Training, Research, and Consulting for Successful Intelligent Metaverse Initiatives – An HMS Perspective

Amjad Umar[*#], Adnan Javed[*], Nauman Javed[*], Kamran Khalid[*]
* NGE Solutions, Inc., Elizabethtown, USA
# Harrisburg University of Science and Technology, Harrisburg, USA
Emails: Umar@amjadumar.com, Adnan@ngesolutions.com, Nauman@ngesolutions.com, Kamran@ngesolutions.com

***Abstract*—Intelligent Metaverse, dubbed "iMeta", is a convergence of Metaverse, Generative AI, Blockchains, Cloud Computing, IoTs and other cutting-edge technologies. iMeta goes beyond the Generative AI -- it blurs the distinction between real and virtual and thus has the potential to transform the way we will live and work in the future. However, it is quite complex with intricate interdependencies between multiple layers that raise many social, legal, ethical and governance issues which could further exasperate the already high failure rates of 70 to 90%. Our small team has developed an e-factory to address these challenges, and we have now embarked on an ambitious Training, Research and Consulting (TRAC) practice that has exposed us to very interesting Human-Machine-Systems (HMS) scenarios. Basically, we are discovering different types of HMS scenarios with LLMs and Augmented Collective Intelligence ("Superminds") as key players. This paper presents an overview of our results and lessons learned from this highly interesting journey with our students and colleagues at the United Nations.**

Keywords—Intelligent Metaverse, Augmented Collective Intelligence, Training Research and Consulting.

I. INTRODUCTION

Intelligent Metaverse (iMeta) integrates Generative AI and blockchain with Metaverse, and thus could create new markets and revolutionize the current industrial landscape [1]. However, it could also be a "knowledge storm" that disrupts industries and jobs but also creates new opportunities and initiatives. Unfortunately, many of the technology driven initiatives fail. For example, digital transformation (DX) initiatives have reached 70-90% failure rates [22]. This creates further economic challenges for already stressed communities. Surprisingly, not enough attention is being paid to failures of DXs. We are proposing an innovative platform that concentrates on successful iMeta initiatives by relying on a creative e-Factory and a highly flexible Training, Research and Consulting (TRAC) Practice. It is a very interesting playground for innovative HMS experiments and research.

We are focusing on pushing the envelope of innovative applications of iMeta while systematically reducing the failure rates of technology-driven initiatives that have been in the 65-80% range since the first Standish Report in 1995 [18]. Despite several developments in Critical Success Factors (CSF), the failure rates have stayed high. Our latest research on this topic has been reported in the IEEE, UN and other conferences/journals since 2022 [2-10]. Our work is driven by the well-recognized UN Sustainable Development Goals (SDGs) [5] and by the following research Questions:

- RQ1: How is iMeta evolving and what are the potential promises and pitfalls of iMeta-based initiatives? Our research, published in [5, 6, 7, 8, 9, 10], has found that iMeta has great potential to change the way we live and work but it also exposes us to numerous social, ethical, and security/privacy risks. Section II presents our basic platform and playground.
- RQ2: What is the most appropriate approach that maximizes the benefits and minimizes the risks? Given the intricate trade-offs between the opportunities and challenges introduced by iMeta, our research is paying special attention to these tradeoffs with special attention to minimizing failures (See Section III for details).
- RQ3: What are the HMS aspects of our work and what role does the Augmented Collective Intelligence play in our work. See Section IV for our approach and Section V for main results so far.

II. SPACE E-FACTORY – THE BASIC PLATFORM

Given the opportunities offered and challenges introduced by Metaverse and other technologies, it is virtually impossible to handcraft the needed integrated solutions for sustainable initiatives in the public and private sectors. 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, an e-factory assists in producing cyber-physical components (*the artifacts*) according to end-user requirements *through* an assembly process [11]. *Our objective is to minimize failures and expedite the UN SDG agenda.* We are specifically proposing an e-factory model that, when combined with TRAC practice and Supermind experiments, is an innovative approach to meet our objective.

At the time of this writing, the SPACE e-factory supports the following Usage Scenarios illustrated later in Table 1:

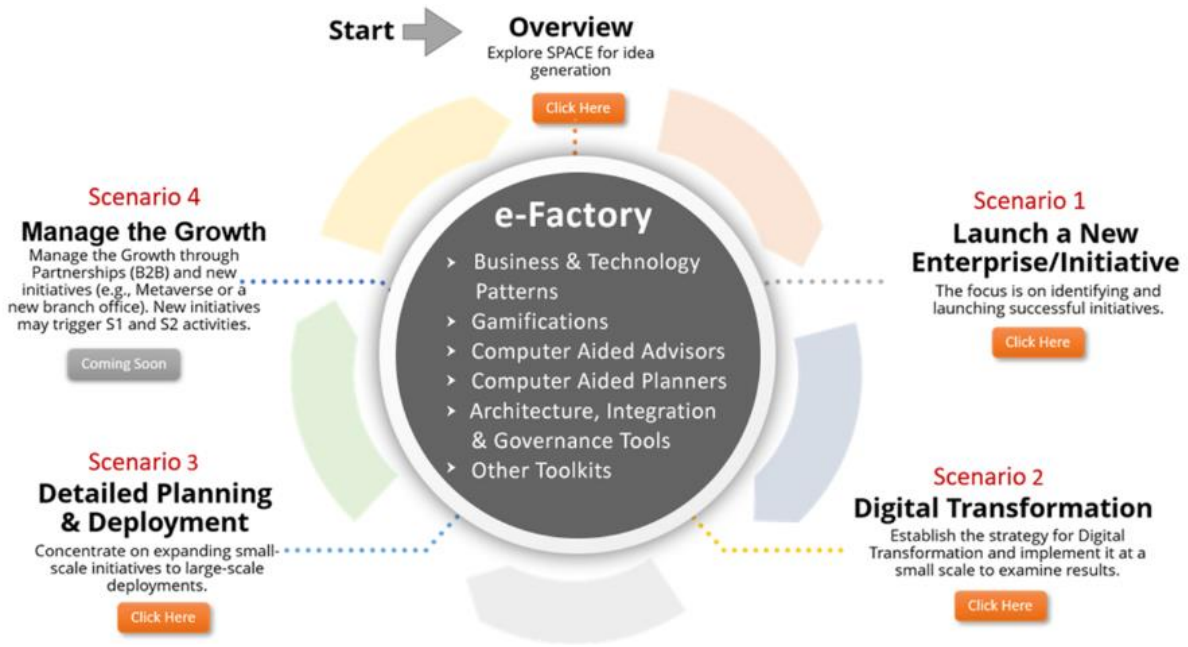

Fig. 1. Conceptual View of the SPACE Platform: An eFactory and Lab for Strategic Planning, Engineering, and Management of Sustainable Communities, Cities, and Enterprises. The inner circle, core of the e-Factory, displays the extensive array of tools that can be invoked individually. The Usage Scenario Labs (Scenario1 to Scenario4) invoke the needed tools to support the Learn-Plan-Do-Check cycle. Please see a 2.5-minute video clip [27] and visit the SPACE website [12].

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.

A. *Extending the Scope of SPACE*

The focus of SPACE (Strategic Planning, Architecture, Controls & Education), displayed in Figure 1, 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, 19-24]. 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 1, 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 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]. In addition, graduate-level teaching and research based on SPACE Platform has led to CITO (Certificate for IT Officials) courses [15]. Table 1 illustrates how SPACE could be used in innovative Use Cases such a "Metaverse Knowledge Storms" that could shake-up several regions in the world.

B. *iMeta Focused Training, Research & Consulting (TRAC) Practice – A Quick Overview*

The SPACE e-Factory has become a core product of our current business – it has been used to educate more than 7,000 MS & PhD students and help over 40 countries through the UN system. We have learned several technical, business and societal lessons in our work so far. The key lessons learned are: a) consistently high failure rates of technology-based initiatives are a continued concern, and b) the failures do not occur in one phase but in all phases of the Demming Learn-Plan-Do-Check (LPDC) life cycle [19-24]. Thus, the solution must also cover the entire LPDC cycle. This observation spurred us to launch an iMeta Focused Training, Research & Consulting (TRAC) Practice that relies heavily on the SPACE e-Factory for success. In particular, we want to continue our research quest: How can the iMeta orgs be planned, engineered, and managed successfully anywhere in the world

by using a combination of e-Factory and TRAC? As displayed in Figure2, the e-Factory is at the core of TRAC Practice:

Detailed description of TRAC capabilities is beyond the scope of this paper. Specific capabilities that are relevant to HMS discussions and Augmented Collective Intelligence will be explicated where needed. The main results and Innovative use cases of our work will be reviewed in Section IV.

- TRAINING: The objective of CITO Program is to educate professionals in the public as well as private sectors. The focus is on exploring the role of emerging technologies (i.e., AI, Blockchains, Cloud Computing, Semantic Web, Metaverse, and others) in transforming enterprises around the globe. These courses intend to explore iMeta technologies for immersive education.
- RESEARCH: We have found that failures happen in all phases of system life cycle, not just in ideation stage. We have analyzed the major causes of failures that are unique to iMeta. Solutions may include innovative ideas such as extensions of blockchains to disabling the bad actors. We will only discuss Superminds experiments here.
- CONSULTING: Computer Aided Consulting (CAC) is an interesting area to illustrate how different types of intelligent systems can be used to succeed. We are interested in using the knowledge and toolkits embedded in the SPACE e-Factory for computer aided consulting engagements. An HMS interface assures that the SPACE platform supports an e-Factory plus a TRAC practice. As discussed below, we are interested in the future trends and emerging technologies in Human-Machine Systems.

III. Platform for AI-Augmented Collective Intelligence – The Supermind Model

As stated previously, we are interested in using SPACE platform for the Planning, Engineering and Management of Successful Metaverse initiatives -- a complex multi-disciplinary undertaking. A metaverse initiative requires the collaboration of experts in different areas of knowledge, thinking and solving the problem collectively. Such a collaboration requires a coherent approach in dividing the problem into subproblems, solving these subproblems, and integrating these solutions into a cohesive collective solution.

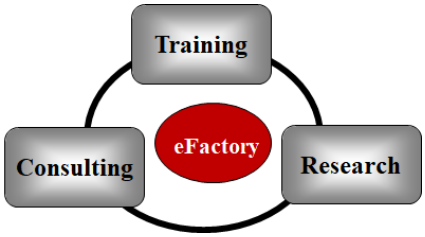

Fig. 2. Conceptual View of Training, Research & Consulting (TRAC) Practice.
Note: e-Factory is at the core of planning, engineering & management of successful initiatives.

A "Supermind" is a group of individuals acting together in ways that seem intelligent [37, 38]. Such collaborations may aim for better decision making, or problem solving. A group of experts working together to implement a metaverse initiative for a city government is a good example. Conceptually, it demonstrates superior intelligence if the performance of collective intelligence is better than the best performing group. Figure 3 illustrates a collective intelligence group as a network of people connected and working on different artifacts to solve a problem. Later, three nodes in this network are replaced or "augmented" by automated decision support and/or expert systems. This would evolve into a superior Human-Machine Collective Intelligence System.

Giacomelli [37] summarizes the following elements of Supermind collective intelligence network (see Figure 4):

1) Nodes of the Network: The network (the group of experts and/or machines) drive impact and contributes towards the goals of the initiative. Advisors in SPAC E, such as Industrial Analysis Workbench, Digital Transformation Advisor, SDG Advisor and Technology Planner are decision support nodes in this network. The users interact with these tools and with each other to form a network of augmented collective intelligence.

2) Incentive for Collaboration: Sentient beings do not demonstrate intelligence without an external stimulus. The Scenarios provide the impetus for this collaboration. Training Research and Consulting practices are also the motivation towards invoking such a collaboration.

3) Information Sources: Given enough information, lesser intelligent systems can simulate higher intelligence. Knowledgebases in the SPACE system connect the nodes with the information as well as have the capability to gain additional knowledge. The users are given guided questionnaires to lead the effort to collective problem solving.

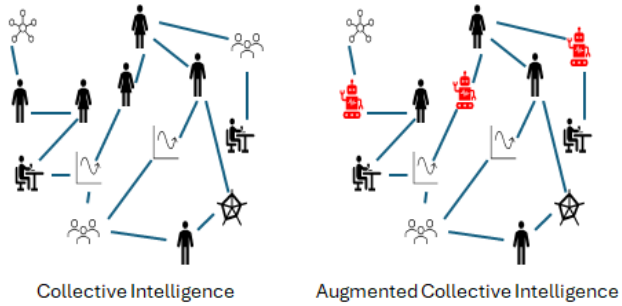

Fig. 3. Collective and *Augmented* Collective Intelligence (three humans are replaced by Machines - Red)

4) Collaboration Environment: Finally, the collaborative environment provides a platform for different nodes working together. SPACE eFactory provides the collaborative platform connecting all of these elements. The Smart Global Village module is an example of the collaborative environment for the collective intelligence network.

It should be noted that e-Factory as well as TRAC offer numerous HMS use cases in Supermind Collective intelligence settings. For example, TRAC produces a very large number of use cases for Information & Referral industries to offer

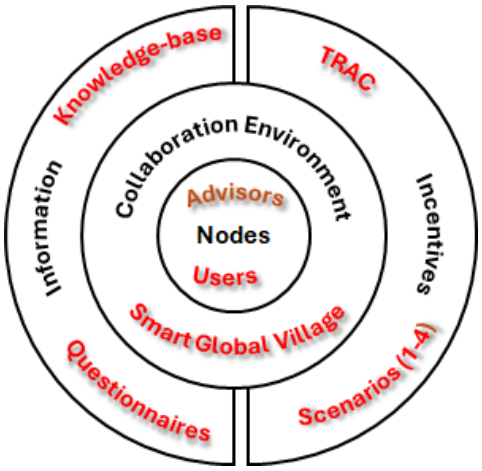

Fig. 4. Supermind Collective Intelligence Network [38]
(Please note the SPACE e-Factory capabilities in Red)

emergency help to underserved populations, Health and Human Service industries in transportation of medication and food, disaster resilient supply chains, moderation of debates about high failure rates of digital transformations, and computer aided consulting services for entrepreneurs. Table 1 displays a few quick examples of HMS and Supermind experiments as a starting point. We are expanding this table into a database that could support powerful R&D agendas by different organizations.

IV. Sample Research Results — Supermind Experiments

We have conducted a large number of experiments in the past to learn how the SPACE capabilities could be used to plan, engineer, and manage successful initiatives. We are excited to add Supermind (*Augmented* Collective Intelligence – ACI) experiments to our repository. Table 1 shows a few examples to illustrate the main ideas of ACI experiments. It also shows how a *Sandbox, called Smart Global Village (SGV), could provide high value to the developing as well as developed countries*. Figure 5 shows the home page of SGV and also a collaboration matrix that captures collaboration scenarios between countries (rows) and topics (columns). This matrix is a powerful tool for capturing horizontal (i.e., the same country), vertical (same topic) and diagonal B2B trade scenarios at global levels. We are currently preparing advanced SGV experiments to better understand immersive education, tourism, disaster resilience and other topic areas. Please note the following:

- Our supermind experiments use LLM-based expertise first and then invoke SPACE Advisors to create a supermind model. We use GANs concept to create adversarial relationships between ChatGPT and SPACE. The discriminators are human. The main idea is to use ChatGPT and SPACE as Generators and ask humans to be the Discriminators.
- Table1 shows that ChatGPT does very well in simpler experiments but starts hallucinating in complex integration levels like B2B exchanges that involve global supply chains that cross borders.

It should be noted that the SGV currently supports PESTLE (Political, Economic, Social, Technological, and Environmental) considerations at a global level [35]. The PESTLE global database (currently work in progress), combined with the global collaboration matrix shown in Figure 5, presents substantial opportunities for business, cultural and economic research and supermind experiments at global levels.

V. Conclusions and Future Directions

To better understand the different aspects of the Metaverse, we have developed an e-factory and a training, research and consulting practice to produce smart collaborating hubs. These hubs populate a Smart Global Village (SGV) 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 significantly extending this e-factory and SGV to make them worthy competitors to LLM-based systems.

The Smart Global Village simulates the collective intelligence of interconnected communities engaged in diverse scenarios, including but not limited to disaster response, supply chain management, and education. Augmenting this inherent collective intelligence with artificial intelligence yields AI-Augmented Collective Intelligence, a concept distinct from Artificial General Intelligence(AGI) and Artificial Super Intelligence(ASI) [17,36,37]. While AGI & ASI aim to *replace* human intelligence, ACI, sometimes referred to as "supermind," leverages AI to enhance, rather than replace, human intellect within a group context.

Collaboration Matrix: Snapshot of Smart Global Village

Note: The implementation plan shows horizontal (regional development), vertical (ecosystems) and diagonal (specialized scenario) collaborations

	Healthcare (telemedicine Hubs)	Edu & Capacity Building Hubs	Entrepreneurship & Ecommerce	Food & Agriculture Services Hubs	Disaster Resilience Hubs	Community Centres
Jamaica	Hypertension		Techpreneurship			Heath & Agriculture
Solomon Islands		Business Management	Digital Marketing		Storms	Health & Education
Tanzania		ICT4 Teachers	Techpreneurship			
Nigeria	General	ICT4Teachers		E-Agriculture		
Rwanda	General		E-Consulting			
Sri Lanka	General Telemedicine		Digital Marketing	Farming & Fisheries	Storms	Plastic Waste
Pakistan	General		E-Consulting		Floods	Education

Fig. 5. Smart Global Village (SGV) and Global Collaboration Matrix

It should be noted that the SGV currently facilitates the consideration of global PESTLE factors. The integration of a forthcoming global PESTLE database with the global collaboration matrix depicted in Figure 5 presents substantial opportunities for research and experimentation pertaining to business, cultural, and economic dynamics, as well as the augmentation of collective intelligence. This topic will be revisited in our future research.

Future research aims to develop a framework for augmenting the SGV to maximize the collective intelligence it can embody. Table 1 reports on our recent findings. This ongoing research explores different approaches to enhancing the SGV supermind for the following scenarios:

- AI-augmented disaster response in smart cities and communities.
- AI-augmented B2B Modeling for improving supply chain logistics and operations.
- AI-augmented epidemic monitoring and response.
- Supermind experiments to address global business and cultural exchanges by using SGV sandbox.

ACKNOWLEDGEMENTS

The technical staff of NGE Solutions (Kamran Khalid, Adnan Javed, Nauman Javed, Hannan Dawood, Arslan Dawood, and Abdul Qadir) have developed the SPACE platform presented in this paper. Their creativity, professionalism, and hard work are greatly appreciated.

TABLE I. SUMMARY OF HMS RELATED EXPERIMENTS BASED ON SAMPLE USE CASES, MOSTLY RELATED TO KNOWLEDGE STORMS

Use Cases for SPACE	SPACE TRAC Capabilities Needed	SuperMind Experiments & Results (only for competitive adversaries)
Scenario 1: How iMeta 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. Additional information: • GEZA provides extensive info to users about how to prep pitches & locate funding sources. • IAW provides advice on competitive & strategic issues	Training: suggests study topics in entrepreneurship Research: identifies the type of failures that can occur in entrepreneurship and what can be done about them. Special attention is needed to detect and eliminate the failures unique to iMeta. We are planning to conduct Supermind sessions with focus on iMeta failures. Consulting – what type of tools, beyond SPACE GEZA & IAW could help. We are using these observations to improve the SPACE Platform.	Note: These experiments were conducted with graduate students, family members & friends For GEZA & IAW: • SPACE Advisors offer clear topic-specific information, and ChatGPT gives very informative general answers, • For topic & location-specific info (e.g., metaverse for tourism in Sri Lanka) SPACE tools are stronger. • Adversarial scenarios generated insightful discussions about the implications of knowledge storms.
Scenario 2: The DTA (Digital Transformation Advisor) and PISA (Planning Integration & Security Advisor) tools guide the users through the transformation & implementation tasks needed to deal with iMeta Knowledge Storms. Additional information: These tools provide implementation level details. Missing these details could cause failures.	Training: suggests study topics in Digital Transformation (DX) and detailed planning needed to deal with iMeta Knowledge Storms. The training is location-specific. Research: what type of failures can occur in DX and Planning tasks, a & what should be done. This strengthens training activities. Consulting – what type of tools, besides DTA & PISA could help the users?	For DTA & PISA • SPACE Advisors provided very detailed information and ChatGPT gave good general answers. • For topic & location specific info (e.g., iMeta DX of health in Nigeria) SPACE tools are stronger. • Adversaries for DX triggered interesting debates especially about KPIs were being used and PISA results triggered vendor tradeoffs.
Scenario 3: SPACE Extensive Planner fully supports this scenario for various enterprise architecture and integration configurations. The information provided is location specific. For example, reliable cloud services are not available in developing countries. Scenario 4: B2B impact of iMeta (e.g. disaster resilient global supply chains and Health and Human Services) networks that utilize the Metaverse.	Training: courses on successful enterprise architectures and integration within an enterprise and B2B settings (e.g., supply chains). Research: what type of failures can occur in architecture & integration, especially at B2B levels, and what can be done about them. Consulting – what type of tools (besides SPACE extensive planner) can help. Especially location and topic specific B2B exchanges at global levels.	The SGV (Smart Global Village) is an excellent sandbox for a very large number of B2B scenarios at global levels. The collaboration matrix displayed in Figure 5 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. Also, the global collaboration matrix and PESTLE opens avenues for global collaborations and culture-centered supermind experiments

REFERENCES

[1] The 2nd International Conference on Intelligent Metaverse Technologies & Applications (iMETA2024). 26-29 Nov. 2024, Dubai

[2] A. Umar, "A Software Factory in the Cloud for Pandemics and other Disasters," in 2020 IEEE Cloud Summit, IEEE, 2020, pp. 79–84.

[3] A. Umar, "A Digital Transformation Lab for Developing Countries and Small to Medium Enterprises," in 2022 IEEE European Technology and Engineering Management Summit, IEEE, 2022, pp. 160–165.

[4] A., Umar, "Training and Education for Smart Cities, Communities and Enterprises Using ISEM Concept", 2022 IEEE European Technology and Engineering Management Summit (E-TEMS)

[5] A. Umar, "Metaverse and Other Technology Bundles for UN SDGs – Opportunities and Challenges," May 2024

[6] A.Umar, K.Khalid, N. Javed, A. Javed, "e-Factory for Metaverse-based Smart Communities, Cities and Enterprises", Accepted for publication -- IEEE Intelligent Metaverse Conference, Dubai, Nov 2024

[7] A.Javed, N. Javed, A. Umar, "Pixels to Reality: A Maturity Spectrum of Immersion", Accepted for publication -- IEEE Intelligent Metaverse Conference, Dubai, Nov 2024

[8] O. Cosgun, A. Umar, D. Delen, "Operational Assessment of Nursing Homes at Times of Pandemic: An Integrated DEA and Machine Learning Approach", Accepted for publication, -- Operational Research journal (Springer – Fall 2024)

[9] A. Umar, "Metaverse for UN SDGs–An Exploratory Study. Science-Policy Brief for the Multistakeholder Forum on Science, Technology and Innovation for the SDGs, May 2022, 13-28," 2022.

[10] A. Umar, "Metaverse for Public Welfare and the United Nations Sustainable Development Goals," in 2022 Int. Conf. on Cloud Comp., Big Data and Internet of Things (3CBIT), IEEE, 2022, pp. 160–165.

[11] David Alan Grier, "Software Factories." Accessed: Aug. 01, 2024. [Online]. Available: https://www.computer.org/publications/tech-news/closer-than-you-might-think/software-factories

[12] "SPACE – A Computer Aided Planning, Engineering & Management Platform developed by NGE Solutions, Inc." Accessed: Dec. 24, 2024. [Online]. Available: www.space4ict.com

[13] "UN ICT4SIDS Partnership Website." Accessed: Dec. 24, 2024. [Online]. Available: www.ict4sids.com

[14] "Smart Global Village (SGV) Sandbox." Accessed: Dec. 24, 2024. [Online]. Available: http://space4ict.com/njsamples/countryCount.aspx

[15] "CITO- (Certificate for ICT Officials). NGE Institute ." Accessed: Dec. 24, 2024. [Online]. Available: https://nge-institute.com/

[16] A. Umar, "Smart collaborating hubs and a smart global village-an alternative perspective on smart cities," in 2018 IEEE Technology and Engineering Management Conference, IEEE, 2018.

[17] Javed, A, et al, " Integration of LLM-based Expert Systems with Rules- NGE-20, Jan 13, 2025. Nge Solutions Working Paper

[18] T. Clancy, "The Chaos Report on IT Failures" Standish Group, 1995.

[19] B. Boorsma, "When Smart City Initiatives Fail-and Why," 2018, Accessed: Dec. 24, 2024. Available: https://linkedin.com/pulse/when-smart-city-initiatives-fail-why-bas-boorsma

[20] S. A. Ebad, "An exploratory study of ICT projects failure in emerging markets," Journal of Global Information Technology Management, vol. 21, no. 2, pp. 139–160, 2018.

[21] N. Ramesh and D. Delen, "Digital transformation: How to beat the 90% failure rate?," IEEE engineering management review, vol. 49, no. 3, pp. 22–25, 2021.

[22] S. Oludapo, N. Carroll, and M. Helfert, "Why do so many digital transformations fail? A bibliometric analysis and future research agenda," J Bus Res, vol. 174, p. 114528, 2024.

[23] D. Dada, "The failure of E ‐ government in developing countries: A literature review," The electronic journal of information systems in developing countries, vol. 26, no. 1, pp. 1–10, 2006.

[24] S. Wray, "Seoul splashes out on the metaverse, smart CCTV and more." Accessed: Dec. 24, 2024. [Online]. Available: https://cities-today.com/seoul-splashes-out-on-the-metaverse-smart-cctv-and-more/

[25] "General Data Protection Regulation (GDPR)." Accessed: Dec. 24, 2024. [Online]. Available: https://gdpr-info.eu/

[26] "SPACE Platform overview", Accessed: Dec. 24, 2024. [Online Video]. Available: https://www.youtube.com/watch?v=ceVA99fA8tc

[27] G. Salierno, L. Leonardi, and G. Cabri, "The future of factories: different trends," Applied Sciences, vol. 11, no. 21, p. 9980, 2021.

[28] S. Karagiorgou, G. Vafeiadis, D. Ntalaperas, N. Lykousas, D. Vergeti, and D. Alexandrou, "Unveiling trends and predictions in digital factories," in 2019 15th International Conference on Distributed Computing in Sensor Systems (DCOSS), IEEE, 2019, pp. 326–332.

[29] S. S. Gill et al., "AI for next generation computing: Emerging trends and future directions," Internet of Things, vol. 19, p. 100514, 2022.

[30] A. Holzinger, K. Keiblinger, P. Holub, K. Zatloukal, and H. Müller, "AI for life: Trends in artificial intelligence for biotechnology," N Biotechnol, vol. 74, pp. 16–24, 2023.

[31] F. Sovrano and F. Vitali, "Explanatory artificial intelligence (YAI): human-centered explanations of explainable AI and complex data," Data Min Knowl Discov, pp. 1–28, 2022 news/closer-than-you-might-think/software-factories

[32] A. Aggarwal, M. Mittal, G. Battineni, "Generative adversarial network: An overview of theory and applications", - International Journal of Information Management", April 2021, Elsevier

[33] "Superminds: How humans and machines can work together", Deloitte Report, 2019

[34] Y. Liu et al, "PersonaFlow: Boosting Research Ideation with LLM-Simulated, Expert Personas", cs.HC, ACM, 19 Sept, 2024

[35] "PESTLE Analysis Tool." Accessed: Dec. 24, 2024. [Online]. Available: https://pestleanalysis.com/

[36] Malone, T. W. (2018). Superminds: The Surprising Power of People and Computers Thinking Together. New York: Little Brown, p. 20.

[37] Giacomelli, G. (2024), Augmented Collective Intelligence: Principles, https://www.supermind.design/s/Augmented-Collective- intelligence-3102024-PRINCIPLES.pdf

[38] Heyman, Jennifer, Rick, Steven, Giacomelli, Gianni, Wen, Haoran, Laubacher, Robert et al. 2024. "Supermind Ideator: How Scaffolding Human-AI Collaboration Can Increase Creativity", ACM|Collective Intelligence Conference

[39] C. Ling et al, "Domain Specialization as the Key to Make Large Language Models Disruptive: A Comprehensive Survey", ACM, 2024, arXiv:2305.18703 **[cs.CL]**