Training and Education for Smart Cities, Communities and Enterprises Using ISEM Concept

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***Abstract* - Smart digital enterprises and cities require interdisciplinary skillsets that cover the entire system life cycle and integrate knowledge from information systems, systems engineering, technology management and emerging digital technologies. This paper describes the ISEM (Information Systems Engineering and Management) concept that concentrates on the planning, engineering/reengineering and management aspects of Smart Digital Enterprises and Cities. Case study of one ISEM program is used to illustrate how such a program could be used to educate leaders of Smart Enterprises, Smart Cities and Communities. This paper also shows how an innovative Digital Transformation Lab could be used to educate and train graduate students and government officials through hands-on experiments.**

Keywords - Digital Transformation, Strategic Planning, Enterprise Architecture, Enterprise Integration, Information Systems, Systems Engineering, Engineering Management

I. INTRODUCTION

Smart cities, communities and enterprises (SCEs), according to NSF [1], are populations that live and work in different locations but are connected through intelligent technologies. Examples of SCEs include smart towns, community centers, small to medium businesses and public service centers. SCEs offer many promises and job opportunities for society [10] – [19] but many (around 70 to 80%) of SCE projects are failing due to unclear objectives and shortage of skillsets [20] - [28]. This is creating opportunities for education and training -- the main objective of this paper. The goal is to answer the following questions:

- What are the key promises and pitfalls of SCEs, especially in developing countries (Section II attempts to answer this question and introduces a research methodology)
- What type of education and training programs are needed to address the challenges (Section III proposes a simple education framework that is based on integration of information systems, systems engineering and management concepts for this purpose)
- Are there examples (use cases) of educational programs that address the challenges (Section IV introduces a case study that is used as an example to illustrate the key elements of such programs)
- What type of tools are needed to support the needed educational programs (Section V introduces such a Lab)
- What are the use cases, key results and lessons learned that are of value (see Section V and Section VI)

II. SMART CITIES, COMMUNITIES AND ENTERPRISES (SCES) -- PROMISES AND PITFALLS

SCEs and their variants (e.g., Industry 4.0, Manufacturing 4.0, and Next Generation Enterprises) are public and private enterprises that rely heavily on digital technologies. In fact, most digital transformations result in such enterprises. There is a great deal of activity in this area. For example, the global smart cities market is expected to grow annually by 20% during 2021-2026 and the global spending may surpass USD three trillion by 2026 [29, 30]. In particular, Digital Transformations are the key enablers of SCEs and this market is expected to double from USD 469.8 billion in 2020 to over USD $8 billion by 2027 [29]. SCEs and DTs are creating tremendous opportunities for skillsets such as AI for Business, Blockchains, IoTs and Cyber-physical Systems according to Price Waterhouse Consulting, Mckinzy and others [11]-[15]. Finally, according to the US Bureau of Labor Statistics: "As more industries are pushed to IT, the demand for management of Technology is also increasing" [10].

While SCEs offer many benefits and job opportunities, it seems that 70-80% of smart city and digital transformation projects are failing [19, 20]. Several smart city projects seem to have generated a jungle of expensive technologies that are not providing any benefits to the citizens [22, 23, 24]. The reasons for such failures are lack of planning and project management but span the entire system life cycle with emphasis on unclear user benefits [25, 26, 27]. In fact, many ICT (digital) services projects fail on a regular basis and are never used in practice. The Standish Group Chaos report [21] published in 1995 made a major splash by contending that ICT project failures exceed 65%. Failures in developing countries, as reported by Dada [28], are much higher – exceeding 80%. Additional research still shows failure rates for developing countries between 70-85% [25, 26]. This is a serious problem because the poor countries have no room for failures and cannot seek help from expensive consultants.

Most failures occur due to re-invention of the wheel throughout the system life cycle as shown in Fig. 1. These causes are based on the analysis of the afore-mentioned literature and firsthand knowledge gained through working

with several United Nations and small to medium business projects. See [8, 31, 32] for additional details.

The entire life cycle activities shown in Figure 1 must be executed properly for success. Specifically, the key players need to *Learn* what needs to be done, *Plan* how to do it right, *Do* whatever needs to be done, and *Check* to see if it is done right. The know-how to address the issues is available, but the major challenge is: *how to transfer the know-how to the needy parties rapidly, economically, and globally*. This challenge was raised in several United Nations Conferences in 2010-2011 and resulted in development of a toolkit called SPACE (Strategic Planning, Architecture, Acquisition, Controls & Education). SPACE will be discussed in section V.

Figure 1: Typical Reasons for Digital Services Failures, in Terms of the Learn-Plan-Do-Check Cycle

III. The ISEM Concept For Education and Training

The ISEM (Information Systems Engineering and Management) concept integrates knowledge from the following three disciplines to plan, engineer and manage SCEs. Specifically:

- *Information Systems*: emerging digital technologies and associated methodologies (e.g., artificial intelligence, big data, business intelligence, blockchains, cloud technologies, IoTs, satellites, web technologies, wireless communications)
- *Systems Engineering*: planning of digital transformations, enterprise architectures and integration of SCEs, and deployment of systems of systems that are at the core of smart cities and communities
- *Management:* business strategies, project management, entrepreneurship, cyber security and governance, and agile management in global settings

ISEM concept, as displayed in Fig. 2, emphasizes the entire system life cycle instead of one narrow area of work. The major advantage of this concept is that it easily includes systems engineering of cyber physical systems as many physical systems evolve into cyber physical systems. For example, classical systems engineering principles were used to build Roman Highway Systems around 300 BC but now the modern systems engineering principles are used to build IoT and surveillance camera enabled highways and bridges.

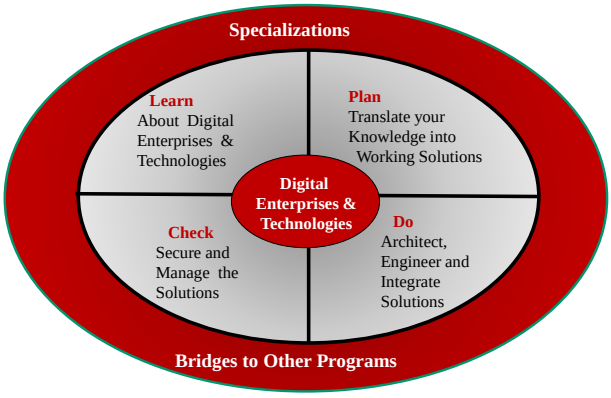

Figure 2: Conceptual View of ISEM.

In the Industry 4.0 world, the *operational technologies* of physical buildings such as air conditioning and heating systems are being integrated with the digital technologies to form smart buildings. In Industry 4.0, the bridges, buildings, roads, automobiles, washers, refrigerators and all other physical systems are becoming sources of information. *It seems that systems engineering has evolved into information systems engineering due to the onslaught of cyber physical systems. In fact, factories, towns, smart cities and enterprises in the public and private sectors are becoming large scale complex information systems that contain tremendous knowledge about the environment and user communities that can quickly detect major events, adjust accordingly and learn from each other for further improvement.* For example, smart vehicles are *learning* from smart roads and vice versa This is creating unprecedented educational and training challenges and opportunities.

Several university programs were surveyed to locate the programs that are based on the ISEM concept and found that the following three programs are closest to the spirit of ISEM (i.e., they integrate information systems, systems engineering and management concepts that are of value to SCEs):

- The John Hopkins Information Systems Engineering (ISE) program [2]. This is a very strong and highly rated program but the focus is heavily on engineering and not on management. In fact, a student can get an MS in ISE degree without any management courses.
- The Information Systems Engineering and Management Program at the Hector School of Engineering, Germany [3]. This is a very strong program that is very close to the ISEM concept. According to the Hector catalog: ".. in this program, IT specialists and computer scientists as well as business administrators and engineers will be

enabled to advance internal and external digitalization and to assume leadership functions, especially in the field of digital transformation of companies". The program offers the following Focus Areas for students:

- Artificial Intelligence & Machine Learning
- Artificial Intelligence as a Services (AIaaS)
- Blockchain Technology
- Cloud Computing
- IT Security and Privacy

- The Information Systems Engineering and Management Program at Harrisburg University of Science and Technology (HU), Harrisburg, USA **[4].** This program was launched in 2010 and currently offers MS and PhD degrees. This 36 semester hour interdisciplinary program is totally based on the conceptual ISEM model presented in Fig. 2. It offers the following flexible specializations (alphabetically) in:
  - AI and BI for Business
  - Blockchains and Quantum Computing
  - Digital Transformations
  - Smart Enterprises & Industry 4.0
  - Technology Management & Techpreneurship
  - PhD in ISEM
  - Build Your Own (Three Courses in a Topic area plus a Capstone)

This program is examined as a case study in the next Section. The purpose is not to promote one program over the others but to share information, ideas and lessons learned from a unique program being offered at a small university that is supported by an interesting Lab and a Partnership with the UN.

IV. Case Study - ISEM Program at Harrisburg University (HU)

Information Systems Engineering and Management (ISEM) Program at HU concentrates on the planning, architecture, engineering, integration and management of SCEs. ISEM at HU, rated among the top ten IS programs in USA in 2022 [34], is designed to support the digital transformation initiatives that are being launched in the public and private sectors around the globe [11-15, 29, 30]. As displayed in Fig. 3, numerous digital technology components are needed to support the existing and future enterprises and initiatives. Examples of these components are the wide range of software components that are becoming available on the cloud as services. Interesting examples are AI as a Service, Blockchain as a Service and IoT as a Service. These services and components are changing the role of systems engineers.

It is important to note the dotted line in Fig. 3 that separates the component engineers from systems engineers. Please note that more technologies are becoming available as plug and play components of the digital technology infrastructure below the dotted line. This is placing more pressures on systems engineers and managers above the dotted line to build highly reliable, flexible and manageable enterprise systems by using these new components. Thus the need for well trained and educated systems engineers and managers is also increasing.

Examples of the enterprises that are based on these digital services are Smart Cities and Communities, Industry4.0 Enterprises, Digital Health Networks, eAgriculture Farms, Future Transportation Systems and many more. ISEM core courses focus on these and other enterprises by using the concepts shown in the red circle. Students can take electives to specialize in different topic areas displayed in Fig. 3 (above and below the dotted line). For example, students can specialize in technology management, smart cities and enterprises, digital transformation, AI for business, Techpreneurship, next generation technologies and others. Students with business and non-technical background can take beginning courses to gradually develop background in digital technologies.

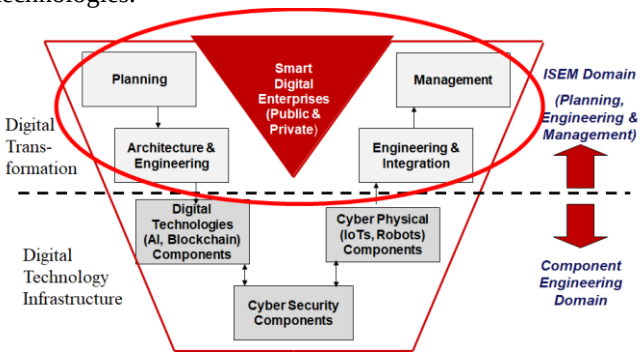

Figure3: The Emerging Role of Digital Technologies as Enablers of Modern Enterprises in Public and Private Sectors *(Based on: International Council on Systems Engineering - InCOSE).*

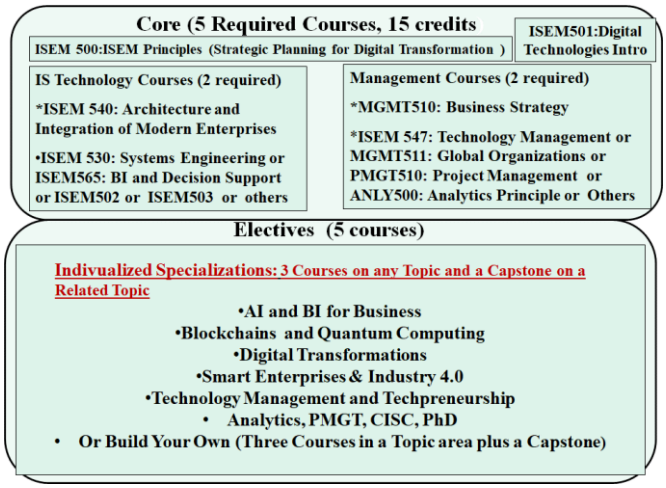

Figure 4: MS Program in ISEM.

Fig. 4 displays the overall structure of the 36 semester hours MS Program and the specializations. Table 1 shows additional information about the core courses and specializations. Please note that the five core required courses provide a balanced foundation of technical and management principles. After the core, the students may take *any* graduate course being offered at HU as ISEM elective. This opens the opportunity for ISEM

students to take electives in topics that range from project management to biotechnologies, The students may build their own specialization or choose to specialize in predetermined subject areas displayed in Table I. Individualized Specializations shown in Table I are based on an analysis of the job market trends. The two capstone courses at the end allow the students to synthesize their knowledge into an experiential project or a research thesis.

Table I: ISEM Courses at a Glance

5 Core Courses for all MS in ISEM Students

- *Strategic Planning* for Digital Transformation
- *Business Strategy* & Management Principles
- *Architecture & Integration* of Smart Enterprises
- Any One Technical Course from the Following List: AI Principles, Human Centered Design, etc
- Any One Management or Methodology Course from the Following List: Digital Enterprises, Systems Engineering Principles, Decision Support and BI.

ISEM Capstone (Required)

- Research Methods & Writing
- Applied Project or Research Thesis

ISEM Specialization Courses

Artificial and Business Intelligence (AI & BI) Courses:

- *Artificial Intelligence* Principles and Applications
- *Big Data* & Machine Learning
- *Business Intelligence* & Decision Support

Blockchain and Quantum Courses

- *Blockchains* and Trusted Systems
- *Ethereum* and Smart Contract Programming
- *Blockchain* Applications and Scalability
- Foundations of *Quantum* Information Science

Digital Technologies for Transformation Courses

- Introduction to *Digital Technologies*
- *Database* Design and Management
- *IT Infrastructure* & the Cloud
- *Mobile Computing* and Wireless Systems

Smart Enterprises and Cities Courses

- *Systems Engineering* Principles
- *IoTs* and Industry 4.0
- *IT Quality* Assurance
- *Smart Cities* and Strategic Intelligence

Technology Management Courses

- *Technology Management*
- *Cyber Security* Management
- Business *Entrepreneurship* Principles
- *Marketing* in the Digital Age
- Financial and Managerial *Accounting*

Different students take different courses based on their specialization. For example, a student specializing in Digital Transformation or Smart Cities would take the required courses in Strategic Planning, Enterprise Architectures, Strategic Management, Analytics and Systems Engineering. The specialization courses would include AI, Blockchains, IoTs and Industry 4.0, Smart Cities, Cyber Security and Project Management. For capstone, students can select a very wide range of digital transformations R&D projects centered around SCEs in the public or private sectors.

V. Digital Transformation Lab & Corporate Training

HU ISEM students have access to a *Digital Transformation Lab* that has been developed primarily due to collaborations with enterprises around the globe and the UN. This Lab, displayed in Fig. 5, supports the research, education and training of ISEM students and also corporate training courses and workshops on a wide range of SCE topics. The capabilities of this Lab are viewed in terms of the following layers:

- SPACE Toolset, in the top layer, provides an extensive array of capabilities for digital transformation. These include a patterns repository, gamifications, decision support advisors, planning tools, and specialized tools that invoke different capabilities for different types of scenarios. For details about SPACE, please see [7, 8, 9].
- The agile methodology layer in the middle supports the entire Learn-Plan-Do-Check cycle that also behave as the preprocessing, production, post-processing and customer support of a typical eFactory. As displayed in Fig. 5, these phases invoke different capabilities of SPACE as needed (e.g., the Digital Transformation Advisor is invoked is invoked to initiate planning tasks).
- The main product produced by the SPACE Toolset is a *Smart Collaborating Hub* -- a center of activity that contains highly specialized and smart artifacts such as an Administrative Portal, a Citizen App, Training Materials and relevant Policies on a particular topic. *These hubs are generated in less than 30 minutes* and have pre-fabricated capabilities or collaboration with each other to form a *Smart Global Village.*

The Smart Global Village is populated by this Lab and currently houses more than 1100 smart hubs that are located in more than 130 countries and support 12 industry and government sectors. This Village is an excellent sandbox for students, industries and government officials for SCE experiments. See [6, 8] for additional information about the Village. Table II displays a sample hands-on Workshop that uses this Lab.

Table II: Hands-On Workshop based on the SPACE Lab

"Strategic Planning for Smart Cities and Enterprises"

6 Week Hands-On Workshop, one hour online session per week

- *S1: Overview* –Introduction to the course and Lab, overall Methodology and selection of Projects to be conducted.
- *S2: Planning for SCEs* -- **P**lanning concepts for the selected Project. Then learn about the Lab to produce a strategic plan, feasibility study, funding proposals and other artifacts.
- *S3: Initial Planning*: Use the Lab and analyze the plan produced by SPACE Tool. Discuss the results with other participants by using the discussion forum.
- *S4-5: Extensions*: Refine and extend the solutions produced
- *S6: WRAPUP*: Presentations and discussions by attendees

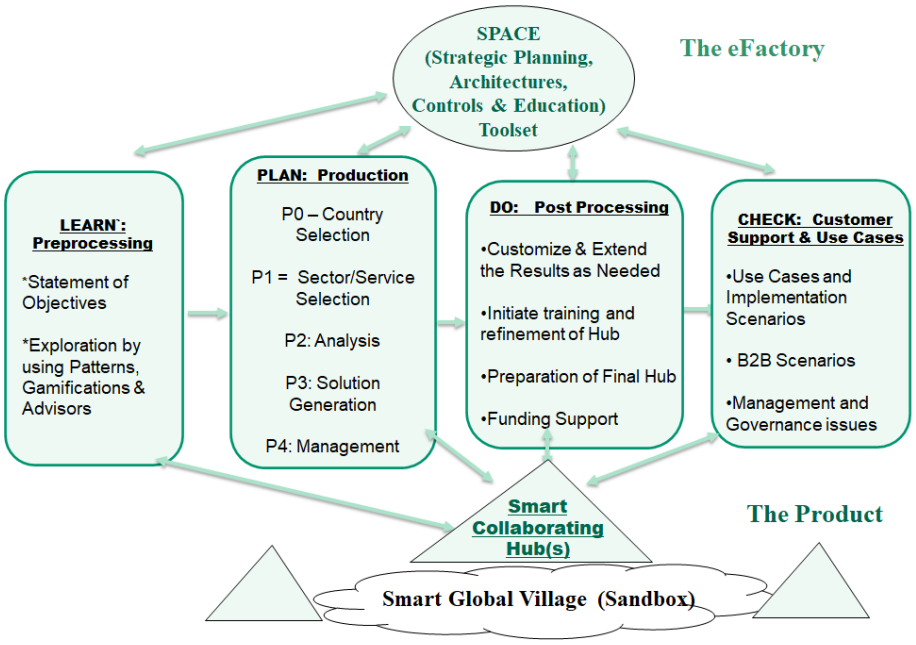

Figure 5: Vision of the Digital Transformation Lab (The SPACE Toolset, the Learn-Plan-Do-Check Methodology and the Product).

VI. Key Results - A Use Case IN Synthesis

The concepts presented so far can be synthesized by showing how SCEs (Smart Cities, Communities and Enterprises) can be planned, engineered and managed as a series of projects in the ISEM Program (displayed in Table I) by using the Lab illustrated in Fig. 5:

- A student develops the strategic plan, by hand, of a small SCE in the *Strategic Planning Course*. The student then uses the Lab to generate the same plan and refines/extends the plan generated manually – a great learning exercise.
- In the *Architecture & Integration* course, the student develops a sophisticated SCE by using SPACE. This SCE is added to the Smart Global Village to explore and evaluate possible B2B collaboration scenarios.
- The student experiments and expands different aspects of this SCE while taking elective courses in AI, Blockchains, IoTs, Cyber Security, Technology Management, Quality Assurance and other courses depending on the student interest.
- In the *Smart Cities* course, the student works in a team to develop complete project management plan of an actual smart town by using the methodology introduced by Gassmann [33]. The student teams also implement different aspects of the town by using the Lab.
- In the *Capstone*, the students design artifacts or conduct research in a wide range of topics that span intrusion tolerant smart cities, innovative applications of AI/Blockchains/IoTs in SCEs, disaster resilience scenarios, and entrepreneurship communities. They may use the Smart Global Village in their investigations.

It is important to assure the quality of interdisciplinary programs such as ISEM. As expected, different sets of standards have been introduced for quality assurance in education [35]. The overall quality of the ISEM Program, and other higher education programs in the Commonwealth of Pennsylvania, is assured through compliance with the Middle States Commission on Higher Education. All academic programs at Harrisburg University are currently accredited by this Commission.

VII. Concluding Remarks and Lessons Learned

Smart digital enterprises and cities require interdisciplinary skillsets that cover the entire system life cycle and integrates knowledge from information systems, systems engineering and management (ISEM). The ISEM concept was used to launch a graduate program that has evolved into planning, engineering and management of Smart Cities, Communities and Enterprises (SCEs). This program has evolved over time and now is focusing on the promises (i.e., job opportunities) as well as failures of SCEs. In particular, we have learned a great deal by analyzing the causes of failures and have adjusted the program accordingly. The participation in development of a Digital Transformation Lab has been highly beneficial. This Lab has been especially useful for hands-on experiments *in academic as well as industrial educ*ation.

It is surprising to find that only three programs are in the ISEM space even though ISEM lies at the complex intersections of information systems, systems engineering and engineering management. It seems that this concept needs more exposure. The long range partnership between UN, a small university (HU), and a startup has produced very interesting and valuable results with focus on developing countries. We want to expand this relationship by inviting new partners.

VIII. Acknowledgement

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