Case Study:

Expansion of Lifeline Services in Colorado Springs, CO

Instructor Guide

Disclaimer: While this case study uses actual system data available from Colorado Springs Utilities, the scenario is completely fictional. Beyond the use of this data, no actual persons, organizations, entities, or project proposals are used.

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Abstract

Students, by virtue of the fact they have used the infrastructure their entire lives, are familiar with it. Many, however, struggle to define, describe, and explain it, particularly if they have to do it concisely and for audiences with different levels of knowledge. This challenge is particularly problematic because problem solving methodologies begin by understanding, visualizing, and describing the current state of the system. This case study is an exercise in describing and assessing the current state of three lifeline infrastructures in Colorado Springs, Colorado. The goal of the exercise is not to produce a fully complete description of the Colorado Springs infrastructure, but rather to reduce a very large amount of data to a manageable and meaningful description of the system. Once described, the students will assess the Demand/Capacity ratio of each infrastructure. While the case study is placed in the context of a discussion in infrastructure expansion, the students focus on describing and assessing the current state of the infrastructure, not planning the expansion.

Colorado Springs, CO was selected as the target community because it is a metropolitan region that is large enough to challenge the students but not so large as to overwhelm them. Additionally, there are many regions of similar size that face similar challenges throughout the nation so it provides a classroom exercise that prepares them for something they might actually do after graduation. Finally, sufficient information is available in an appropriate format to support the case study. The same case study could be adapted to any city or metropolitan area by simply changing out the reference data and changing the script to reflect the new location.

Case Study Objectives

1. Use the Component Model as a framework for understanding, visualizing, and describing the electric, water, and wastewater infrastructures in a metropolitan region.

2. Assess the current demand/capacity ratios of these infrastructures and quantify the capacity to support growth given the existing system.

3. Present a description of these infrastructures that is technically correct, useful for facilitating discussions on system expansion, and accessible to all audiences.

Instructor Guide

This section contains notes for the instructor on introducing and executing the case study. Additional sample questions and discussion prompts are provided for the discussion period. This section should not be provided to the students because too much foreknowledge of the discovery process can inhibit learning.

General Case Study Notes:

Students, by virtue of the fact they have used the infrastructure their entire lives, are familiar with it. Many, however, struggle to define, describe, and explain it, particularly if they have to do it concisely and for audiences with different levels of knowledge. This challenge is particularly problematic because problem solving methodologies begin by understanding, visualizing, and describing the current state of the system. This case study is an exercise in describing and assessing the current state of three lifeline infrastructures: water, wastewater, and electricity. It is important to note that the goal of the exercise is not to produce a fully complete description of the Colorado Springs infrastructure, but rather to reduce a very large amount of data to a manageable and meaningful description of the system. Students will not be able to find all the information they want, but that leads to good questions in the discussion period. A good execution of the case study leads to comments like "I wish we had more time to explore_____" and "Wow, I'm amazed that we could get a reasonable description of so much stuff in so little time."

Colorado Springs, CO was selected as the target community because it is a metropolitan region that is large enough to challenge the students, but not so large as to overwhelm them. Additionally, there are many regions of similar size that face similar challenges throughout the Nation so it provides a classroom exercise that prepares them for something they might actually do after graduation. Finally, sufficient information is available in an appropriate format to support the case study. The same case study could be adapted to any city or metropolitan area by simply changing out the reference data and changing the script to reflect the new location.

Students may want to jump right in to solving the problem, which, by the way, has not been defined yet, so the instructor should keep the students focused on first describing the infrastructures, then assessing their demand to capacity ratios. By the end of the case study, students may start to comment, "Hey, the problem is really with this element right here. There is sufficient capacity for expansion in all the functions but this one." If this happens, then the case study was successful.

Demand Capacity Ratios

For those unfamiliar with the term, a 'demand to capacity ratio' or D/C ratio is exactly what it sounds like. Take the system demand or requirement and divide it by system capacity. The result should be a number less than or equal to 1.0. This is a useful tool is assessing the ability of an infrastructure to support growth. If the D/C ratio is 0.8, then a 20-percent increase in demand

can be supported. If the D/C ratio is 0.99, then the system cannot support growth, and if the D/C ratio exceeds 1.0, then the system is overloaded and is probably experiencing failure. If not covered previously in the class or curriculum, be sure to introduce this concept to the students as it plays a role in the case study.

Introducing the Case Study

This discussion is suggested for the lesson before the case study is assigned to introduce the students to the challenges of the case study. If not done beforehand, it can be used as an introduction on the case study lesson.

Before they are challenged to actually do so, students often overestimate their ability to accomplish simple sounding tasks like "describe the water infrastructure". A good way to present this challenge and set up the case study is to pose the question: "You are at a party on the 20th floor of a building and the governor is in attendance. When it is time to go, you find yourself chatting with the governor as you wait for the arrival of the elevator. As you board the elevator, the governor says to you, "So, you are in the infrastructure business and that is something I don't really understand well, but need to. Can you explain the water infrastructure to me before we get off this elevator?" Most people, even those knowledgeable about the water infrastructure will struggle to do this in 90 seconds. Ask a student to try and see how he does.

If the student does well, offer congratulations, if poorly, thank him or her for having the courage to try. Then explain that this is a very difficult task and that the purpose of this case study is to be able to perform that difficult task well. Furthermore, all problem solving processes begin with some description of the existing state of the system. The tools used to explain an infrastructure to the governor are also useful for understanding, visualizing, and describing to stakeholders interested in the problems and the project team trying to solve the problems. This is the case study we will do today/next lesson.

The authors of the West Point Infrastructure Models used in the case study are always interested in discussing them with those who have used them. Please contact the lead author, Dr. Steven Hart at hart.engineering@yahoo.com for more information or with feedback.

Student Preparation and Homework

With only three hours available for the case study, the students must be prepared to accomplish all objectives. The models used for the case study are explained in the referenced reading. Thirty minutes of preparation is ample time to read and digest the paper. If this case study is used in conjunction with the *Designing Resilient Infrastructures* course, then the students will have already been introduced to the models. If not, ask the students to read the paper, then spend 30 minutes developing a description of the natural gas infrastructure of the United States. This particular infrastructure is suggested because most students have only a passing familiarity with it and there is a wealth of information available on the internet. If students do not come to class with a basic understanding of the models, then it is unlikely that the case study will be successful.

Infrastructure Problems as Social Problems

One important point to stress in the introductory discussions, and throughout the case study, is that "infrastructure problems are social problems" that have strong technical, scientific, financial, and regulatory dimensions. The problems are social problems because infrastructure serves a societal need. Failing to understand this characterization of the problem results in the selection of inappropriate problem solving techniques or proposals of unacceptable solutions. If a student doesn't seem to accept his, offer the following: "I can solve all your water, wastewater, trash, and electricity issues for the next 100 years, but to do so I'm going to have to put a nuclear reactor next door to the elementary school, tear down the county courthouse on the town square, and put solar panels over all the city parks." People will almost immediately say "NO!" without ever getting to the technical, scientific, financial, and regulatory dimensions because the solution does not describe a community they want to live in. As students progress through the case study, continually prompt them to go deeper into how their visualizations and descriptions address concerns cover the social, political, financial, and technical dimensions.

Team Organization—assigning teams or self-selection

It is recommended that the students be allowed to self-organize into the three teams. Students tend to self-organize for a variety of reasons, but they tend to forget selection based on diverse skills and abilities. Self-selection then leaves open the opportunity in the discussion period for the question, "Who would you have like to have had in your group but did not?"

Team Organization—small vs large class

Each team is ideally three or four students. Fewer, and the team will struggle to complete the requirements; more, and then the chance for free-loading increases. Accordingly, if the class has more than twelve students, there will be more than one team addressing this issue. It is better to have multiple teams working on a particular infrastructure than to have a large team with under performers. If there are multiple teams working the same infrastructure, select the best team (or perhaps the worst team if a point needs to be made) to present.

Optional 4th utility: Colorado Springs Utilities is also the local natural gas provider. Depending on class size, a fourth team could be established to perform the same analysis on the Natural Gas system. All necessary information for the case study is available on the CSU website.

Team Organization—assigning or not assigning leadership roles

Though not required, it may prove beneficial to the class to assign two students to the roles of Inga Neer and I.B. Rich. To successfully play these roles, the participants should consider the perspectives that each of these two different individuals bring to the discussion. Though they are friends, colleagues, and co-chairs, they might have differences of opinion as to what should be presented, how it should be presented, and what should be emphasized. To keep Inga and I.B. from interfering with the teams as they do their work, consider assigning them a task appropriate for committee co-chairs like writing a 500 word op-ed to submit to the local newspaper or a two

page position paper to submit to the governor. Whether or not this is done really depends upon the students. This would be a challenging task for good students and beyond most average ones at this point in the course, though hopefully all should be able to do it by the end of the course. The instructor should only do this if there would be a clear benefit to students and the course.

Scheduling and Time Management

Time management is essential to the execution of this case study as the objectives cannot be achieved if the students do not get to the descriptions. Student preparation by reading the assigned article and familiarizing themselves with the reference material is essential to timely completion. The following timeline is recommended:

0-10 minutes	Case Study Introduction
10-20 minutes	Case Study scenario presentation and requirements definition
20-30 minutes	Team organization
30-120 minutes	Research and slide preparation
120-150 minutes	Team Presentation
150-180 minute	Instructor facilitated discussion and assessment

Instructor role during the case study;

Once introduced, this is intended to be a student-driven case study with the instructor's role being mainly to keep the students on task. With 90 minutes for research, some will move off task. For those that think they have completed the tasks with time to spare, challenge them to go deeper. Ask questions like:

> "How would a gas station owner, a home building contractor, a stay at home parent, a single parent living below the poverty line, or a *insert your stakeholder of interest here* see this issue and understand yourr presentation?"
>
> "How does your description address social, political, economic, and technical considerations?"
>
> "Is your presentation both technically correct and accessible to all audiences?"
>
> "Do you think the people in the back of the room can read your slides?"

These questions can also be revisited in the discussion period. Additionally, observations of the student discussions will most likely generate questions that should be raised during the discussion period.

Student Presentation

One of the most effective means of evaluating the student presentations is to get three people, preferably of very diverse backgrounds, to sit in on the final presentation to play the role of the

citizens of Colorado Springs. They could then provide feedback on the clarity of the presentation.

Discussion Period

The purpose of the discussion period is to get the students to assess their work and figure out how they can do it better next time. The instructor should prompt with questions and encourage students to do most of the talking, discovery, and learning. Suggested prompting questions include:

All questions listed in the section above

"So, how did you do?"

"To what degree did you achieve the learning objectives?"

"What was the hardest part of the case study? …the easiest?"

"To what degree did your presentation achieve Inga and I.B.'s purpose and intent?"

"One important function of leadership is to make sure the right people are sitting at the right table during the problem solving process. If you had access to anyone in the Colorado Springs area, who should be sitting in each team for this case study?"

"Did the models help or hinder you in the process?"

"Is it useful to the conversation to have one model that works to describe multiple infrastructures?"

"How do you think different stakeholders will receive and understand your presentation?"

"If Colorado Springs stopped using water for landscaping, how much more capacity would there be for growth? Can you still have a nice landscape if you don't water it? See http://www.youtube.com/watch?v=DKoxL31qPbE&list=UUcJ9AXx0ZBRivA8Fdcn2JcA

What information do you need to improve your presentation and where do you think you could find it?

If you were going to develop a study plan for this presentation, how many people would you need to do it and how many hours would you allocate?

The discussion of the D/C ratios for the waste water treatment system should be interesting and can foreshadow how this type of analysis can be used to focus in on the correct problem. The D/C ratios for both of the treatment plants are good and if the CTC were added on top of currently projected growth, both plants would probably be fully loaded for average demand by 2030. There might be issues with peak demand but these numbers are not readily available in the provided reports. The Solids Handling and

Disposal Facility is another question. The 2008 reports indicated that these will go over capacity in different segments by 2014 and 2023. This facility cannot support the CTC driven growth. Colorado Springs Utilities has a model with will provide the D/C ratio for the pipes in the system. This information is not provided in the report but if it were available, it could indicate which areas in the system have excess sewer capacity to support growth and which do not.

The Electric Integrated Resource Plan does a good job of laying out demand and capacity in the system. There is good demand/capacity information shown in the sample brief. What is not available is the D/C for the transmission and distribution lines. It does no good to increase generation capacity without bulk transmission and distribution lines to carry this capacity. This provides interesting discussion beginning with "If we need 25% more power, can't we just build another plant?" Well, no as we will also need bulk transmission and distribution lines for the electricity. And fuel for the plant. And a bulk transmission system to bring fuel to the plant. And trained operators for the plant. And state and federal permits for the plant. And a funding mechanism to pay for the plant.

References

Preparatory Reading (Please read this article before coming to class for the case study. It introduces and explains the Component and Assessment Models which are used in the case study.)

Reading 1: Hart, S. D., Klosky, J. L., & Katalenich, S. (2013). Conceptual Models for Infrastructure Leadership. *Jounal of Management in Engineeering*.

Technical References (Please familiarize yourself with these references from Colorado Springs as they provide the technical data which will be used in each of the case study steps.)

Reference 1: Pikes Peak Area Council of Governments (2008). Public Utilities and Infrastructure Technical Report: Fort Carson Regional Growth Plan.

Reference 2: American Society of Civil Engineers, Colorado Section (2010). Colorado Infrastructure Report Card.

Reference 3: Colorado Springs Utilities (2012). Electric Integrated Resource Plan.

Reference 4: Colorado Springs Utilities (2012). Water Tour.

Reference 5: Colorado Springs Utilities (2008). Waste Water Integrated Master Plan.

Reference 6: Colorado Springs Utilities Web page: https://www.csu.org/Pages/default.aspx Click on the "Residential" or "Business" tabs at the top of the page, then on the "About Us" tab for some useful information.

Note: the publication date on these references vary, but for purposes of this case study, consider all of them to be current.

Introduction

Infrastructure exists to provide a function that society needs to survive, thrive, and grow. This function, like everything else in life, does not happen without significant effort and does not come for free. For example the water, wastewater, and electricity are lifeline services that allow the American way of life to thrive. For these services and the related infrastructure (power stations, pipelines, treatment plants) to exist in the community, someone owns it, someone operates it, someone maintains it, someone uses it, and someone pays for it. Considering that none of these functions are done by the same groups of people gives some sense of the variety of stakeholders involved in sustaining the infrastructure: owners, operators, governments, regulators, customers, taxpayers, non-profits, leaders and other influential people in the community, urban planners, lawyers, and engineers.

The challenge of communicating across a highly diverse group of infrastructure stakeholders was addressed in Conceptual Models for Infrastructure Leadership (Hart, Klosky, & Katalenich, 2013) which proposed a family of infrastructure models as a "universal framework for understanding, visualizing, and describing complex infrastructure systems in a manner that facilitates communication, fosters participation in infrastructure decisions, and allows engagement with design processes, significantly improving the odds that a project will be successful."

This case study is an exercise in understanding, visualizing, and describing the water, electrical, and wastewater infrastructures for a mid-sized metropolitan area for the purpose of community discussions on the future of these systems. Participants will use the Infrastructure Component and Assessment Models recommended by Hart, Klosky, and Katalenich as well as information provided by the local utilities to prepare a presentation based on the scenario provided.

It is recommended that the class divide into teams with each team working on one infrastructure. The case study concludes with presentation on the water, wastewater, and electrical infrastructures of Colorado Springs and a class discussion on the process.

Case Study Scenario

Spurred by a proposal from the Governor of Colorado to create the Colorado Technology Cluster (CTC), a conglomeration of twelve major high-tech corporations is considering relocating their combined manufacturing operations to the Colorado Springs metropolitan area. This move will substantially increase the population, provide new jobs and new opportunities, boost both home and commercial construction, and increase the tax base. The Institute for Urban Planning and Development at High Plains University estimates that this development will result in a 25% increase in demand for the water, electrical, and waste water infrastructures in the Colorado Springs metropolitan area. Public opinion is divided on the issue with perspectives ranging from "Support Smart Growth" to "Keep The West Wild and Free—Horses not Hard Drives!" Though there are disagreements, the local citizens remain on good terms with each other and are striving to keep the debate very civil and focused on the facts.

Accordingly, the Institute for Urban Planning is convening a two day forum called "Forging our Future-High Tech on the High Plains" to foster community discussion on this complicated issue. The morning of the first day will be dedicated to "Just the Facts…A Discussion of the Current State of the Pikes Peak Region." The local Chamber of Commerce and the local chapter of the American Society of Civil Engineers have partnered to give a 30 minute presentation on "Water-Wastewater -Electricity: A Status Report on Essential Services." You have volunteered to serve on the committee that will develop the presentation.

The co-chairs of your committee are Inga Neer, a noted local civil engineer, and I. B. Rich, president of the Pikes Peak National Bank. Inga and I.B. have proposed the committee divide into three groups, each focused on one of the three lifeline services. The committee has obtained several reports on the infrastructure from Colorado Springs Utilities that will support the work of each task group. Inga and I.B. have asked each group to use the infrastructure component model (Hart, Klosky, & Katalenich, 2013) to reduce these technical reports to a four slide (or fewer) descriptive presentation of each infrastructure that is informative, technically correct, and accessible to any audience.

After describing the infrastructure using the Component Model's six functions (Generation, Bulk Transmission, Distribution, Use, Waste Management, and Cooordination), Inga and I.B. would also like each group to look at the demand/capacity ratio of each function. This will involve considering the 'required' and 'ready' prompts of the infrastructure assessment model (the other prompts are organized, tough, redundant, and prepared). When the demand/capacity ratios are considered, can the existing infrastructure support a 25-percent expansion? Each task group will summarize this information on a fifth slide.

When the committee's work is complete, Inga and I.B. will have 15 slides to be presented in 30 minutes that will describe both the current state of the Colorado Springs area infrastructure and its capacity for expansion.

Case Study Tasks:

Task 1: Organize the Team

Divide the class into three teams to address the three required descriptions. Pay careful attention to team organization and the skills each member brings to the team.

Task 2: Describe the Drinking Water Infrastructure

Use the component model to complete the requested description of the drinking water infrastructure. Use the assessment model to determine the demand/capacity ratio of the water infrastructure, and, if possible, the demand to capacity ratio of the six functions. Prepare the requested presentation and present it as part of the team.

Task 3: Describe the Wastewater Infrastructure

Use the component model to complete the requested description of the wastewater infrastructure. Use the assessment model to determine the demand/capacity ratio of the wastewater infrastructure, and, if possible, the demand to capacity ratio of the six functions. Prepare the requested presentation and present it as part of the team.

Task 4: Describe the Electrical Infrastructure

Use the component model to complete the requested description of the electrical infrastructure. Use the assessment model to determine the demand/capacity ratio of the electrical infrastructure, and, if possible, the demand to capacity ratio of the six functions. Prepare the requested presentation and present it as part of the team.

Task 5: Prepare and give the "Water-Wastewater &Electricity: A Status Report on Essential Services" Presentation

Assemble the three presentations into a 15 slide presentation and give this presentation to the class.

Task 6: Discussion and Conclusion.

Discuss the results of the case study, the level to which students met the lesson objectives, the ease or difficulty in assembling the requested information, and the effectiveness of the presentation. Students should also asses their level of understanding of the complexity of sustaining and increasing the capacity of lifeline infrastructure.