can exist in large cities of developing countries and in capital cities of some LDCs and SIDS that have the needed IT infrastructure. For example, Nigeria and Pakistan can have Stage4 hubs in cities like Lagos and Lahore, respectively.
- Developed and rapidly developing countries may have Stages 1-4 but LDCs usually have stages 1-2 hubs. For example, India may have stage1 and 2 hubs in rural areas but also have Stage3 and 4 hubs in its large urban cities. The Global Center, located in the cloud, offers tools and expertise to guide the developing countries. This is an important element of this vision.
- We are currently exploring a Metaverse hub (Stage4+) for advanced experiments in immersive education, tourism and disaster resilience [27], [28].

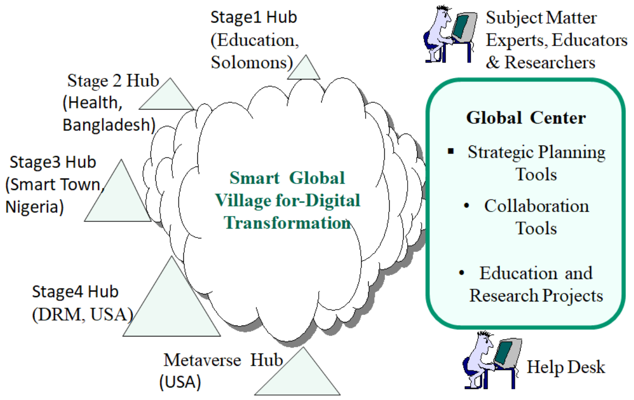


Fig. 5. A Use Case for the Digital Transformation Lab

**The Lab Assessment**: The Digital Transformation Lab is assessed in Table II. This assessment is based on the challenges posed in Section I, the progress made so far, and the possible areas of future research and development. The following notes attempt to provide additional insights:

- All SPACE advisors are striving to use the latest developments in machine learning to discover new business patterns [29] from UN and other data sources.
- The overall goal of the SPACE Factory is that the generated solutions *and* the factory itself must have smart capabilities based on the KDAL (Knowledge, Detections, Adjustment, and Learning) metric. At the time of this writing, most generated solutions are rich in knowledge but poor in DAL. However, SPACE tools are also rich in Knowledge. Machine and Deep Learning will be used extensively to improve DAL and move SPACE towards a highly Intelligent Factory.

TABLE II. DIGITAL TRANSFORMATION LAB ASSESSMENT

| **The Challenges** | **Current Progress** | **Future Research** |
|---|---|---|
| C1: Needed artifacts must be generated quickly (within one hour) | 95% (most artifacts are generated in 10-15 minutes but some processes are manual ) | Need to automate all processing activities (mostly pre and post processing) |
| C2: Artifacts must be customized for topic & geographic locations (local considerations and guidelines) | 90%: Almost all topics are covered in the Patterns Repository and all artifacts are customized for location specific data | Expand local data by using ML (Machine Learning) to use satellite images. Also expand the Patterns Repository by ML |
| C3: Collaborations between services for greater regional growth and creation of composites must be supported | 80%: B2B collaborations are supported fully between key players and large and complex solutions can be composed from SPACE generated smart hubs | Need to support trusted collaborations by using Blockchain. Larger solutions should carry more semantics and relationships |
| C4: SPACE Factory itself plus the Generated solutions must be smart | 50%: SPACE tools are rich in Knowledge. Most generated solutions are rich in knowledge but poor in intelligence . | Use Machine Learning extensively to improve intelligence and move towards an Intelligent Factory |
| C5: the Lab must support research & education | 80% SPACE Factory and the Lab has been used at HU since 2016 | Need to make these capabilities available to other institutions |
| C6: Digital transformations must be supported | 80% a Strategic Advisor and Planner to implement this strategy are available | The Advisor and the Planner need to be expanded to support Metaverse models |

- Process mining and blockchains are being explored to support trusted B2B collaborations and enforcement of policies through smart contracts [30].
- The Metaverse hub, displayed in Figure 5, provides an excellent foundation for exploring how a Metaverse model can be used to develop highly innovative solutions for Global issues. This is an important and active area of future research for us.

## V. CONCLUDING REMARKS AND LESSONS LEARNED

This paper has shown how design science research is being used to develop a Digital Transformation Lab. Developing this Lab iteratively while teaching, researching and also leading industry projects on this topic has been a highly enjoyable journey. Every iteration has been driven by few challenges displayd in Table II. The major outcome is a Smart Global Village that consists of large number of hubs that are distributed over 140 countries and represents over 12 major industry sectors that include agriculture, education, health, smart towns, disaster resilience and others. This Village is an excellent sandbox for a very large number of collaboration scenarios [14] and other innovative use cases that focus on small to medium enterprises at a global level. We will keep discovering more challenges and use cases in future iterations. The two main lessons learned are that well thought out partnerships are very valuable and flexible solutions that can be customized are much better than the rigid point solutions.

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