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e-Factory for Metaverse-based Smart Communities, Cities and Enterprises

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***Abstract*— Metaverse is the next advancement of the Internet that could usher in unprecedented opportunities for sustainability, resilience and growth in our society. However, it could also expose us to significant challenges in security, privacy, governance and ethical concerns. Additionally, the Metaverse is complex and transformations to it could be prone to failures. This is unfortunate because ICT and digital transformation projects have reached 70-90% failure rates. This paper proposes an innovative 'e-factory' model for planning, engineering and management of sustainable Metaverse solutions to address the huge challenges of security, governance, compliance and failure rates. A working prototype of such an e-factory is currently operational and is being used to support our work with the United Nations, as well as research and teaching assignments at academic institutions. Main results based on short case studies are shared and future research directions are discussed.**

Keywords—SDGs, AI, Blockchain, digital transformation, strategic planning, SPACE, enterprise architecture, enterprise integration, information systems, systems engineering, engineering management

I. INTRODUCTION

The Metaverse is an *integrated technology bundle* (ITB) that allows us to create a virtual world—it exists solely on the internet and is not limited by the physical world. Although each of the Metaverse technologies (AI, Blockchain, AR/VR/MR/XR, Web3.0) is a powerhouse in its own right, when integrated together, they support a virtual environment where avatars and digital twins provide services, purchase goods in virtual shopping malls, and make payments using digital currencies called NFTs (non-fungible tokens). Metaverse, introduced in the early 1990s, initially gained popularity with gamers and hobbyists around the globe. But large organizations paid more attention to it around 2018 when Facebook changed its name to Meta. Covid-19 slowed down the progress towards Metaverse and now AI is dominating the post-Covid limelight, but Metaverse could be the next megatrend that converges single strands such as AI, blockchains, AR-XR (*we will use this term as an abbreviation of AR/VR/MR/XR*) and others into an integrated technology bundle that could alter the way we think, behave, and work.

This paper concentrates on how Metaverse could be used to support Smart Communities, Cities, and Enterprises (SCEs) of the future [1, 2, 3, 5, 6]. Our goal is to minimize the possible negative impacts and failures of Metaverse transformations by using an e-factory model. This paper is a major synthesis and extension of the previous and current work by the same author [2, 3, 10, 11, 12]. The main research problem being addressed is: How can Metaverse technologies be used in the planning, engineering, and management processes of current and future SCEs of any type, anywhere in the world? Specifically, we are interested in exploring the use of meta technologies in the final SCEs (the product) as well as the process of developing this product. We will focus on answering the following sub-questions (we will use "Meta-SCEs" as an abbreviation to represent Metaverse-based SCEs):

- **RQ1**: How are the Meta-SCEs evolving? Section 2 presents a few artifacts that help us understand the interdependencies between meta-technologies and SCEs.
- **RQ2**: What are the potential promises and pitfalls of Meta-SCEs? Section 3 attempts to answer this question based on available literature. We have found that there are many benefits, but minimizing failures and security/privacy exposures needs serious attention.
- **RQ3**: What is the most appropriate Meta-SCE approach that maximizes the benefits and minimizes the risks? Given the complex trade-offs between the opportunities offered and challenges introduced by Meta-SCEs, it is virtually impossible to handcraft the needed integrated solutions for sustainable communities, cities, and enterprises. Section 4 describes an e-factory approach that is very appealing. A short case study, introduced in Exhibit 1, will guide the discussion.

It should be noted that our objective is to share our results so far and trigger innovative future research investigations that could be of high value to all of us.

Exhibit 1: A Simple Case Study to Illustrate Key Points

The government of a small fictitious country, Zeenan, wants to launch an Intelligent Metaverse initiative for economic development but aims to manage and minimize the risks of failure, security, and privacy. The main idea is to push the cutting-edge technology envelope, expedite the UN SDG (Sustainable Development Goals) agenda, and educate the staff for success. We will use this case study where needed and finalize it in Section IV.

II. Evolution of Metaverse-based Smart Communities, Cities and Enterprises (SCEs)

The evolution of technology-based smart and sustainable enterprises in the public and private sectors can be visualized by an approximate stage model displayed in Figure 1:

- The X-axis represents the use of digital technologies for core business operations such as marketing and customer support (from eBusiness 0.0 to eBusiness 4.0).
- The Y-axis represents the use of digital technologies for industry-specific operations (from Industry 0.0 onwards).

Special Case A represents a scenario where business operations use the latest digital technologies, but the factories (e.g., textile mills) rely on 18th-century steam engines. Case B represents an opposite scenario (e.g., the US Air Force using cutting-edge technologies in command-and-control systems but legacy systems in business operations). Management needs to balance the two. Case A and Case B may result in failures. Please note that these stages could also indicate Capability Maturity Model Integration (CMMI) levels [32].

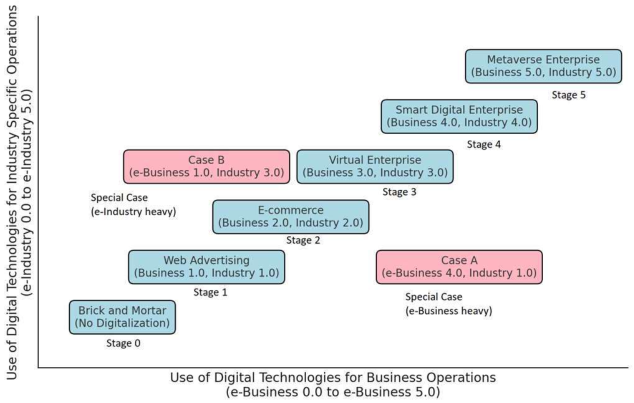

Fig. 1. Stage Model for Evolution (transformation) (Extension of Umar [11, 12]). Stage 5 is a Meta-SCE. Please note that Y-axis could represent City/Community specific processes

We suggest that Stage 5 represents Next Generation Enterprises (NGEs) that capture Metaverse-based business and industry-specific operations. Stages 0 to 5 in this model are introduced to broadly represent any organization, in any part of the world, as it evolves from Brick and Mortar to a Next Generation Enterprise. Essentially, NGEs exploit the latest bundle of highly interdependent technologies that support the virtual world of the Metaverse. Simply put, the Metaverse is a convergence of multiple "Meta Technologies" that collectively create a persistent virtual world -- not limited by the physical world. For example:

- Virtual realities (AR-XR) are integrations of real and virtual world artifacts that present 3D immersive simulations when viewed through specialized lenses.
- Blockchain: Basically, a digital ledger that is stored in such a manner that it cannot be tampered with. Unique digital identifiers, called Non-Fungible Tokens (NFTs), are stored on a blockchain. NFTs can be sold and traded and also enable cryptocurrencies. For example, you can buy and sell virtual property and goods such as paintings and music by using NFTs in Metaverse virtual markets.
- Web 3.0: This is the semantically rich web content that can be understood by other machines and stored on a blockchain. For example, any web page could be a block on the blockchain. This means that a web page could be owned, bought and sold in an NFT marketplace.
- Artificial Intelligence (AI): Machines exhibit intelligent human behavior. Mahine Learning (ML) and Generative AI add very interesting dimensions to the Metaverse where machines learn directly from available data and then generate innovative solutions for the Metaverse.

These technologies are at the core of the Metaverse and can be represented by a simple ten-dimensional model shown in Figure 2 that identifies specific digital technologies for enterprises to evolve through the Stage Model. A set of informal values {Low, Medium, High}, based on an approximate estimation, indicates the level of adoption for each dimension. Thus, the inner circle represents a Stage 1 organization, and the outermost circle depicts a Stage 5 (Metaverse) organization. As organizations progress from the inner circle to the Metaverse circle, they encounter new challenges and need new policies to address these challenges.

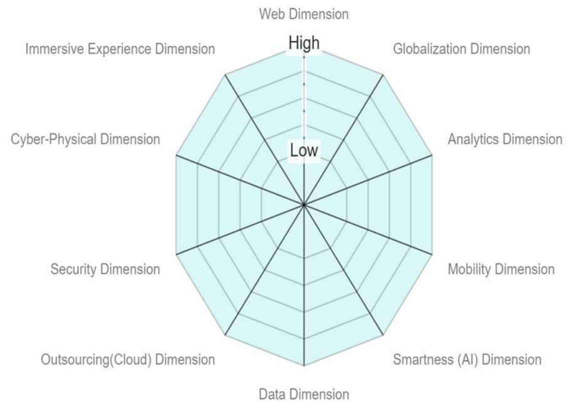

Fig. 2. Metaverse Technologies as a Multidimensional Model (Extension of Umar [11, 12]).

The main appeal of Metaverse is that it converges Meta Technologies to create highly immersive virtual worlds and enables highly creative business scenarios that cut across tourism, agriculture, healthcare and others [2, 3]. Smart cities, communities, and enterprises (SCEs), according to the NSF [13], are populations that live and work in different locations but are connected through intelligent technologies. Examples of SCEs include smart towns, small to medium businesses, public service centers, and community centers. Metaverse projects typically start with building the necessary digital twins, and then the information processing layer and the AR-XR user interfaces. Fortunately, the following three-layered model, displayed in Figure 3, captures the essence of many Metaverse initiatives:

- **Presentation Layer** with complex AR-XR capabilities that includes specialized lenses to interact with the digital twins, i.e., recognizing/responding to digital twin actions.

- **Processing (Digital Information) Layer** that will handle the operations of digital twins. These twins represent real-world objects such as furniture, cars, buildings, and roads. It is a mixture of AR-XR content in different formats and includes semantic web and blockchain artifacts.
- **Physical Layer** that may include actual physical objects such as people, animals, airplanes, bridges, trees, and mountains. This is the world that we perceive through our natural senses such as seeing, hearing and touching,

Our main interest is in sustainable (also known as resilient and smart) communities, cities, and enterprises that have the ability to absorb and recover from future shocks in economic, environmental, and social conditions. Planning, engineering, and management of such SCEs (sustainable communities, cities, and enterprises) are challenging tasks, especially in developing nations. Besides financial and skillset shortages in such situations, the solutions must be location- and topic-specific and must also comply with local policies and industry-specific guidelines. In addition, these solutions need to be produced rapidly and at massive scales to meet the needs of large populations around the globe. The needed solutions cannot be handcrafted individually for such diverse and widely dispersed populations.

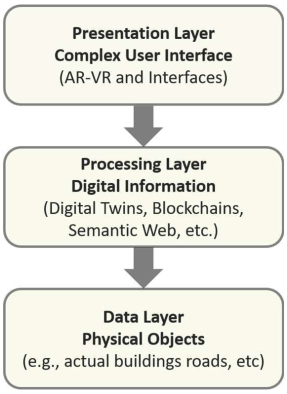

Fig. 3. Conceptual View of a Metaverse Solution (Extension of Umar [3]).

Exhibit 2: About the Zeenan Case Study

The artifacts shown in Figures 1, 2, and 3 could be used to represent different aspects of Zeenan. For example, the tourism department may be in Stage 5, while other departments may be in lower stages in Figure 1. The use of technologies in different departments could be captured by Figure 2, and different layers of Meta Tourism could be represented by Figure 3. For example, a Stage 1 organization that relies on a web browser and an Excel spreadsheet can be easily mapped to the three layers of Figure 3. Thus, these three artifacts can be used to represent the essence of any Meta SCE initiative anywhere in the world.

III. Metaverse-Based SCEs – Promises and Pitffals

Numerous studies published by the UN and academic/research institutions have shown that digital technologies can play a major role in making SCEs more sustainable by automating critical business processes [1, 2, 3]. Most sustainability initiatives align with the United Nations' Sustainable Development Goals (SDGs), which have been accepted as global goals to be achieved locally around the world. These 17 goals, adopted by all UN member states, focus on basic sustainability needs such as ending poverty, improving health and education, reducing inequality, spurring economic growth, and addressing climate change, among others [1, 2, 3].

Figure 4 displays a conceptual Business Pattern for SCEs—it shows the core business functionalities of a sample city (indicated by grey boxes) and the individual departments as yellow boxes (both core and optional). This pattern covers health, education, public safety, public welfare, and other vital services in the public and private sectors. Careful automation of such patterns, using the conceptual view of Metaverse solutions shown in Figure 3, can yield a large number of Meta-SCEs that support almost all 17 SDGs. The idea for this pattern is based on the work by Adams [28]. The SPACE e-factory, described later in Section IV, has a large repository of business patterns that represent almost 20 industry sectors. These patterns provide a very powerful tool for developing models for a wide range of SCEs. For example, we can develop models of small or large cities, create smart hubs, and build B2B exchanges using these patterns.

About Zeenan Case Study: The federal government of Zeenan could be represented by the business pattern shown in Fig. 4.

A. *Promises and Opportunities for Meta-SCEs*

As stated previously, Metaverse technologies (AI, Blockchain, AR-XR, IoTs, Web 3.0) are integrated to support a virtual environment where avatars and digital twins provide services, purchase goods in virtual shopping malls, and make payments using digital currencies such as NFTs. The Metaverse could be used to accelerate many UN SDGs, especially when these meta-technologies collaborate with each other to expedite the UN SDG agenda in areas like food and agriculture, healthcare, tourism, education, industrialization, and climate control. For example (see [1, 2, 3, 5, 6] for expanded discussions):

- **Goals 1 and 2 (End poverty and hunger)** could be impacted by increased cottage industries and potentially have a significant effect due to Meta-based indoor farming.
- **Goals 3-6 (Ensure healthy lives and education):** "MetaHealth", with the convergence of AI, AR-XR, Web3.0, IoTs and robotics, could revolutionize healthcare; immersive tutorials, gamifications, and simulations could transform education for diverse populations. We are especially interested in educational applications to reduce the failure rates of ICT projects.
- **Goal 7 (Ensure access to energy)**: Metaverse will likely consume more energy, but it could significantly reduce travel emissions as white-collar workers would not need to commute to work every day.
- **Goals 8, 9 and 10 (Economic growth, resilient infrastructure and sustainable smart cities)**: These goals will significantly benefit from the Metaverse.

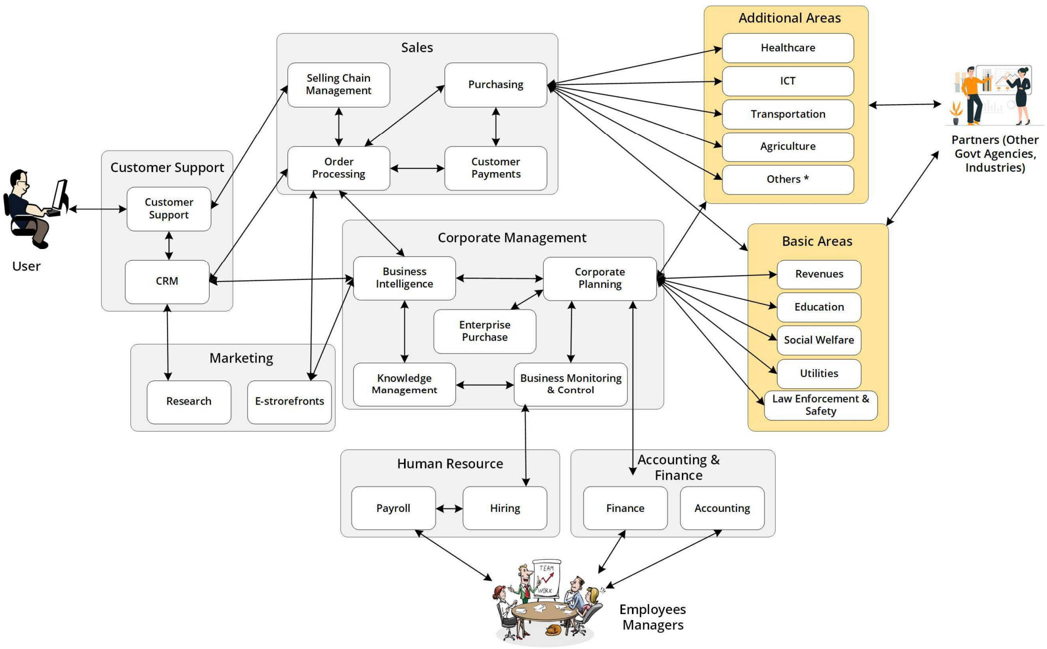

Fig. 4. Business Pattern

- **Goals 13 to 16** (combat climate change, terrestrial ecosystems, and vital institutions): These goals will be strengthened through peaceful use of AI and other meta-technologies such as AR-XR, IoTs, global-cloud-based systems and vector databases.

B. Challenges and Risks of Meta-SCEs

Meta SCEs are creating unprecedented opportunities for sustainability but are also introducing serious challenges in security, privacy, governance, and ethics. For example, AR-XR platforms are major energy consumers. On the other hand, Metaverse could reduce travel-related emissions due to an increase in remote work. Another concern is that the Metaverse requires expensive equipment such as lenses and very fast networked computing systems. This limits the potential users of the Metaverse to only affluent populations and countries. However, the Metaverse could be of high value to SIDS (Small Island Developing States) because it would integrate Blue Economies and Disaster Resilience capabilities with other solutions.

Well-known concerns exist regarding security complexities and data privacy in a digital society due to the increased sharing of sensitive and personal data. We are subject to continuous surveillance with numerous cameras, sensors, and other IoTs. This leads to well-known privacy violations, data misuse, and ethical concerns. For example, proposed Metaverse cities such as Seoul, use closed-circuit TV to monitor and record all movements of their citizens—a highly criticized decision [30]. Another concern is bad actors who may take advantage of the Metaverse's reality-altering capabilities to inject political or dangerous messages or trigger false alarms and disasters that appear very real. Finally, new laws will be needed to address new situations such as NFTs and ownership rights. Governance frameworks, such as the General Data Protection Regulation (GDPR) [31], may also be challenged by machine-generated content. In addition to Responsible AI, there will be a need for a 'Responsible Metaverse'—it seems.

Numerous legal and social issues are being raised by digital avatars that look and behave like us and are created based on the expert systems of the past. We may have to face a new wave of "Meta-Crime" that would require a new breed of lawyers with "Meta-Forensics" skills. These "Avatar Lawyers" could offer services such as company incorporation and arbitration regarding the use of digital land for unlawful activities. Policymakers will also need to update their skills, and popular frameworks like PESTLE (Political, Economic, Social, Technological, Legal, and Environmental) [7] may need a serious facelift for the digital society. For additional details, please see [3]. Additionally, the Metaverse is complex, and transformations to it could be prone to failure. This is unfortunate because digital transformation projects have reached 70-80% failure rates. In the next sections, we propose an approach to face these challenges.

C. Policy Issues and Risks of Failures at a Glance

As mentioned previously, Metaverse technologies raise several legal and policy issues, such as the following [1, 2, 3, 4, 5, 6, 11, 12]:

- Potential users of the Metaverse may be limited to only well-to-do populations and countries due to expensive equipment. In addition, major privacy concerns need to be addressed if all movements of citizens are watched. Data stewardship is also crucial because children growing up in an increased AR-XR world may not be able to distinguish real artifacts from virtual.

- Serious attention needs to be paid to the consequences of the Metaverse in the hands of bad actors. Digital avatars may be created that look like us but perform malicious and dangerous acts. These challenges could create demand for future lawyers who specialize in "Meta-Crime and Forensics." Innovative applications of blockchain are needed in this area of potential growth.

- Approaches such as Smart Metaverse hubs may be needed to address the aforementioned issues (see the discussion of Smart Global Village in Section IV). Policymakers need to make sure that the principles of public welfare, public safety, and inclusion drive the technology regulations so that no one is left behind.

In general, Meta-SCEs can offer many benefits and job opportunities, but it seems that 70-80% of smart city and digital transformation projects are failing [11, 20-26]. In fact, digital transformation projects have reached 90% failure rates [25, 26]. Metaverse is a complex and new set of technologies that could further exacerbate the situation. An innovative approach, proposed next, could address the challenges.

IV. An Innovative Approach To Address Failures in Smart Communities, Cities, and Enterprises (SCEs)

A. An e-Factory-based Approach -- Conceptual Overview

Given the opportunities offered and challenges introduced by Metaverse and other technologies, it is virtually impossible to handcraft the needed integrated solutions for sustainable SCEs. A factory model is needed to rapidly build highly customized solutions, much like auto factories that have built millions of highly customized cars with integrated multiple technologies to satisfy the mission, safety, and comfort needs of very diverse customer populations. Simply stated, a factory (in our case, an e-factory), assists in producing cyber-physical components (*the artifacts*) according to end-user requirements *through* an assembly process [8]. *Our objective is to minimize failures and also expedite the UN SDG agenda.* We are specifically proposing SPACE e-factory that, in our view, is an innovative approach to meet our objective.

The basic concepts of e-factories, initially known as software factories, have been around since the 1960s [9] and have evolved over the years from handwritten process diagrams to the more recent Google Repository that maintains *all* source codes from more than 30,000 software engineers at Google [9]. It should be noted that many "digital factories" are in fact old manufacturing factories that have been "face-lifted" as digital factories and are not relevant to SCEs [34, 35]. Most e-factories so far have been developed for specialized needs of large organizations such as NASA, the Air force, the IRS, Google, manufacturing shops, and others [9, 10, 34, 35].

Unfortunately, the concept of e-factory has not been fully explored for addressing many problems in SCEs such as high failure rates and SDGs. Our idea is to envision an e-factory for the very large number of small to medium businesses and towns around the globe that urgently need location and topic-specific solutions for economic development, pandemics, and other needs. These users do not have adequate financial and technological resources and need assistance throughout the plan-do-check cycle. Our UN Partnership (ICT4SIDS) developed the SPACE platform for planning, engineering and management of SCEs with focus on ICT for Small Island and Developing States (SIDS). SPACE has matured over the years to also support our teaching, research, and advising practices around the globe. Specifically, SPACE morphed into an e-factory during the COVID pandemic [11] and was then expanded to support additional capabilities needed by users.

Exhibit 3: Innovative Example of Using the SPACE e-Factory to Handle a "Metaverse Knowledge Storm"

An official in Zeenan could invoke the following Usage Scenarios displayed in Figure 5 (each scenario can trigger multiple tools):

- *Scenario 1*: How Meta will impact entrepreneurship and industry dynamics. Specifically, GEZA (Global Entrepreneurship Zone for All) and IAW (Industry Analysis Workbench) tools guide the users through multiple tasks to provide useful insights.
- *Scenario 2*: The DTA (Digital Transformation Advisor) and PISA (Planning, Integration & Security Advisor) tools guide the users through the transformation & implementation tasks respectively.
- *Scenario 3:* SPACE Extensive Planner, aka e-Planner, fully supports this scenario for various enterprise architecture and integration configurations. The focus is on enterprise-wide implications of Meta, such as introducing Metaverse-enabled CRM systems.
- *Scenario 4*: B2B impact of Meta (e.g., global supply chains, and Health and Human Services) networks that utilize the Metaverse. The SGV (Smart Global Village), displayed in Figure 6, captures the main idea of how a small Metaverse hub could collaborate with others around the globe. We are actively exploring a broad range of Metaverse-based global B2B scenarios.

Bottomline: *These scenarios are excellent foundation for education and are used in our CITO Programs [17].*

At the time of this writing, the SPACE e-factory supports the following Usage Scenarios illustrated in Exhibit 3: *Scenario 1* supports economic development through an Entrepreneurship Advisor and an Industry Analysis Workbench for strategic planning and competitive analysis of these opportunities; *Scenario 2* provides a Digital Transformation Advisor for detailed analysis of opportunities and implications for selected transformations, it then invokes an Implementation Planner that further informs the user on how to succeed; *Scenario 3* invokes an Extensive Architecture and Integration Planner that allows users to develop detailed enterprise-wide integration plans and then deploy them anywhere in the world as working portals; and *Scenario 4* manages the growth of the company through B2B partnerships and a Smart Global Village – a powerful sandbox, described in detail later. An SDG Advisor can be invoked from any of these scenarios to assure compliance with UN SDGs.

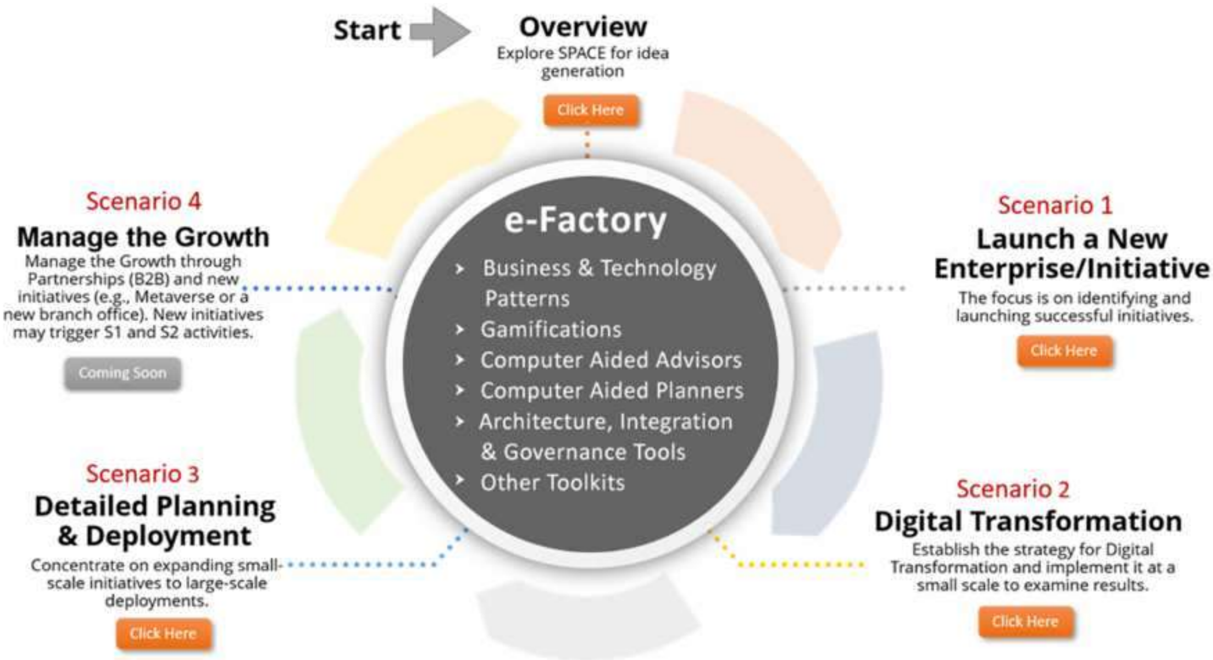

Fig. 5. Conceptual View of the SPACE Platform: An eFactory and Lab for Strategic Planning, Engineering, and Management of Sustainable Communities, Cities, and Enterprises. The inner circle, core of the e-Factory, displays the extensive array of tools that can be invoked individually. The Usage Scenarios Labs (Scenario1 to Scenario4) invoke the needed tools to support the Learn-Plan-Do-Check cycle. Please see a 2.5-minute video clip [33] and visit the SPACE website [14].

The SPACE e-factory systematically includes the artifacts introduced earlier, such as the Enterprise Evolution Model (Figure 1), the ten-dimensional technology model (Figure 2), an operational Metaverse system (Figure 3), and the business pattern (Figure 4)—these are the core components of the e-factory and also provide the key SPACE vocabulary. The e-factory recommends appropriate actions, including policies, for different locations and industry sectors. It is evolving into a powerful platform that supports our training, research, and consulting practice in using the cutting-edge technologies to help the underserved populations.

B. SPACE e-Factory – A Closer Look

The focus of SPACE (Strategic Planning, Architecture, Controls & Education), displayed in Figure 5, is on failure reduction throughout the Learn, Plan, Do, Check (LPDC) cycle of SCEs. As noted previously, 70-80% of SCE projects keep failing, and failures occur throughout the LPDC cycle [11, 20-26]. SPACE e-factory offers extensive tools, displayed in the core circle, to help SCEs succeed. These tools produce powerful reports and portals that support the SCEs. The Scenario-based Labs, introduced previously, also concentrate on success in each phase of the LPDC cycle by invoking appropriate patterns, gamifications, advisors, and planners. The artifacts generated are integrated into *smart collaborating hubs* that communicate with each other through an extensive sandbox, described later. As displayed in Figure 5, the users are engaged in entrepreneurship, competitive analysis, digital transformations, strategic planning, enterprise architectures & integrations, B2B trade, and security/governance experiments.

The Smart Collaborating Hubs, generated through different scenarios, populate a Smart Global Village—a sandbox that supports hands-on experiments and graduate education. These capabilities, further explained below, are based on published research, graduate teaching, and the lessons learned from actively working with more than 40 UN projects spanning almost 50 countries [14, 15]. In addition, graduate-level teaching and research based on SPACE Platform has led to CITO (Certificate for IT Officials) courses [17]. Exhibit 3 shows how SPACE could be used in an innovative Use Case of a "Metaverse Knowledge Storm" that could shake-up several regions in the world. For more examples, please see the next two sections. We are currently exploring how the *convergence* of several cutting-edge technologies could be used in further enriching the SPACE platform and its educational applications through our CITO courses.

C. Smart Global Village (SGV) Sandbox for Metaverse and Smart Collaborating Hubs

The SPACE Smart Global Village (SGV), displayed in Figure 6, currently accommodates a large number of smart hubs that collaborate with each other and represent most countries and the most important industry sectors. This Village, generated through hands-on experiments in the four Usage Scenario Labs, is an excellent sandbox for students, industry practitioners, and government officials for a wide range of creative investigations in economic development, strategic planning, enterprise integration, digital transformation, B2B exchanges, and the like. These Smart Collaborating Hubs have been generated due to our engagements with organizations around the globe and academic exercises. The hubs are categorized by approximate stages of enterprise evolution introduced in Figure 1: Stage 1 represents Brick and Mortar Enterprises, Stages 2 and 3 are in the initial and middle stages of automation, Stage 4 enterprises are using Industry 4.0, and Metaverse hubs are in Stage 5. The Lab tools systematically guide the SCEs to transition from lower stages to higher ones, thereby simulating highly inventive situations in global B2B trade. The following examples illustrate the key points.

D. Simple Illustrative Examples of Metaverse Use

Suppose the government of a small country wants to launch a Metaverse Initiative for economic development but wants to manage and minimize the risks of failures and other factors discussed above. Exhibit 3 displays how the SPACE capabilities could be used to plan, engineer, and manage such initiatives. Exhibit 3 also illustrates how our SGV could be used as an innovative *Metaverse Sandbox of high value to the developing as well as developed countries*. Please note that these hubs are in different stages of digital transformations, locations and provide services in different industry sectors. A Global Center monitors the activities of the hubs. We are currently preparing advanced experiments with the Metaverse hub (Stage 5) to better

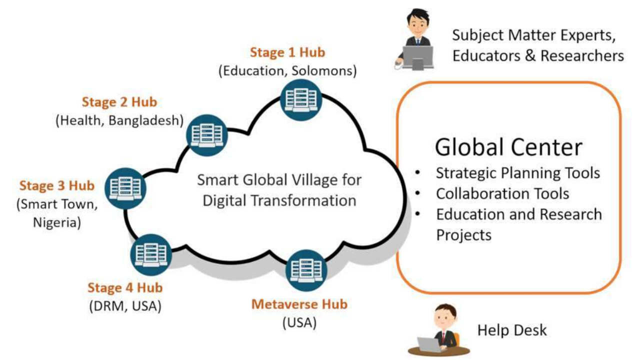

Fig. 6. Sample Use Case for the Smart Global Village (1200+ hubs, dispersed across 140+ Countries) [16]

understand immersive education, tourism, and disaster resilience. The interactions between Metaverse and lower-stage hubs in developing countries are of particular interest to us. We can simulate different SGV scenarios for the following use cases:

1. Information & Referral industries, such as United Way, offer help to underserved populations.
2. Health and Human Service industries that are responsible for transportation of medication, clothes, food, etc.
3. Manufacturing supply chains that could survive disruptions due to disasters such as COVID.
4. Computer aided consulting services for entrepreneurs, including CITO (Certificate for IT Officials).
5. Predictive and optimization models to capture delays due to one server serving multiple clients and optimal resource allocation demands.
6. Extensive use of Machine Learning and Generative AI to study how the SGV models can learn from available data to make effective decisions. The PESTLE model [7] can be entirely data-driven based on ML. For example, changes in political, economic, social, technological, legal, and environmental conditions of a country can drive entrepreneurship opportunities, market competition, urban planning, and supply chain decisions.

These and other experiments utilize different capabilities of the e-factory, as illustrated in Exhibit 3. For example, a user selects a country C (say, China) and an industry I (say, Retail) and then invokes SPACE Scenario 1, which utilizes PESTLE, GEZA, and other tools to get an idea of the situation. The user may then invoke Scenario 2 to utilize Digital Transformation Advisor and select a supply chain that needs to be "metaversed." Scenario 3 can invoke the SGV to create a supply chain for some locations (countries) where goods (say, shoes) are produced and then shipped to China. The cost of production and border issues can be included in the SGV. The possibilities for this sandbox are vast. Essentially, all the e-factory tools support these experiments, truly demonstrating the power of the SPACE platform.

V. Conclusions and Future Directions

To conclude, this paper has shown that the Metaverse offers many capabilities that could be of tremendous value to public welfare, as specified by the UN SDGs. However, several social and policy-level challenges must be addressed. To better understand the different aspects of the Metaverse, we have developed a systematic methodology based on a few artifacts shown in Figures 1 to 4, and an e-factory displayed in Figure 5, that uses these artifacts to produce smart collaborating hubs. These hubs populate a Smart Global Village, shown in Figure 6, that can be used to simulate a large number of highly useful situations in a global marketplace. We have created a lab for experiments and are currently using and significantly extending this e-factory and SGV.

The approach in this paper is based on extensive literature surveys. However, our main contribution is that we have gone beyond identifying gaps in literature -- we have *actually developed* an innovative approach to fill these major gaps. Our proposed e-factory is a starting point for future research efforts around the area of specialized e-factories. We are planning to launch initiatives such as meta4agriculture, meta4health, meta4manufacturing, meta4cities, etc. Our e-factory already has the core knowledge to support these and other such initiatives. We are specifically exploring new ITBs (Integrated Technology Bundles) that combine Explainable AI, Biotechnology and closed loop systems with humans as the key feature of our SPACE Labs [36, 37, 38]. We are particularly interested in innovative applications of SPACE e-factories and SGVs in Urban Planning and Building Information Models that could accelerate the sustainability of smart cities, communities, enterprises and UN SDGs. We are especially interested in dramatically decreasing failure rates by improving educational aspects of the SPACE Platform.

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