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Implementing Smart City And Autonomous Vehicle Concepts into Construction Management (CM), Civil Engineering (CE) And Architectural Education Programs

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Implementing Smart City-Inspired Energy Efficiency Education in Civil, Construction, and Architecture Disciplines

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Abstract
As urban areas enlarge worldwide, the demand for sustainable energy solutions within cities has become gradually significant. One of the main goals or focal points of Smart City development initiatives is the drive for electricity efficiency, can be achieved through advanced data analytics, Internet of Things (IoT) systems, and energy-efficient construction technologies. Despite the potential of Smart City technologies, contemporary educational programs in Construction Management (CM), Civil Engineering (CE), and Architecture often lack inclusive training in these advanced, data-driven procedures. Traditional curricula focus principally on functional and structural design, materials science, finance and project execution, leaving a gap in the integration of energy optimization methods and smart infrastructure resolutions. Addressing this gap requires a reimagined approach to education that includes courses and concepts such as, energy-efficient building design, automated energy management systems, and real-time data monitoring as fundamental components of urban infrastructure development under one course. This paper explores the integration of Smart City principles into CM, CE, and Architecture programs as one course. It reviews the current state of educational curricula, identifies gaps, and proposes a curriculum model of course work strategies for embedding Smart City energy efficiency concepts that can be offered to three different education programs as part of the implementation process as the first phase of designing the framework of this course.

Introduction

The global urban population is expected to grow substantially and exponentially in the coming years, escalating the demand for urban areas to deliver sustainable and efficient services. Many cities have started adopting the concept of smart city construction through various contexts like governance, healthcare, energy, transport, etc. [1]. The evolution of smart cities has taken place by the end of the previous century when cities like Amsterdam and Barcelona in collaboration with big companies like IBM and Cisco have made attempts to connect digital and physical environments but not until 2015 the world has started seeing big developments and applications like digital implementation to physical structure and infrastructure especially into service sector [1]. The new challenges like the COVID-19 pandemic, energy crisis, political and climatic changes and need for transitions have exerted more importance for such practices and needs that will benefit mankind [1]. In sustainable urban development, energy efficiency plays a pivotal role, with buildings alone accounting for nearly 40% of global energy consumption [2]. Smart Cities, which incorporate information and communication technologies (ICT) with urban infrastructure, present a capable approach to encountering the compound challenges of urban energy management. These policies not only moderate environmental impact but also subsidize economic resilience and operational cost savings, predominantly in the construction and building management sectors. Adoption of Smart City construction facilitates the integration of cutting-edge technology and infrastructure, allowing for continuous surveillance of energy consumption process [3]. Moreover, additional technological innovation with Smart City concept can achieve the effective real time operation of various urban systems which include energy.

Researchers state that this will strengthen the correlation among various links related to energy utilization, which as a result will support in achieving energy use and proficiently reduce energy waste [3,4]. In the literature, data from various urban cities of China to statistically prove that smart city construction proves urban energy efficiency [5]. One of the main goals or focal points of Smart City development initiatives is the drive for electricity efficiency, can be achieved through advanced data analytics, Internet of Things (IoT) systems, and energy-efficient construction technologies. Despite the potential of Smart City technologies, contemporary educational programs in Construction Management (CM), Civil Engineering (CE), and Architecture often lack inclusive training in these advanced, data-driven procedures [6]. Traditional curricula focus principally on functional and structural design, materials science, finance, and project execution, leaving a gap in integrating energy optimization methods and smart infrastructure resolutions. Addressing this gap requires a reimagined approach to education that includes courses and concepts such as energy-efficient building design, automated energy management systems, and real-time data monitoring as fundamental components of infrastructure development in one course.

This paper explores and examines the methods and technical frameworks necessary to incorporate Smart City, Energy efficiency into CM, CE, and Architectural undergraduate education. It highlights essential areas for curriculum development, including IoT-based energy monitoring, data analytics for predictive maintenance, concepts of smart grids and energy modeling software which are commonly not available for undergraduate students. Furthermore, it emphasizes interdisciplinary approaches, such as the application of Building Information Modeling (BIM) for energy simulation and lifecycle analysis, which equips students with skills to implement electricity-efficient systems at various scales of urban development [6]. By introducing these core competencies in these fields, educational institutions can foster a generation of professionals equipped to contribute to the sustainable growth of urban centers through advanced energy management in Smart City contexts right after students' undergraduate education instead of procuring other supplementary certifications or courses outside the institution for topics relevant to energy efficiency and smart city concepts.

Literature Review

This section reviews the background of smart cities concepts necessary for understanding the meaning, relevance and necessity of introducing and implementing energy efficiency topics to the interdisciplinary programs.

1. Smart Cities and Energy Efficiency

The term "smart" describes an automated system used to carry out the intended task inside a domain. A smart city is an urban lifestyle where traditional networks use digital and telecommunication technologies to enhance efficiency, sustainability, security, and quality of life using automation systems which can exercise on given data. It integrates ICT (Information & Communication technology) and IoT (Internet of Things) across governance, services, and urban operations, focusing on six dimensions: governance, people, environment, economy, mobility, and living, with centralized monitoring for optimized functionality [7]. By 2050, with 68.4% of the population in cities, addressing rising fossil fuel use, power plant strain, and buildings' 40% global energy consumption, including 7% from residences, is necessary and becomes alarmingly crucial [7,8]. Smart cities have adopted energy conservation systems to manage energy in urban areas and buildings.

2. Energy Efficiency and smart technologies in built environment and urban living

Cities are responsible for 60-80% of the greenhouse gas emissions and 75% of its natural resources and energy, while occupying only 3% of the planet's surface suggesting how big an impact is being created by the lifestyle and the demands that are necessary to be catered lately [3]. To tackle this, various initiatives have been launched by organizations like US Smart Cities Initiative, the EU's EIP-SCC (European Innovation Partnership on Smart Cities and Communities), and the UN's GI-REC (Global Initiative for Resource Efficient Cities) to encourage and promote energy efficiency among various types and functions of buildings and infrastructure [3]. To exercise a dependable, low-carbon, and efficient energy supply, real-time management and optimization are necessary by integrating energy systems that combine various kinds of energy vectors like heat, gas, and electricity [3]. Hence, using smart technologies, which combine technology with physical environments and services to run and serve depending on the environment's needs, which will therefore minimize energy consumption, is necessary. Researchers propose using Industry 4.0 technologies, such as ICT, IoT, and AI, to improve domestic energy efficiency; these developments are referred to as "smart city concepts" and believe that buildings such as residential homes/individual apartments can improve convenience and usefulness while lowering energy consumption by 12% to 20% by integrating smart appliances and load monitoring [8].

3. Core Competencies of Smart City for energy efficiency

By leveraging advancements in emerging technology, the smart city can transform into an intelligent community. Several technologies collaborate and play an important role in the implementation of smart cities, but there are some core competencies of the smart cities which are most suitable for the application of energy efficiency such as Information and communication technology (ICT). A broad spectrum of blockchain and artificial intelligence applications promise distributive technologies which can be adopted in the power grid system of the energy supplies of the infrastructures which can transform them into intelligent grid systems. Blockchain system with collaboration with AI can also help with energy consumption optimization in Area Energy management systems [10]. For smart cities to function, energy efficiency is essential. To handle energy irregularities in smart buildings and improve consumption efficiency, researchers suggested a data-mining-based decision support system using information systems. Furthermore, the Power Controlled and Stability-based Routing protocol (PCSR) improves route stability, lowers consumption, and increases energy efficiency while extending network lifetime [6]. Using the Internet of Things, a J2EE-based application model can be used to build a scalable, secure, and reliable enterprise energy efficiency management platform with features that guarantee adaptability to complicated environments [11]. Users can use a PC, tablet, or smartphone at any time to access monitoring, optimization, forecasting, and control features devices (e.g., smart thermostats, lighting systems, and power meters) which can transform the data into real-time monitoring and share with respective mobile devices for any actions will successfully provide lower energy requirements [11,17,18]. Employing IoT technology applications, energy consumption can be optimized by using renewable energy resources by implementing a solar energy tracking panel that turns to maximize power generation by tracking the sun's course, increasing efficiency from 20% to 50%. Mobile apps, cloud servers, and smart devices are all integrated for monitoring and control in an Internet of Things and cloud-based smart system. Smart devices use wireless connections to process and analyze data, guaranteeing energy economy, security, and user-friendliness [18]. A smart grid is a modernized and semi-automated power grid that uses electricity flows, distributed intelligence, and bi-directional communication to improve sustainability, efficiency, and dependability. Although an interdisciplinary approach is necessary, emphasizing the necessity of a workforce with a variety of expertise for its implementation because of its complexity [12]. Building Information Modeling (BIM) is a process for creating and managing digital representations of buildings, encompassing physical and functional characteristics [13]. A computer simulation that accounts for all the physical effects that take place within a building, such as radiation, convection, thermal conduction, and phase changes, is called a building energy model (BEM) [16]. Similarly Building Energy Modelling (BEM) and BIM applications like Energyplus can be used to stages like in planning, designing, operating, and monitoring energy management, enabling reliable decision-making. BIM software lets engineers virtually in energy modelling and simulation for real-time energy usage, savings and managing energy load balancing before physical execution and operation begins [14-16]. Building Energy Modeling (BEM) and BIM integration presents a creative way to cut energy use. To maximize energy utilization, this integration integrates data from energy-efficient building automation systems (EBAS) with building information software [15,16,20]. Design knowledge and concepts like having sky gardens/roof gardens, passive cooling/heating design systems, environmentally friendly oriented buildings designs, aerodynamic building form designs and principles, choice of indoor blinds, outdoor facades and glazing [19,20]. Appropriate smart lighting systems programmed glazing systems, insulation, HVAC design and its energy simulation can bring down up to 27% of energy savings of a building [20]. Best suitable technologies were summarized for various entities of a smart city such as usage of sensory devices and IoT to sense the conditions and pass the information to the network gateways which will communicate with each other to adjust to suitable conditions without creating great loads on the energy systems collaborating with blockchain technology [21]. Whereas AI can facilitate the administering and examination of the data generated from machine-to-machine communication in the smart energy automation setup. That also includes that sustainable design principles and energy modelling applications can bring down great energy savings and give a big picture of the energy system of the infrastructure before the physical environments are even built providing real-time data analysis and monitoring during the operation phase of the infrastructure. Smart grids and metering systems play an important role in energy monitoring and auditing practices [21].

4. Current Educational Approaches in CM, CE & Architecture programs

Traditional undergraduate educational programs in Construction management (CM), Civil Engineering (CE) and Architecture do not sufficiently incorporate Smart City principles independently. While the foundations and fundamentals of these programs are essential and required for built environment education, they often fall short to address the rapid technological advancements in relation to smart city concepts. The conventional CM, CE and Architecture programs are not sufficient by themselves and can hinder the students into the energy efficient subjects, but can benefit the students when an interdisciplinary approach is adopted as a core course which will provide the undergraduate students with ability to understand and address the interconnected challenges of energy-efficient urban development without the necessary of pursuing online or supplementary courses outside or post their undergraduate program. Although many educational institutions have begun to offer and exercise smart city, sustainability and energy management programs as major or minor courses of graduate level programs, only a small number of colleges or universities have been able to implement courses which will educate the CM, CE and Architecture program students about energy efficient studies with an interdisciplinary approach [22-31]. A few examples of such popular programs are described in Table 1.

Table 1: Some of the current universities and their programs related to smart cities and energy efficiency

Institution	Level of Program	Major	Minor
Rochester Institute of Technology	Master of Science Degree	Construction Management	Smart Cities
Vanderbilt University	Master of Engineering	Construction Management	Smart Cities
University of Central Florida	Master of Science Degree	Civil Engineering	Smart Cities
Case Western Reserve University	Online Master of Science	Mechanical Engineering	Smart Cities and Infrastructure
Standford University	Master of Science Degree	Sustainable Design & Construction	
The University of Alabama	Online Master of Engineering	Sustainable Smart Cities	
University of Illinois	Bachelors and Masters in Civil Engineering	Civil Engineering	Energy-Water-Environment Sustainability
The Geroge Washington University	Online courses/certifications	Energy Resilience and Sustainability	
University of Colorado	Certification Program	Smart Cities	
University of Michigan	Bachelors in Engineering	Civil/ Environmental/ Materials/ Naval/ Data science/ Electrical	Smart Cities and Infrastructure
University of Pennsylvania	Masters of City Planning	City and Regional Planning	Smart Cities
The University of Oklahoma	Master of Science	Sustainability	Energy and Materials
University of South Florida	Graduate Certificate	Urban planning	Smart City Technology

5. Gaps and limitations in CE, CM and Architecture educational approaches

In the USA, over the past few years, only about one-fifth of students have pursued graduate programs such as master's or PhDs [32, 33]. A significant portion of students who choose to enter the workforce immediately after completing their undergraduate studies are unlikely to pursue a master’s degree unless market demands, or work requirements encourage further education much later in their middle ages. Current smart city and energy efficiency programs offered in many universities offer graduate level courses and some educational institutions offer entirely separate undergraduate programs with urban developments, smart cities or sustainability topics as majors like describe in Table 1. This will create a hinder for CM, CE and Architecture undergraduate in the urban level design, technologies and developments. This will often force students in their final years or recently graduated from undergraduate to highly rely on supplementary online courses or certifications available which may not be cost efficient for all cases. Therefore, there is a need to offer more courses, particularly interdisciplinary ones, to equip students with the skills in energy-efficient urban development.

Methodology

To develop a robust and interdisciplinary curriculum framework for energy-efficient smart cities, a systematic and two-layered approach is adopted [Table 2]. The first step involves conducting a detailed content review of undergraduate programs in Civil Engineering (CE), Construction Management (CM), and Architecture. These reviews have assessed current course offerings, skill coverage, and their relevance to the needs of smart city development. The curricula from Eastern Michigan University (for Construction management and Civil engineering) and the University of Michigan (for Architecture) have been taken as a foundational case study, providing a baseline for comparison and evaluation, ensuring consistency and relevance across programs as listed in Table 3 [38-40]. Following this, a comprehensive literature review has been performed to identify the core competencies essential for smart city development, particularly in the context of energy efficiency. These competencies have included areas such as IoT integration, energy modeling, sustainable urban design, and advanced construction practices. The review has successfully uncovered the need for interdisciplinary skills that bridged application based, technical, managerial, and design aspects critical for equipping undergraduates to address challenges in urban energy efficiency effectively as described in Fig.1. To ground the curriculum in practical applications, case studies of effective smart city projects Amsterdam, Copenhagen, and Songdo have been analyzed [34-37]. This analysis focused on identifying the most effective practices, innovative strategies, and lessons learned from these projects as depicted in Fig.2. The insights gained will inform the curriculum design by incorporating proven methodologies and approaches that align with real-world needs and core chapters of the course. Finally, a curriculum model is proposed which incorporates a core course across all three programs, aligning learning objectives with key skills like IoT, energy modeling, and sustainability. This integrative framework prepares graduates to lead in developing and operating energy-efficient smart cities.

Table 2: Two level data collection and study approach

Data Source	Focus Area	Methods	Expected Outcome
Curriculum Analysis	Syllabi and course structures	Content review	- Identify gaps in courses in relation to Smart City and energy modules - Choose the necessary courses from each program to match the core competencies of smart city and energy efficiency concepts
Case Studies	Smart City projects (e.g., Copenhagen)	Project documentation review and analysis	- Study and filter the practices used for implementing energy efficiency in the three different smart city projects. - Extract best practices for energy efficiency into the curriculum.

Table 3: Strength and limitations of each program based on energy efficiency courses

Program	Strengths	Identified Gaps
Construction Management	Strong in Project logistics and execution	Limited exposure to IoT and energy modeling
Civil Engineering	Solid foundation in infrastructure	Insufficient focus on smart grid applications and design
Pre-Architecture/Architecture	Foundation in sustainable design and energy modelling	Lack of interdisciplinary integration with the two

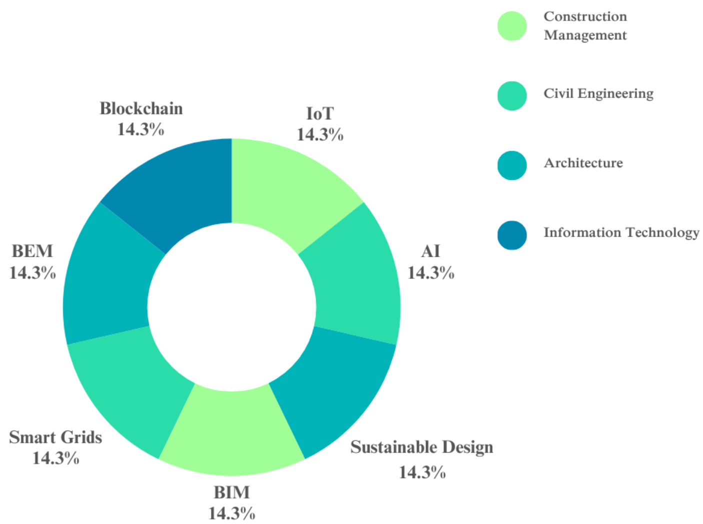

Fig. 1: The need for collaboration among the programs to solve Smart City challenges

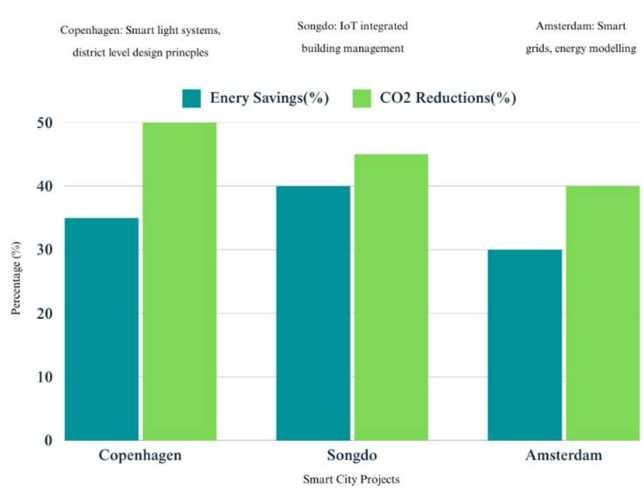

Fig. 2: Best practices for energy efficiency based on popular smart cities.

Results

Finally, a curriculum model mapping with the design course implemented as a core course to all three programs is created to visually represent the alignment of identified core competencies with the learning objectives of the programs. The modules will be implemented as a part of the existing courses and also new course development is also part of the next phase of the study. The new course will be initially an elective course and then it will be implemented as a core course in the curriculum. The total credit hours will be balanced with the university and accreditation requirements. Since a certain credit hour limit cannot be exceeded, the program will be designed with the maximum effort of balancing. The curriculum mapping highlights how specific skills such as IoT, urban design, energy modeling, and sustainability practices intersect with and enhance the educational goals of the programs. It will also illustrate the interdisciplinary nature of smart city development, demonstrating how these programs can work together to prepare students to address the multifaceted challenges of urban energy efficiency. This comprehensive approach aims to foster an integrative educational framework that equips graduates with the knowledge and skills to lead in the development and operation of energy-efficient smart cities.

Proposed Curriculum Model & Outcomes

The curriculum mapping of the construction management undergraduate program is given to explain how the proposed 'Introduction to Urban Technologies & Smart Cities' would fit into the three programs. Curriculum Model Details are given in two parts: Part A and Part B in Table 4 and Table 5 respectively.

Table 4: Curriculum Model Details for Part A

A-1	Introduction to Sustainable Design & Smart Cities: Explore the interdisciplinary nature of Smart Cities, spanning technology, policy, environmental science, and social considerations. Foster collaboration across diverse fields of study to address complex urban challenges. Introduce students to the fundamentals of sustainability, urban resilience, and the principles of Smart City.
A-2	Energy-Efficient Technologies: Develop urban planning strategies to reduce energy consumption, including transit-oriented development, renewable energy integration, and green infrastructure. Incorporate design principles for low-energy buildings, passive design strategies, and renewable energy systems.
A-3	Familiarizing IoT and Smart Grids in Built Environments: Teach how energy efficient building designs and IoT systems contribute to Smart Cities. Provide practical training on IoT devices (e.g., smart thermostats, lighting systems, and power meters) that monitor and optimize energy usage. Equip students with knowledge of energy auditing, monitoring, and the installation of smart grids and metering systems. Explore IoT-driven solutions for real-time data collection and decision-making to enhance sustainability in urban environments.
A-4	The Role of Energy Modeling & Simulation Concepts and Software: Introduce data analytics, energy modeling, and simulation tools to analyze real-time energy usage, project energy savings, and manage energy load balancing. Provide hands-on experience with software such as BIM, EnergyPlus, and other simulation tools for lifecycle energy performance analysis. Demonstrate the use of modeling tools in optimizing energy efficiency during both design and operation phases of buildings.

Table 5: Curriculum Model Details for Part B

B-1	Learning from Case Studies: Analyze successful Smart City projects, such as those in Amsterdam, Singapore, Copenhagen, and Songdo. Highlight practical implementations of energy-efficient practices and discuss the challenges encountered. Encourage critical thinking through comparative studies of various Smart City models worldwide.
B-2	Interdisciplinary Collaboration Capstone Project: Facilitate joint projects involving CM, CE, and Architecture students to solve Smart City design challenges collaboratively. Promote knowledge-sharing and integrated thinking across disciplines. Organize student participation in real-world projects or competitions to develop energy-efficient smart city prototypes.
B-3	Policy and Ethical Considerations: Educate students on global and local energy policies, regulatory frameworks, and their role in Smart City planning. Discuss the ethical implications of implementing Smart City technologies, including data privacy, social equity, and environmental justice.
B-4	Technical Skill Development and Industry Collaboration: Offer practical modules on the following: • IoT integration and energy management systems. • Smart grid technology, including design, implementation, and maintenance. • BIM for energy simulation and lifecycle analysis. Partner with industry stakeholders to provide internships, workshops, and guest lectures
B-5	Evaluation and Continuous Improvement: Assess learning outcomes through a combination of theoretical exams, practical assignments, and real-world project evaluations. Continuously update the curriculum to reflect advancements in Smart City technologies and evolving industry needs

Conclusions

The proposed curriculum framework equips Civil Engineering, Construction Management, and Architecture students with the interdisciplinary knowledge and skills necessary for energy-efficient smart city development. By integrating core concepts such as sustainability, IoT, energy modeling, and policy, the curriculum fosters critical thinking, collaboration, and practical problem-solving. Practical training with tools like BIM and EnergyPlus, alongside case studies and capstone projects, bridges the gap between academic learning and real-world application. Additionally, partnerships with industry stakeholders provide students with exposure to current practices and trends, ensuring the curriculum remains relevant and impactful. Table 6 presents Proposed Curriculum Model and Table 7 presents Sample Student Learning Outcomes.

After the implementations are completed, here are the next steps in the research:

1. Pilot Implementation at EMU

Roll out pilot courses, starting with foundational modules like "Introduction to Urban Technologies & Smart Cities," gradually progressing to advanced topics.

Promote interdisciplinary teaching methods by fostering collaboration among faculty.

2. Outcomes Assessment

Evaluate learning outcomes through assignments, projects, and feedback, tracking students' ability to apply concepts to practical challenges.

3. Industry Collaboration

Strengthen partnerships with industry stakeholders to offer internships, workshops, and guest lectures, enhancing real-world relevance.

4. Continuous Improvement

Refine the curriculum based on pilot results, addressing gaps and incorporating advancements in smart city technologies and policies.

5. Scaling and Application

Use EMU as a case study to adapt the curriculum for broader application.

This phased approach ensures a robust, adaptable curriculum aligned with the evolving needs of energy-efficient smart cities.

Table 6. Proposed Sample Curriculum Model

Proposed Curriculum Model for CM, CE, and Architectural Education Programs					
Model	**Emphasis**	Outcome 1	Outcome 2	Outcome 3	Outcome 4
1. Introduction to Sustainable Design & Smart Cities	Explore the interdisciplinary nature of Smart Cities, spanning technology, policy, environmental science, and social considerations.				
2. Energy-Efficient Technologies	Develop urban planning strategies to reduce energy consumption, including transit-oriented development, renewable energy integration, and green				
3. Familiarizing IoT and Smart Grids in Built Environments	Teach how energy-efficient building designs and IoT systems contribute to Smart Cities.				
4. The Role of Energy Modeling & Simulation Concepts and Software	Introduce data analytics, energy modeling, and simulation tools to analyze real-time energy usage, project energy savings, and manage energy load balancing.				
5. Learning from Case Studies	Analyze successful Smart City projects, such as those in Amsterdam, Singapore, Copenhagen, and Songdo.				
6. Interdisciplinary Collaboration Capstone Project	Facilitate joint projects involving CM, CE, and Architecture students to solve Smart City design challenges collaboratively.				
7. Policy and Ethical Considerations	Educate students on global and local energy policies, regulatory frameworks, and their role in Smart City planning.				
8. Technical Skill Development and Industry Collaboration	Offer practical modules on various energy management systems				
9. Evaluation and Continuous Improvement	Assess learning outcomes through a combination of theoretical exams, practical assignments, and real-world project evaluations.				

Table 7. Sample Student Learning Outcomes

Construction Management Program Students Learning Outcomes	Construction Management Required Courses																		
	CNST 125 - Intro to Construction	CNST 201 - Construction Systems	CNST 202 - Construction Materials	CNST 206 - Surveying	CNST 213 - Construction Safety	CNST 228 - Construction Graphics	CNST 229 - Analysis of Comm. Prints	CNST 302 - Contr. Doc, Reg., & Spec	CNST 303 - Elect., Mech., & Equip. Sys.	CNST 304 - Const. Estimat. and Bidd.	CNST 361 - Planning and Scheduling	CNST 385L4 - Cooperative Ed. In CM	CNST 403 - Production Control	CNST 406W - Construction Law	CNST 412 - Fund. of Structural Design	CNST 436 - Heavy/Highway Const.	CNST 440 - LEED for New Const.	CNST 450 - Fund. of Const. PM	XXX 000 - Intro to Urban Technologies & Smart Cities
1) Create written communications					X									X					X
2) Create oral presentations		X			X	X			X	X	X			X				X	X
3) Create a construction project safety plan.	X				X			X										X	
4) Create construction project cost estimates.	X						X	X	X	X								X	
5) Create construction project schedules.	X										X		X					X	
6) Analyze professional decisions	X	X			X	X	X	X	X	X				X		X	X	X	X
7) Analyze construction documents	X	X		X		X	X	X		X				X		X		X	
8) Analyze methods, materials, and equipment	X	X	X				X		X						X	X			
9) Apply const. managt skills in a multi-disciplinary team.	X						X	X											
10) Apply electronic-based technology			X	X		X	X			X	X		X					X	X
11) Apply surveying techniques				X		X													
12) Understand different methods of project delivery	X							X							X			X	
13) Understand construction risk management.	X				X		X	X					X	X		X		X	
14) Understand construction accounting and cost control.	X							X	X							X			
15) Understand construction quality assurance and control.	X		X				X									X		X	
16) Understand construction project control processes.	X						X						X						
17) Understand the legal implications	X		X		X			X						X					X
18) Understand the basic principles of sustainable construction.	X		X			X		X	X							X	X	X	X
19) Understand the basic principles of structural behavior.		X	X												X				
20) Understand principles of mech., elect. and piping systems.		X				X	X		X										
21) Understand smart cities, energy efficiency, smart grids, energy modelling.		X				X	X		X										X
22) Understand IoT, Blockchain, energu auditing procedure and applications.		X				X	X		X										X
23) Understand interdisciplinary collaboration and work on capstone project.		X				X	X		X										X

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