



BEAMCity BuildIt

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Fields of Interest: Civil Engineering, Physics

Brief Overview:

Mentees will explore the realm of city planning and aspects of civil engineering. They will be designing their own city layout with zones for residential, industrial, and agriculture as well as a metro system.

Agenda:

- Introduction (5 min)
- Module 1: “This is the Land of Your People” (10-15 min)
- Module 2: Subway Surfers (10-15 min)
- Module 3: “This is Not the Land, this is Glendale” (20-35 min)
- Conclusion (5 min)

Main Teaching Goals/Key Terms:

- Zoning
 - ◆ Agricultural zone
 - ◆ Residential zone
 - ◆ School zone
 - ◆ Industrial zone
 - ◆ Environmental/Recreational zone
 - ◆ Business zone
- Terrain
- City Blocks
- Connectivity
- Stations
- Subway Lines
- Coverage
- Density
- Green Space
- Sustainability
- Green Roofs

Background for Mentors

Module 1

- Zoning
 - Agricultural zone
 - Residential zone
 - School zone
 - Industrial zone
 - Environmental/Recreational zone
 - Business zone
- Terrain
- City Blocks

Zoning is a practice civil engineers use to divide land into specific areas for different purposes in order to reduce conflict, improve safety, and increase efficiency. For example, an **agricultural zone** is meant for farming and food production, while a **residential zone** is designed for housing. A **school zone** prioritizes student safety and accessibility, and an **industrial zone** is set aside for factories or manufacturing, often placed away from homes due to noise or pollution. **Business zones** support economic activity like offices and stores, while **environmental/recreational** zones preserve green space, parks, and natural resources for community health and sustainability (touched upon in module 3).



Figure 1: Urban planning zoning diagram

Terrain plays a major role in planning because the shape and features of land (mountains, rivers, flat areas) affect where and how construction and partitioning of zones in a city can occur. San Francisco is a prime example of a nearby city with poor terrain considerations, highlighted by infrastructure planted on a fault line and steep hills. Also a familiar concept may be **city blocks**, which organize buildings into structured groupings surrounded by streets, helping cities stay navigable and systematically arranged.

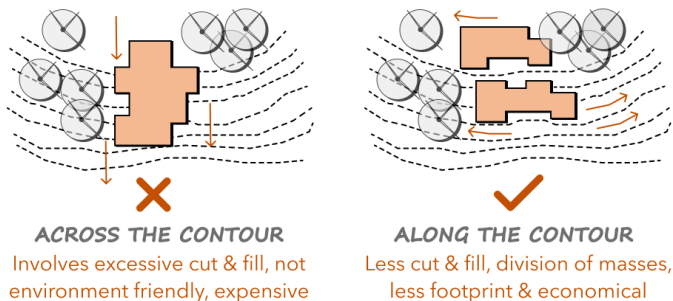


Figure 2: City planning with terrain in mind

Background for Mentors

Module 2

- Connectivity
- Stations
- Subway Lines
- Coverage
- Engineering Design Process

Connectivity isn't just about getting from point A to point B. It also influences where people choose to live, where businesses locate, and even how a city develops over time. It can be thought of as how easy it is to reach a broad range of destinations using the transit network without having to go far out of the way or getting "stuck" due to a missing link. Well-connected cities tend to be more equitable, as residents can access jobs, schools, and services more easily, while poor connectivity can isolate communities (elaborated in the "coverage" definition).

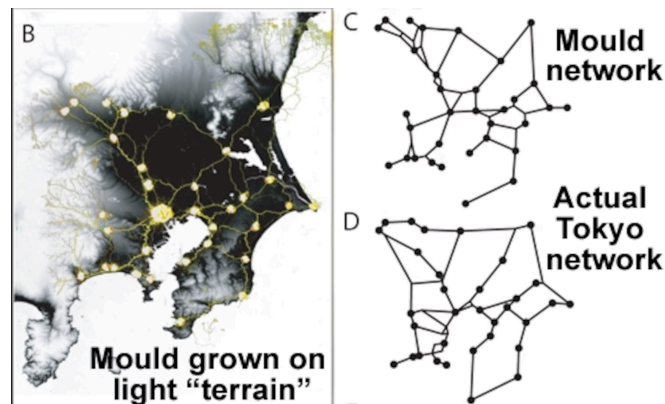


Figure 1: Yellow slime grows in a pattern similar to the Tokyo railway system, depicting the efficiency of the city's public transit system.

Subway lines and **stations** are the backbone of urban transit. A subway line is a specific, individual route taken by trains differentiated by color, letter, or number to connect points in a city along a defined corridor. Stations are designated places along a subway line/route in which passengers can board and depart. Designing these aspects of transit requires careful planning: lines must balance direct routes with coverage, and stations need to be placed strategically to serve high-demand areas without overcrowding.

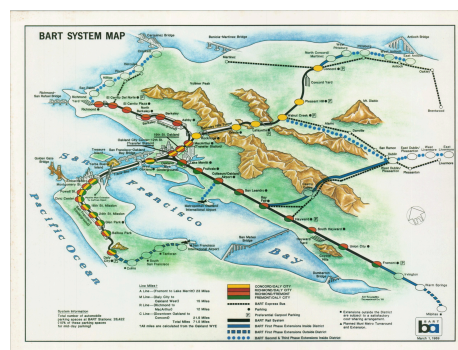


Figure 2: BART system map

	Coverage, or the geographic range that the transit system covers, is a critical measure because it determines which neighborhoods benefit from public transit and which may remain underserved. A critical historical example of poor coverage again lies in SF in the 20th century, specifically in Bayview-Hunters Point. This predominantly Black and low-income community remained physically isolated from the rest of the city by freeways, industrial operations, and other infrastructure. For a majority of the 20th century, Bayview-Hunters Point lacked any rapid transit connection, while the rest of San Francisco gained MUNI and BART access, effectively cutting residents off from economic opportunities. Urban planners or public transit officials often utilize the engineering design process, which is the trial-and-error process by which engineers test and refine the design of their invention or concept repeatedly before finalizing the most effective version of it.
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Background for Mentors

Module 3

- Density
- Green Space
- Sustainability
- Green Roofs

As cities are built up, **density** refers to how many buildings or people are in a given area, influencing traffic, housing availability, and infrastructure needs. Balancing infrastructure with livability, **green spaces**, such as parks, gardens, and natural areas, provide more than aesthetic value. They can help improve air quality, reduce urban heat, support mental and physical health, and create spaces for community interaction. **Sustainability** in urban planning focuses on meeting present needs without compromising the ability of future generations to thrive, which involves careful management of resources, energy use, and environmental impact.

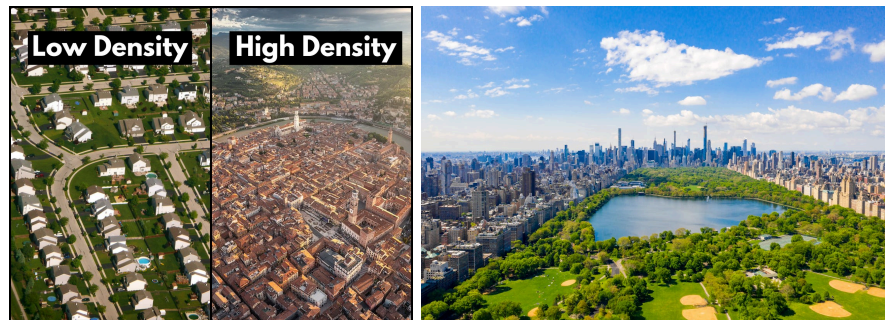


Figure 1: Density comparison and New York's central park - an example of greenspace in a city that works to break up dense infrastructure.

Green roofs are a practical application of sustainability, where vegetation is planted on building rooftops to reduce stormwater runoff, improve insulation, and lower energy consumption while providing additional habitat for urban wildlife. Together, these strategies reflect how engineers and planners integrate environmental, social, and economic considerations into the design of cities, highlighting the trade-offs and innovative solutions needed to balance growth with ecological and human well-being. Green spaces, sustainability, and green roofs are all central to designing cities that are healthy, resilient, and livable.



Figure 2: Green roofs in cities

Introduction

Cities are usually carefully designed using engineering and planning principles. In this lesson, mentees will explore how zoning, transportation, and land features shape how people live and move through a city. By designing their own city, mentees will see how engineers balance creativity, problem-solving, and sustainability in the real world.

Concepts to Introduce ● City Design ○ Explain that city design is planning where everything in a city goes so people can live, work, and travel easily. You can compare it to designing a board game map where everything needs space and clear paths. ● Civil Engineering ○ Describe civil engineering as the type of engineering that builds things people use every day, like roads, bridges, buildings, and subways. ○ A good example is asking mentees to name structures they used that morning.	Questions to Pique Interest ● How did you get to school today? ● What are some nearby structures you see near your school? ● What do you think would happen if a city had no rules about where buildings could go? ● If you were designing a city, what would you build first?
Scientists, Current and Past Events ● Bo01 in Malmö, Sweden, was planned as a model of sustainable urban design with renewable energy and green spaces to make city living healthier and more eco-friendly. Planners focused on how people, nature, and buildings can live together in balance. ● San Francisco is an example of city design that didn't factor terrain into the design.	Careers and Applications ● Civil Engineer ○ Civil engineers design and build infrastructure that cities depend on every day, such as roads, bridges, buildings, water systems, and public transportation. ● Architect ○ Architects design buildings and spaces that are functional, safe, and visually appealing.

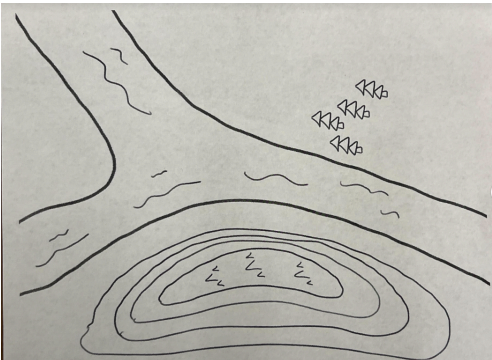
Module 1: “This is the Land of Your People”

Mentees will utilize the allotted terrain to design a city with proper zoning to create their own city blocks.

Teaching Goals 1. Zoning: The process of sectioning a landscape into different areas made for specific uses or purposes. ○ Agricultural zone ○ Residential zone ○ School zone ○ Industrial zone ○ Environmental/Recreational zone ○ Business zone 2. Terrain: The shape and features of the land, like whether it is flat, hilly, rocky, or mountainous. 3. City Blocks: Groups of nearby buildings with similar purposes.	Materials ● 1 Landscape Map per mentee ● Pencils
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Different Methods for Teaching

- 1. Zoning - Home Zoning analogy**
 - a. “Home Zoning”: You want a bathroom, kitchen, bedroom, etc.
 - b. Recognizing **the things you need** and **how much space you have**
- 2. Terrain - Discussion!**
 - a. **Questions to Ask:** “How would you describe the terrain we live in?” “Have you ever been to San Francisco? What was the terrain like?” - Expect them to say hilly

Procedure - Each mentee is given a printed landscape map showcasing terrain features such as mountains and rivers. a. Note: the circular rings on the bottom of the map is a topographical representation of a hill/mountain range/elevated area. This is not a teaching goal, so you can just describe it as a mountain range when showing mentees the map. - Mentors should hold a classroom discussion about “What are some things you might need in a city?” “What zones make up a city?” and	 Figure 1: Empty landscape map
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“Where should cities be built?”

3. Mentees use markers to draw and section out on their map industrial zones, agricultural zones, residential zones, recreational zones, school zones, and business zones.
4. Mentees should be encouraged to think about how they might want to structure their zone to account for terrain. (For example, building a neighborhood directly over a river might be a bad idea, but an agricultural zone could benefit from the nearby water source!)

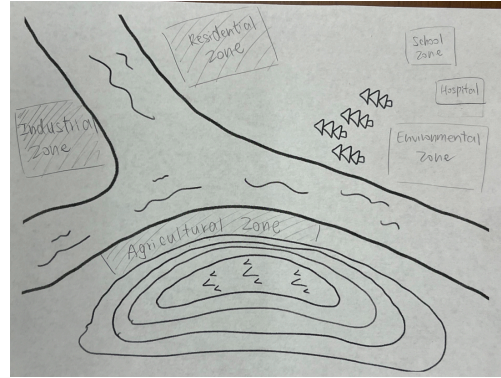


Figure 2: Zoned landscape map

Classroom Notes

Mentees do not have to include all the provided zones! For younger sites, focus on Residential, Agricultural, and School zones (potentially industrial zones as well).

Module 2: Subway Surfers

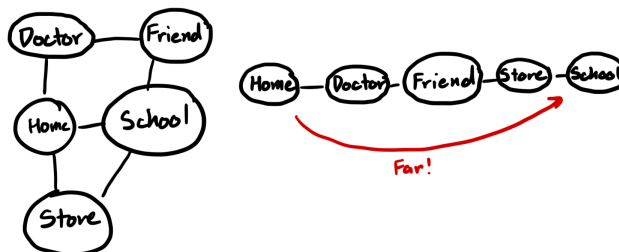
Mentees add a public transit element to their cities and construct a tactile representation on their map, drawing connections to the BART system.

Teaching Goals 1. Connectivity: How easily people can travel from one place to another. 2. Stations: Places where people get on and off the subway. 3. Subway Lines: The routes that subway trains follow. 4. Coverage: How much of the area the subway reaches. 5. Engineering Design Process: A series of steps that engineers follow to come up with a solution to a problem, usually including multiple stages of trial and error.	Materials • 1 Transparent Sheet Protector • Dry Clean Markers • Multicolored Pipecleaners • Glue dots • Multicolored Mini Stickers
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Different Methods for Teaching

1. Connectivity + Coverage – Equitability:

- Emphasize the fact that connectivity and coverage are key for a city that is both fair and efficient.
 - You could visualize this with a model on a whiteboard (if available) that illustrates the need for developed and widespread connectivity and coverage.



2. Subway Lines + Stations - BART in your backyard!:

- The mentees are likely to be familiar with the BART system, which is a prime example of a public transport system that connects very disjointed regions of land. Have the mentees think about their backyard transit system when describing subway lines and stations.
- Question to ask mentees: “How many stations should we have for our subway?” Ask them the pros and cons of very close versus very far stations. Things to consider: Convenience, resources to build stations, clutter, etc.

3. If possible, drive home the Engineering Design Process!

- The beauty of this module lies in reiteration. If your mentees are advanced enough, praise them for practicing the engineering design process with their trial

and error.

Procedure

1. Mentees will receive a transparent sheet protector to slot their map into.
2. With white board markers, mentees will design a subway system for their city using the Engineering Design Process.
 - The Engineering Design Process is a natural process of iteration, so mentees should be encouraged to erase and redraw their subway lines as they edit the designs of their city!
3. Design subway system based on a ruleset (can adjust based on site age group):
 - One route can only connect one zone of the city to another
 - Entire subway map should connect the entire city
 - Each line must have stations. Big stations can have multiple subway lines.
4. After their subway map is finalized, mentees will glue pipe cleaners of *different colors* to represent their subway lines with glue dots. Use multicolored mini stickers to represent subway stations.

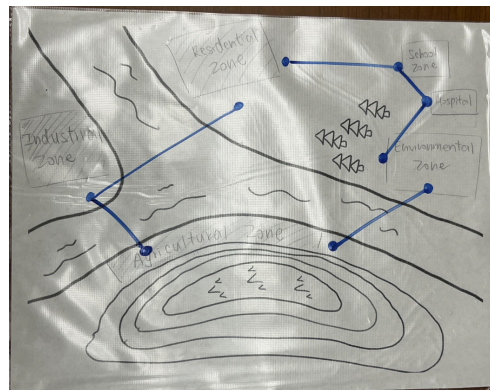


Figure 1: Subway map drawn with dry clean marker

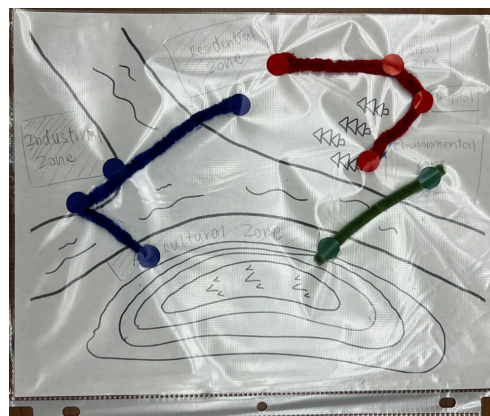


Figure 2: Completed subway system

Classroom Notes

If pipe cleaners are too long for a specific subway line, consider bending them to the appropriate length and then twisting them around themselves to secure them. **Pipe cleaners can have pointy ends, so warn mentees to be safe!** Gluedots can be finicky to work with, make sure mentees only start using them when they are absolutely sure of their subway design! **If this is your first site and you anticipate running short on time – you can skip this module.**

Module 3: “This is Not the Land, this is Glendale”

Mentees will create a 3D map of the designed city. They will also add green space to their city with sustainability principles in mind.

Teaching Goals 1. Density: How many buildings are in a certain area. 2. Green Space: Areas with plants and trees, like parks or gardens. 3. Sustainability: Using resources in a way that protects the environment for the future. 4. Green Roofs: Roofs covered with plants.	Materials (per mentee) ● 3D Printed Mini Buildings ○ 3-4 Houses ○ 1 Hospital ○ 1 School ○ 2 Skyscrapers ● 6 Green Pompoms ● Glue dots
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Different Methods for Teaching

1. Density - The word in different contexts:

- a. Older mentees: Can connect it to the physics definition of density, how compact something is in a given space
- b. Physical Demonstration: Have mentors stand far away from another (pretend they're buildings!), and talk about how as they get closer, it becomes more dense

2. Why Green Space?:

- a. Questions to ask: “What are the benefits of having plants and trees?” “Have you been to places that don't have many trees?”
 - i. Possible answers: Cleaner air, makes people happy, adds color!

3. The New Age Problem – Sustainability:

- a. Depict the pollution problem: cities with poor sustainability: Smog, trash everywhere, dirty – how might we fix this?
 - i. You can describe sustainability as being thoughtful/careful with how you use your resources!
 - ii. Questions to ask: “What can we do to increase sustainability? What are some examples of sustainability?”
 1. Not wasting food/water, cleaning up trash, planting trees

4. Green Roofs: Motivation

- a. Illustrate some of the thoughts behind integrating green roofs. For cities that are really dense and have a shortage of usable land space, they can still be made sustainable + add green space.
 - i. Question to ask: “We don't have any space in our city for plants/trees! How can we still add greenery to our city?”
 1. Some mentees might say, “Take away some buildings and replace them with trees!” This often isn't practical and might be more damaging...

Procedure

1. If not yet done, mentees will draw in green zones onto their maps to finalize their city design/blueprint.
2. Mentees will then add 3D structures to their finalized maps!
3. Slip in a piece of construction paper into the translucent folder for more stability.
4. Glue on materials to represent large or important structures.
 - Green cotton balls (shrubbery/greenery, agricultural zones, or green roofs)
 - i. Cotton balls can be added atop structures for green roofs!
 - 3D-printed houses, schools, hospitals, and skyscrapers
5. Mentees will take their maps home! Have a show and tell!



Figure 1: 3D Printed Buildings glued on



Figure 2: Added green space and green roofs!

Classroom Notes

When using glue dots, please place the glue dot down while it is still attached to the strip, then slowly peel back the strip. **Please demonstrate to mentees how to use glue dots prior to passing them out to avoid catastrophe!**

Conclusion

Mentors should invite mentees to briefly share their city designs, highlighting one zoning choice and one feature of their subway or green space. Wrap up by connecting the activity to real-world city planning, emphasizing how engineers use design, trade-offs, and creativity to make cities functional, sustainable, and livable.

References

- Create A City: An Urban Planning Exercise, Gale Ekiss, Arizona State University.
<https://geoalliance.asu.edu/createcity>

Summary Materials Table

Material	Amount per Site	Expected \$\$	Vendor (or online link)
Landscape Map	1 per student		McL
Pencils	1 per student		McL
Transparent Sheet Protector	1 per student		Amazon
Glue Dots	3-4 per classroom		McL
Multicolored Pipe Cleaners	3-4 per student		Amazon
Multicolored Mini Stickers	6 per student		Amazon
3D Printed Mini Buildings			Zach
Green pompoms	4 per student		Amazon