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**Introduction To Civil Engineering**

**Civil Engineering Major**

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**Introduction**

This chapter starts by defining civil engineering and describes briefly the current and future practices of the different civil engineering disciplines. The historical evolution of each civil engineering discipline is featured prominently in this chapter because it is also important for today’s civil engineers to acknowledge the profession’s trailblazers and appreciate their contributions to the growth of the profession.

We will show how the evolution of civil engineering, as well as other disciplines related to civil engineering, have been shaped by changes in human value systems, interactions between the profession and socioeconomic forces, advances in science and technology, and innovations in materials, equipment, and the like. Civil systems engineering is not a new practice; on the contrary, over the ages, civil engineers or persons serving in that capacity have always executed their work from a systems perspective, perhaps at times implicitly. In this text, we will argue that the civil engineering discipline could be further enhanced if the development of its systems explicitly incorporates new analytical tools in systems engineering.

This is particularly important in the current era, with its high population growth demanding new civil systems and increased need for preserving aging civil infrastructure, at a time when funding constraints are a stark reality, stakeholders are more involved in the development process, and users have higher service expectations.

**Civil Engineering Systems And Their Evolution**

**Answers to Exam Questions.**

1. Discuss any two definitions of engineering and identify the systems engineering concepts that are found in these definitions.

**(a) One of many definition of engineering is the application of science, mathematics, business, and other fields to harness efficiently the resources of nature to develop structures and facilities that benefit the entire society at the current time and in the future. The optimization of resources, is a systems engineering concept, has long existed in engineering practice as can be observed in the above definition. For example, in their definitions of engineering, William Smith utilizes words such as least possible waste and best advantage; Hoover and Fish talk of efficient utilization; Ralph Smith makes reference to optimum conversion; and Boelter uses words like perform optimally.**

**(b) Another definition of engineering is the profession in which knowledge of the mathematical and physical sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the progressive well-being of humanity in creating, improving, and protecting the environment, in providing facilities for community living, industry and transportation, and in providing structures for the use of humanity.**

**Other evidence of systems engineering concepts in the above definitions includes the phrase “ broad range of criteria for analyzing and evaluating engineering systems”, which includes reference to the engineer as one who uses the knowledge in all disciplines, including sociology (Doherty), or one who operates at the border between science and society (Brown). This suggests that engineering is not only a science but also goes beyond the tenets of classical science, and thus in the course of their work, engineers typically examine problems from a broad range of criteria, not just those that are science based.**

**2. Is civil engineering both an art and a science? Explain.**

**Civil engineering is both an art and science as with the case of it being an art is it involves technical drawing and there is a certain level of architecture in civil engineering. Civil engineering is however, a science as it deals with science (i.e.; physics and chemistry) with calculations of forces and performing a lot of calculations and also determining future plans of civil engineering needs the use of science and also Civil engineering is considered a science because its practice is consistent with the key characteristics of the classical scientific method.**

1. **N. W. Dougherty stated: “The ideal engineer is a composite.… He is not a scientist, he is not a mathematician, he is not a sociologist or a writer; but he may use the knowledge and techniques of any or all of these disciplines in solving engineering problems.” Discuss.**

**In as much engineers should have a very good reputable mathematics and science background, but I strongly agree with N.M. Dougherty that an ideal engineer should not be a mathematician, a scientist, not a sociologist or a writer but may use the knowledge and techniques of any or all these disciplines in solving engineering problems. If an engineer working for a certain company is strong in mathematics alone, when the time comes where he has to write a report for a particular project, he may struggle as he does not have a good writing background history and same applies to the other disciplines.**

1. **According to R. E. Hellmund, engineering “brings about the utilization of the materials and laws of nature for the good of humanity.” However, it can be a two-edged sword. Discuss how poor engineering practice could be harmful to society.**

**Poor engineering practice could be harmful to society in one or more of the following ways:**

1. **If waste water is not well treated before joining the nearby rivers, it can make those people who use the river water sick.**
2. **A poor constructed tall structure can collapse and injure or even kill a good number of people.**
3. **A poor built road may cause a lot of accidents and frustrations to society.**
4. **Discuss the sociological changes in prehistoric times that ultimately led to the need for civil engineering structures.**

**With the world’s population increasing on a day to day basis, the sociological changes varies directly with the need of engineering structures as when we are a lot of people in an area, more structures for shelter should be built for those people.**

1. **It is desired to extend an existing rail transit line to serve outlying areas of a large city. Identify the various types of civil engineers who likely would be involved over the life of the system.**
2. **Structural engineers**
3. **Geotechnical engineers**
4. **Material Engineers**
5. **Construction engineers,**
6. **Building engineers**
7. **Environmental engineers**
8. **Transportation engineers**
9. **Architectural engineers**
10. **For any one branch of civil engineering, in your own words, discuss the evolution of that branch over the millennia and how developments in other fields fostered advancements in that branch.**

**Structural Engineering: The field of structural engineering has existed, albeit as an informal discipline, ever since humans first began to build their own permanent structures. At the height of their civilization (6000–2000 BC), the Sumerians in ancient Mesopotamia (present-day Iraq), designed and constructed large, layered platforms called ziggurats for supporting their temples, similar to structures that were built in a later era by the Aztecs of Central America.**

**8. Discuss the differences between any two rival philosophies of civil engineering systems design, citing examples from past civilizations. Include a discussion of your preferred philosophy in the context of civil engineering systems resilience and sustainability.**

**The past few decades have seen dramatic advancements in technology and other fields of endeavor. As a result, engineers have come to realize that robust and long-standing solutions to real-world problems cannot be found using the traditional scientific approach alone. This realization hits home particularly in the area of civil engineering systems, where there exists a strong relationship between civil facilities and their surrounding communities through the natural and built-up environment, community safety, sociocultural fabric, and land use. The importance of the human and societal factors in the development of civil engineering systems is one of the key factors that warrant the inclusion of systems approaches in the development of these systems. Another reason for incorporating systems concepts in civil engineering is the growing complexity of civil engineering infrastructure and facilities. Civil engineering has increasingly seen advances in all phases of project delivery.**

**Fundamental Systems Engineering**

1. **Civil Materials Engineering**

**System’s Attributes**

**Physical component**: The system’s physical component comes in a form Mortar, aggregates, and bitumen being used as binding agents. Also, Civil Material Engineers relate the atomic structure of that material to the properties and performance of the material when it is used in a given application.

**Abstract component**: The branch of Civil Materials Engineering is focused on supporting loads. This branch includes forensic engineering and thus covers the study of the failure of Civil Engineering Systems.

**Goals:** The main goal is to ensure safe and economical support of vehicle weights. The study of Civil Materials Engineering shall include geosynthetics (geotextiles, geomembranes, and geogrids)**.**

1. **Civil Engineering Systems**

**(a) A rail Transit system:**

**- *Physical Component:*** *Railway lines****.***

***- Rules:*** For trains transportation purposes only.

***- The Environment:*** Friendly to the environment.

***- Goals or Objectives:*** Provide mobility around an urban area.

***- Performance:*** Congestion Levels, Accident frequency.

**(b) A Hydroelectric Power Generation System:**

**- *Physical Component:*** Steel sections and joints.

***- Rules:*** For electricity production and its load capacity.

***- The Environment:*** Clean energy and is not polluting to the environment

***- Goals or Objectives:*** Safe and economically friendly and helps in producing electricity cheaply and to prevent flooding.

***- Performance:*** Turbines turn to produce power.

**The University Sport Stadium:**

**- *Physical Component:*** Steel sections and joints

***- Rules:*** Supporting Loads.

***- The Environment:*** Deflection and shear.

***- Goals or Objectives:*** Safe and economical support of live and dead loads.

***- Performance:*** Supports a massive number of people.

**A Pedestrian Timber Bridge Spanning a Large Creek:**

**- *Physical Component:*** Wood and joints.

***- Rules:*** For pedestrians only.

***- The Environment:*** Deflection and shear.

***- Goals or Objectives:*** To make it easy for pedestrians to cross without traffic of cars.

***- Performance:*** The capability to withstand the weights of the pedestrians.

**3.** **A Solution to a Nursing Home that Suffers from Traffic Noise:**

I would recommend that the clinic use a barrier or an enclosure systems approach. Floors, windows, walls and ceilings are all forms of barriers that reduce noise transmission in buildings, so this will surely reduce the transmission of traffic noise from the freeway to the clinic.

**4. Engineering Systems Either they are Physical or Abstract (or both):**

* **A hydroelectric Dam:** This is a physical system.
* **Transportation Logistics Schedule:** This is both an abstract and a physical system.
* **Inputs of the systems:**

**Hydroelectric dam**: *Water and the turning of turbines.*

**Transportation Logistics Schedule**: Data items needed for planning and operating logistics systems obtained from sources like customers, company records, published data and company personnel.

**Outputs of the systems:**

* **Hydroelectric dam:** *The kilowatts (1000 watts) or megawatts (1000 000) watts.*
* **Transportation Logistics Schedule**: *Capital, Labour, material.*

**6. Campus Bus Switching from Gasoline to Hybrid:**

* **I would suggest the campus bus transit corporation must switch from gasoline to hybrid because of the following advantages:**

**1) Hybrid runs cleaner and has a better gas mileage which makes it environmentally friendly.**

**11) A hybrid vehicle runs on a twin powered engine (gasoline and powered motor) that cuts fuel consumption and conserves energy.**

**7. Pure Science being enough for efficient management of Civil Engineering Systems:**

**I strongly believe that Pure Science is not good for efficient management of civil engineering systems because of the following reasons:**

1. Pure science alone would not cover all the management aspects civil engineers need to acquire in order to be effective their managerial decision making purposes.
2. Pure science alone would not challenge engineers to even think more like managers when dealing with critical problems, this may lead to dissatisfaction of employees on how they may be treated.

**8. Being the City Engineer of A large City:**

* **The name of the system of systems I would use would be Network vs Non network systems.**
* **Physical network is the highway network and the abstract network is the construction schedule.**

**9. Banathy’s Quadruple-Domain Presentation of System Theory:**

* **Hierarchical Classification**
* **A civil engineering system may be a system or may be comprised of smaller sub systems. In some literature, this dichotomy may be may be described as high-level systems and low-level systems. High-level systems typically exist at a macro level and comprise a combination of sub systems that are physical or abstract or combination.**

**10. Problem Identifications and Solution to The Problems:**

**Bulembu is my busy street. I would go physically and get to see if there are problems in the street, and if there are problems, I would use network systems to solve the problems at hand. That would be, I would make sure I facilitate the building of proper pavements for pedestrians so that they do not have reasons to be found strolling on the busy road.**

**11. Five Conceptual Design Alternatives:**

**(1) Empathise:** I would need to understand the problem.

**(11) Define the problem**: I would then need to be able to identify the problem.

**(111) Ideate:** I would then need to be able to imagine the whole plan successful.

**(1V) Prototype:**

**(V) Test:** Then the body made will have to be accessed on its efficiency and reliability.

**12. Problem Solving Techniques:**

**13. Branches of Civil Engineering:**

(a) (1) Structural Engineering

(11) Geotechnical Engineering

(111) Environmental Engineering

(1V) Transportation Engineering

(V) Earthquake Engineering

(**b) Three systems of Structural Engineering:**

(1) Dynamic Systems

(11) Static Systems

(111) Complex Systems

**(c) Eight phases of development are:**

(1) Problem identification, needs assessment, establishment of goals.

(11) System Planning

(111) System Design

(1V) System Construction

(V) System Operations

(V1) System Monitoring/ Inspection

(V11) System Preservation

(V111) End-of-life Phase

**(d) Phase three (System Design) and its tasks:**

Engineers describe, analyse, evaluate, select from alternative dimension, materials, configurations, and orientations for the system.

**(e) Systems Approach carrying out its tasks:**

With the systems approach, it can be used for (1) establishments of objectives and constraints, and the alternative options. (11) Analysis including investigation of the likelihood of the impacts of the alternatives in terms of their respective costs and benefits; (111) Statement of the analysis outcomes for each alternative, thus enabling an informed choice of the best alternative; and (1V) ex poste evaluation of the choice after implementation.

**Goals and Objectives of Civil Engineering Systems**

1. **Structural engineering to be taken into account during the analysis and design of the structural system:**
2. The loads and stresses of the pedestrian footbridge.
3. The costs of buying the materials for making the bridge.
4. Additional calculations on the estimated number of pedestrians who will be crossing on the bridge.

(1V) the duration of the time estimates from when construction takes place until the completion of the bridge.

(V) Labour and plant hiring costs.

1. **The Efficiency, Effectiveness, and Equity issues:**

**Effectiveness:** Effectiveness refers to the degree to which the system is achieving the benefits that were intended. It often deals with those benefits that are difficult to express monetarily, such as accessibility, public health, reduction in pollution, public welfare, and community development. With the transit bus system, as one bus leave the other should be loading new passengers and fix all broken infrastructure.

**Efficiency:** Efficiency indicates the extent to which the system is providing some output (often monetary) with respect to some input (also often monetary). It is typically expressed as a ratio or difference of costs and monetized benefits (benefit is often considered to be synonymous with effectiveness). The bus drivers should be loyal with the money received from passengers and should not allow credit so that the efficiency of the system is truly reflected.

**Equity:** This is related to fairness, an important societal value that is also strongly associated with ethics and environmental justice. The owners should be fair when pricing up for the passenger’s journey and it should also yield reasonable profit in return. When civil engineers consider equity-related goals in their decision making, they help ensure that all segments of the population have a fair share in the benefits of their system or that certain segments do not suffer disproportionately from the adverse impacts of the system, regardless of their gender, age, income level, social status, disability status, residential or working location, etc.).

1. **Changes to be recommended in our campus bus transit systems:**

I would make sure the campus bus transit system is tarred and neatly polished as at the present moment it is dusty and full of litter on the ground. I will also provide steel benches so that pupils when they are waiting for the bus to arrive, they can sit and wait patiently for the bus.

1. **Two outcomes**
2. **Objectives of Engineering Systems:**

Reduce the frequency and/or rates of fatalities, injuries, and property damage associated with the use of the system. Reduce the frequency and payment amounts for settling tort cases regarding system use.

**Analytical tools are:**

1. Probability

2. Statistics

1. **Values held by the society could influence the establishment of goals and objectives of civil engineering systems:** The community could been doing farming in our area in a large scale where it can cause the structural delay of Civil Engineering structures. At times, civil engineering systems could cause the closure of activities operated by local people, for example; the construction of a new road could cause formerly built homes to be relocated elsewhere.
2. **Structural Engineering System:**

**Effectiveness:** In my town, the effectiveness of structural engineering system comes in one or more of the following ways; building of new main holes for sewage systems, building of new sports ground for children and guests.

**Efficiency:** The efficiency of the whole system can be thought as the ratio at which each guest pay for using the property as to the dollar invested when building the system.

**Equity:** The equity of the structural system can be measured in terms of making the playground fair for all people. For example, a tennis court must also be designed in a way that it also accommodates disable people when playing tennis.

1. **The expansion of an airport near a suburb:**

**Four stakeholders:**

*(1)* ***Government:*** *The government will ensure the airport is completely built so they get their tax in return.*

***(11) Local Construction Companies:*** *They interested in getting the tender to showcase their engineering capabilities and for a good turnover so as to pay their employees.*

***(111) Employees:*** They are interested in good working conditions and getting a pay (proper wages and salaries).

***(1V) Suppliers of the materials for building the airport:*** They are interested in supplying top quality materials so that the airport is well built at a prize that will yield them reasonable profit.

1. **Systems scholars:**

A number of interconnected components, each of which may serve a different function but all of which are intended for a common purpose. An integrated set of operable elements, each with explicitly defined and bounded capabilities, working synergistically to enable a user to satisfy mission-oriented operations needed in a prescribed operating environment with a specified outcome and probability of success. That is why it is important.

1. **Properties of MOEs:**

(1) **Appropriateness:** The MOE should reflect one or more goal or objective of the overall system or of the phase in question. The drainage network will have to be appropriate for the urban area at hand.

(11) **Measurability:** The MOE should allow the systems engineer to assess quantitatively the impact of each alternative in terms of that MOE. Its performance should be measurable.

(111) **Dimensionality:** The MOE should facilitate measurement of the anticipated level of each performance or other attribute that is associated with the proposed system or action. For example, it should be able to measure the effectiveness of actions using appropriate temporal and spatial dimensions that are consistent with the physical structure of the civil engineering system or the reach of its operations or performance. Also, it should also adequately account for the concerns or perspectives of stakeholders. The MOE should be comparable across different geographic regions or time periods. Its dimensions should also be outlined and mapped.

(1V) **Realistic:** It should be possible to extract or generate useful and reliable data that are related to the MOE, without undue cost, effort, or time. The drainage network must be realistic and itself must be attainable.

(V) **Defensible:** The clarity and conciseness of the MOE should be such that using that MOE, the system can be easily assessed and interpretation of the MOE and its levels can be effectively communicated among decision makers and to an audience of technical and nontechnical personnel as well as the general public. Often, this is possible when the MOE is simple enough to permit a determination of its suitability for a given system under various present and future design and management scenarios.

**Tasks Within the Phases of Systems Development**

1. **Seven Phases of the development of a footbridge:**
2. **Tasks at the needs Assessment Phase:** In this phase of needs of assessment, civil engineers address the question of whether there is a need for a new system. Such system of constructing the footbridge is driven by population growth and other forces, the system either in terms of the raw numbers of users or in terms of some derived quantities.
3. **Tasks of the systems Planning Phase:** At this phase, the engineer faces a wide range of tasks, including the evaluation and selection of an appropriate location footbridge which is the civil engineering system at hand. For a proposed system, the tasks encountered at this phase include a specification or establishment of an overall system set-up that would ensure harmony with its natural or man-made environment so that;
4. The system construction and operations would cause minimal disruption to the environment.
5. The environment would cause minimal disruption to the construction, preservation, and operations of the system.

* In carrying out the tasks, the engineer pays close attention to issues relating to ecology, aesthetics, the context sensitivity of the plans, and the functional relationships that are expected to exist between the proposed system and its environment.

1. **Tasks at the System Design Phase:** According to the Accreditation Board for Engineering and Technology(abet), design is the process of devising a system, component, or process to meet desired needs. ABET uses science and mathematics for analysis, synthesis, testing, and evaluation of a civil engineering system.

* Firstly, the engineer will need to describe the physical designs of the footbridge which he can do it by the use of visual media such as artists’ sketches blueprints, or computer simulation.
* If the physical structure of the footbridge is expected to change over time, the engineer may need to predict the future physical of the footbridge at a specified future time.
* Secondly, the engineer will need faces the tasks of analyzing the design. This requires domain knowledge in that branch of civil engineering.
* For example, in structural engineering, this could mean determining the magnitude of the different stress modes, such as bending moments, shear forces, and torsional force in each structural member of the physical structure.

1. **Tasks at the System Construction/ Implementation:** At the construction, installation, or implementation phase, the engineer faces tasks that are similar in purpose to those of the preceding phases.

* As a pre-lude to the evaluation and selection of the optimal construction process, engineers often face the tasks of describing the process intended for the construction before that phase is carried out.
* In such descriptions, involve not only the construction process, but also may involve initial and more fundamental issues such as description of the alternative contracting approaches that could be used when constructing the footbridge.
* In the construction of the footbridge, the engineer will need to ask himself/herself on which alternative will yield the highest benefits at lowest costs?
* What is the best mix of resources (equipment, materials, and labour) and timing of work to achieve each task of the construction process?

1. **Tasks at the System Operations Phase:** A system is said to be in operation when it is being used for its intended purpose. For example, a physical system, such as the footbridge, commences its operations phases when its construction is completed and is commissioned.

* Engineers are constantly engaged in carrying out various tasks consistent with the operations of the footbridge.
* Engineers utilize a variety of analytical tools and domain knowledge from traditional tasks to generate information for the tasks of evaluation and decision making.

1. **Task at the System Monitoring Phase:** In this phase engineers do not implement physical transformation.

* It runs parallel to the systems operations phase because it commences just after the system construction and continues until the system construction reaches the end of its life.
* The system comprises of two aspects namely:

1. Measuring the system’s usage

(11) Inspecting the condition of the system.

- At this phase, engineers undertake the tasks of describing the intended plan for the system usage monitoring or physical inspection.

- The tasks involving analysis include determination of the minimum sample size needed to achieve a certain degree of precision in the usage or performance data collected or the reliability associated with the intended future data collection scheme.

- At this phase, the engineer may encounter the task of evaluating, monitoring, or inspection alternatives and selecting the most cost-effective one for implementation, either for a specific system or for an entire system of system.

**(g) Tasks at the System Preservation Phase:** The engineer will need to have skills on how to preserve the footbridge when it is now in implementation stage.

- At this phase, the engineer must be able to describe the existing condition of the system, the past trends of the deterioration, and expected future deterioration trend as a function of usage, climate condition, age, or other deterioration factors.

- The engineer is tasked with establishing and documenting the possible preservation options for the footbridge.

1. **Three Models at Phases of a Civil Engineering System:**
2. The Stark Classification: Iconic Models; Are scaled version of the real footbridge. Relevant properties of the footbridge are represented by the same properties in the model.

**3** (a) Probabilistic models are considered to be more superior than deterministic models because they are more robust and less precise.

1. Descriptive models are stochastic differential equations whilst prescriptive models are stochastic programming equation.

|  |  |
| --- | --- |
| **Descriptive models** | **Prescriptive models** |
| Difference equation | Linear Programming |
| Differential Equation | Integer Programming |

**4 Scopes for the Civil Engineering System:**

1. **Geographical Scope:** In the task of a civil engineering system which is the construction of the footbridge evaluation, it is important to establish a study area because the geographical or spatial scope of impacts can influence the analysis results of the footbridge.
2. **Temporal Scope:** A civil engineering system may have impacts that lasts only a relatively short time, or may endure for many decades.

* The temporal scope for the construction of the footbridge will have both short-term and long-term impacts, as during construction of the footbridge, heavy machinery will be making a lot of noise and a lot of dust will surely rise to the air. But after construction is implemented, the footbridge will surely last for a very long period of time and will be economically friendly.

**5. The feedback task from a general view point:**

It is an important task for the development of civil engineering systems as presents an opportunity for engineers to refine their work at any phase based on the success and failures of precedent or altered phases.

**Conclusion**

**I have learnt that the Civil engineering major consists of a various forms of engineering disciplines namely; structural engineering, environmental engineering, hydraulic engineering, materials engineering and Construction engineering to just name a few.**

**I have learnt their evolution and how these engineering disciplines were born. I have learnt the different forms of civil engineering definitions. I also learnt why engineers needs not only mathematics or science but other disciplines like writing and good communication skills as they may need these other attributes for other projects with the mathematics and science.**

**I will surely use this knowledge acquired in my job as I work as an assistant civil engineer in Bulembu, in the Kingdom of eSwatini.**

**Bibliography of the Exam**

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