Assessing Student Learning of Civil Engineering Infrastructure

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Abstract
As part of an ongoing NSF-funded effort, materials have been developed for teaching civil engineering infrastructure topics to undergraduate students. These materials are currently being adopted by members of the Center for Infrastructure Transformation and Education (CIT-E) community of practice. CIT-E is a group of faculty from 25 universities in the U.S. and Canada seeking to improve infrastructure education.

To assess how the teaching materials impact student learning, two assessment instruments have been developed:

1. A concept map instrument that assesses student understanding of infrastructure and the systems aspects of infrastructure, and
2. An “Infrastructures Views Survey” (IVS) that seeks to determine students’
   a. Understanding of the importance of infrastructure to society,
   b. Appreciation of the infrastructure problems in the US,
   c. Understanding of the potential solutions to infrastructure problems, and
   d. Interest in infrastructure challenges and solutions, including the pertinence of infrastructure management to their future careers.

This paper provides background on the assessment instruments, describes how they were developed, and presents data from their use in two different classes using the CIT-E materials.

Background
The infrastructure of the United States is exceeding its design capacity, requiring extensive maintenance and renovation. To meet this challenge, a need exists to produce civil and environmental engineers who have a broad understanding of the pressing needs of the infrastructure of the United States and who can solve problems from a systems perspective. With this need in mind, the faculty of the Civil and Environmental Engineering (CEE) Department at the University of Wisconsin-Platteville created, and has been teaching for several years, an undergraduate course that introduces students to infrastructure and helps them understand civil and environmental engineering in terms of interconnected systems.

The course is intended for sophomore students, and is typically one of the first courses students take from the CEE Department. Three of the primary goals of the course are:

Goal 1. To introduce the students to the subdisciplines of civil and environmental engineering while emphasizing the interconnectedness between subdisciplines,

Goal 2. To help students think holistically about civil and environmental engineering, including non-technical and societal aspects of engineering, and

Goal 3. To educate students on the importance and current condition of infrastructure in the United States.
There are other goals of the course, but this paper will be restricted to discussing assessment of these three goals. Further background on the course can be found in previously published work. [1, 2, 3, 4]

To assess the effectiveness of the course in meeting goals 1 and 2 listed above, a concept map assessment instrument was developed. To assess goal 3, a student survey was developed—the Infrastructure Views Survey (IVS).

Concept Mapping for Assessment of Student Learning in Infrastructure

This section presents a brief description of concept maps, their use in assessing student learning, and how concept maps have been used to assess student learning of infrastructure topics. For a more comprehensive treatment, particularly with respect to the infrastructure course described in this paper, see Roberts et al. [5]

Concept maps are diagrams that provide a means of organizing knowledge within a domain by identifying key relationships between concepts in the form of propositions. Novak and Gowin define a concept as “a regularity in events or objects designated by some label” and propositions as “concept labels linked by words.” [6] In a concept map, concepts are enclosed in circles or boxes with lines linking related concepts together. A word or phrase is written with the linking line indicating the relationship between the concepts. For illustrative purposes, a concept map about concept maps is shown in Figure 1.

Concept maps are typically created through a series of steps. [7] These include (a) defining the topic or focus question; (b) identifying the key concepts that apply to this domain; (c) ordering concepts from general to specific; (d) drawing links between concepts; (d) creating phrases that describe the link; and (e) cross-linking concepts in different segments or domains of knowledge on the map. When used for assessment, they can be scored quantitatively through techniques involving counting of concepts, links and propositions and qualitatively based on the overall morphology of the map. [8, 9]

As a visual representation of knowledge, concept maps allow instructors to easily scan for key concepts and relationships while also examining changes in structural complexity over time. [10] As an advantage over more traditional means of assessment, concept maps allow for the portrayal of knowledge as “an integrated network, rather than a collection of facts.” [11] Additionally, concept maps serve as a means to determine correspondence between novice and expert understanding of a given subject.
The infrastructure concept map instrument is typically used as a pre-test and post-test. Student concept maps are scored using a quantitative approach by adding the number of concepts or links in the following six categories:

1. The number of concepts mentioning infrastructure “components” (e.g., roads, bridges, wastewater treatment plants, etc.),

2. The number of infrastructure “sectors” (transportation, structures, flood control, etc.) listed as concepts or implied by the infrastructure components,

3. The number of correct links between technical concepts (infrastructure components, infrastructure sectors, or engineering concepts),

4. The number of concepts for non-technical aspects of infrastructure (e.g., economic growth, ethics, pollution, etc.),

5. The number of correct links between a non-technical concept to any other concept, and

6. The number of engineering concepts (e.g., constructability, design, resilience, etc.).

The six numeric scores from each category can then be compared between the pre- and post-test to determine student learning gains. Detailed instructions for scoring the concept maps are included in Appendix 1. Further details on the development and administration of the concept map assignment can be found in Roberts, et al. [5]
Development of the Infrastructure Views Survey (IVS)

The IVS was developed to assess the impact of infrastructure education, with the goal of determining students’:

1. Understanding of the importance of infrastructure to society,
2. Appreciation of the infrastructure problems in the US,
3. Understanding of the potential solutions to infrastructure problems, and
4. Interest in infrastructure challenges and solutions, including the pertinence of infrastructure management to their future careers.

The IVS was developed by a collaboration with engineering educators and the Psychology Department at Southern Utah University (SUU). Psychology students in SUU’s “Principles of Assessment” class were given information about infrastructure and the current state of America’s infrastructure to give them background knowledge. Using further information and feedback from engineering educators, the students developed the survey questions.

Civil and environmental engineering faculty from the lead CIT-E institutions reviewed the instrument to establish face validity of the survey. Expert reviewers provided input on the content, nature of questions and the degree to which the survey measured its intended outcomes.

After expert review, investigators piloted the survey with senior engineering students at the University of Utah. The students were introduced to the survey with the following information:

“We have designed the Infrastructure Views Survey to understand peoples’ attitudes about issues and challenges facing society today. We will be using the survey with students in introductory engineering courses at universities around the country. We’d like your help in piloting the survey. We’re interested in finding out if the questions are clear, what you think the questions are asking, how the survey looks online and any other feedback you would like to provide. Your feedback will help us refine the survey before sending it to students to complete.”

Students were put into groups and instructed to pull up the online survey. As a group they viewed each question with one of the group members reading it aloud. Each student individually answered the question. After all members of the group had answered the survey question, the group evaluated each survey question by responding to the following prompts:

- What do you think the question is asking you to think about?
- How does the question look on the screen (ex: cluttered, too much text, easy to read, etc).
- Is there anything about the question that you didn't understand? Did everyone in the group interpret the question in the same way?
- How was the language of the survey? Understandable?
- Were the directions for each question clear?
- Did you need a definition of any of the terms?
- Are there other comments you have about the question?

A student recorded the group comments, which were used to improve the survey.
Using the updated survey, five students at SUU took the survey individually with a one-on-one facilitator present. None of the students were engineering majors. They were given the same introduction as the students at the University of Utah, then they worked through the survey. Each student was asked the following for each question on the survey:

- What do you think the question is asking you to think about?
- How does the question look on the screen (ex: cluttered, too much text, easy to read, etc).
- Is there anything about the question that you didn’t understand?
- Were the directions for each question clear?

The facilitator observed each student while completing the survey, looking for places where they seemed to hesitate or seemed to have problems navigating the questions. After finishing the survey, the facilitator asked each student if the survey length was reasonable, if the language was understandable, and if the survey held their attention. Notes from this final round of piloting were used to further improve the survey and create the final version.

While the initial purpose of the survey will be to assess how student attitudes and perceptions of infrastructure change after exposure to the teaching materials, it is anticipated that a modified version of the survey will also be useful in measuring the perceptions and attitudes of the general public regarding infrastructure. The survey will be further refined after the first student results are analyzed. Eventually, the survey could be used to provide valuable information about public perception of infrastructure to policy makers, business leaders, and educators in a variety of disciplines.

The final version of the IVS is included as Appendix 2.

**Interpreting Results from the Concept Map and IVS Instruments**

The concept map and IVS instruments are intended to assess distinct student outcomes of infrastructure education. The concept map instrument is intended to measure general student understanding of infrastructure and the systems aspects of infrastructure. The IVS was designed to assess students’ understanding and appreciation of infrastructure, including the challenges facing policymakers and engineers.

To show the information that can be gleaned by using the concept map instrument, sample results are shown in Figure 2. These results come from students in a sophomore-level class that uses infrastructure topics to introduce students to the discipline of civil engineering. The instrument was administered as a pre-test before class started and then as part of the students’ final exam for the post-test.

The evaluation of the pre- and post-test concept maps followed Pearsall, Skipper & Mintzes\[^{12}\] in determining the statistical significance in the gain of the number of concepts and links. The radar chart in Figure 2 shows the average student pre-test and post-test concept map scores for each of the six categories. Table 1 gives the results of a student’s t-test analysis using the hypothesis that concept map scores would increase from pre- to post-test.
As can be seen graphically in Figure 2 and numerically in Table 1, student scores improved for each of the six categories, with several categories showing statistically significant gains. A more detailed analysis of the results is presented by Roberts, et al. [5]

Table 1 – Average student scores and p-values for the gains in each concept map category (n=49). The p-values were calculated using a student's t-test (one-tail, paired).

<table>
<thead>
<tr>
<th>Concept Map Category</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure Components</td>
<td>6.4</td>
<td>6.7</td>
<td>p &gt; 0.05</td>
</tr>
<tr>
<td>Infrastructure Sectors *</td>
<td>3.7</td>
<td>4.3</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>Technical Links *</td>
<td>2.0</td>
<td>7.7</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>Non-Technical Aspects *</td>
<td>3.0</td>
<td>5.2</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>Non-Technical Links</td>
<td>3.0</td>
<td>3.8</td>
<td>p &gt; 0.05</td>
</tr>
<tr>
<td>Engineering Concepts *</td>
<td>1.5</td>
<td>4.5</td>
<td>p &lt; 0.001</td>
</tr>
</tbody>
</table>

* Statistically significant at the p < 0.05 level.

The IVS has been used in a freshman-level class that introduces all majors (not just engineers) to the engineering field. Infrastructure was one of the modules in the course with 15 lessons (five weeks). Students took the IVS before starting the infrastructure module and then took it again after the module was completed. As part of the IVS, students select a four-digit pin to be entered with the pre- and post-surveys. This allows direct comparison of pre- and post-survey results while maintaining student anonymity.

There are many research questions that could be pursued using the IVS. In this paper results are presented that could be used to investigate three research questions:

Q1. After completing the infrastructure module, do students rate infrastructure systems as more important compared to other government services and products?
Q2. Do students feel that infrastructure challenges are more important to their careers after completing the infrastructure module?
Q3. How do students’ grades* for infrastructure components change after completing the infrastructure module?

Descriptive results are given without statistical analysis because there were only 16 students who completed both the pre- and post-surveys. Several instructors are using the IVS in spring 2016, and it is hoped that the increased sample size will allow reporting of more rigorous analyses.

*Ratings of Infrastructure Importance (Q1)
The IVS asks respondents to rate how important different programs and systems are to our current American society. Ratings are scaled from 1, “Not at all important,” to 10, “Extremely important.” Figure 3 shows how ratings changed for infrastructure systems and other government services and products. The values represent the average of the scores (from 1-10) from the pre- and post-surveys. Error bars represent one standard deviation. Figure 3 is a subset of the IVS categories (see Appendix 2 for the entire list). Figure 4 compares the average rating for infrastructure systems (items in the “Transportation Systems” and “The Built Environment” sections) to the average rating for other government functions and services (“Government Agencies and Services” and “Social Systems and Programs”). As can be seen, students assigned greater importance to infrastructure than to other government services prior to and after completing the module. Infrastructure importance ratings grew very slightly from pre- to post-survey, while government functions and services held steady.

* The idea for infrastructure grades was inspired by American Society of Civil Engineers’ (ASCE) “Report Card for America’s Infrastructure.”[13]
Preliminary findings with a small sample size indicate that students came into the class rating certain aspects of infrastructure highly, including roads and bridges, and ratings for their importance remained high after taking the class. Trends in the data suggest that students placed a greater importance on aspects of infrastructure such as non-motorized transportation and rail lines after participating in the class. As the sample size of students taking the IVS grows it will be interesting to examine whether these trends hold true and whether changes in ratings are statistically significant.

Figure 4 - Changes from pre-test to post-test in mean student ratings of importance for infrastructure systems and other government functions and services.

Importance of Infrastructure to Student Careers (Q2)
The IVS poses the statement, “Infrastructure challenges and solutions will be important to my future career.” Respondents can choose their level of agreement using a five-point Likert Scale: Strongly disagree, Disagree, Neither agree nor disagree, Agree, Strongly agree. Figure 5 shows how the responses changed from pre-survey to post-survey. There was not much change in the number of students agreeing or disagreeing with the statement, but there was a dramatic shift in the numbers from “Agree” to “Strongly Agree.”

Figure 5 - Responses to the statement, “Infrastructure challenges and solutions will be important to my future career.”
“Grades” for Infrastructure Components (Q3)

Inspired by the “Report Card for America’s Infrastructure” [13], the IVS asks respondents the following:

“For each of the infrastructure components below, please select a grade to represent how well you think each is doing in meeting the demands of American society today.”

Each of the infrastructure categories from the ASCE report card were listed, and students taking the survey were asked to choose a grade for each from among the responses shown in Table 2.

Table 2 - Grade scale for infrastructure components and GPA points used to determine average ratings.

<table>
<thead>
<tr>
<th>Response</th>
<th>GPA Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>A = Exceptional</td>
<td>4</td>
</tr>
<tr>
<td>B = Good</td>
<td>3</td>
</tr>
<tr>
<td>C = Mediocre</td>
<td>2</td>
</tr>
<tr>
<td>D = Poor</td>
<td>1</td>
</tr>
<tr>
<td>F = Failing</td>
<td>0</td>
</tr>
<tr>
<td>Don't Know</td>
<td>(not included)</td>
</tr>
</tbody>
</table>

Student responses were used to create an “average rating” for each component using the “GPA Points” shown in Table 2 (e.g., a weighted average was calculated with each “A” response assigned 4 points, “B” responses assigned 3 points, etc.). Responses of “Don’t Know” were not counted in the average rating. A letter grade was assigned to each “average rating” using the following scale:

- 3.15 – 3.50 B+  
- 2.15 – 2.50 C+  
- 1.15 – 1.50 D+  
- 3.85 – 4.00 A  
- 2.85 – 3.15 B  
- 1.85 – 2.15 C  
- 1.15 – 1.50 D  
- 3.50 – 3.85 A-  
- 2.50 – 2.85 B-  
- 1.50 – 1.85 C-  
- 0.00 – 0.50 F

In Table 3, each infrastructure component in ASCE’s “Report Card for America’s Infrastructure” is listed along with the grade assigned by ASCE, pre-survey and post-survey student average ratings and the corresponding grade, and the number of students responding “Don’t Know.” The data show a dramatic shift downward in the grading, with the students’ average “Overall GPA” dropping a full letter grade from the pre-survey to the post-survey, bringing the student grade in better agreement with the ASCE report card. In addition, the number of “Don’t Know” responses drops dramatically from pre-survey to post-survey, perhaps indicating that students are much more confident in rating infrastructure after being exposed to the infrastructure teaching materials.
Table 3 - Student “grades” for infrastructure components. The ASCE column shows the grade assigned in the “Report Card for America’s Infrastructure.” “Avg Rating” is the average rating given by respondents on a four-point scale, “Grade” is the grade corresponding to the average, and “Don’t Know” is the number of respondents selecting “Don’t Know.”

<table>
<thead>
<tr>
<th>Component</th>
<th>Pre-Survey</th>
<th>Post-Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ASCE</td>
<td>Avg Rating</td>
</tr>
<tr>
<td>Aviation</td>
<td>D</td>
<td>3.47</td>
</tr>
<tr>
<td>Bridges</td>
<td>C+</td>
<td>3.13</td>
</tr>
<tr>
<td>Dams</td>
<td>D</td>
<td>3.13</td>
</tr>
<tr>
<td>Drinking Water</td>
<td>D</td>
<td>3.31</td>
</tr>
<tr>
<td>Energy</td>
<td>D+</td>
<td>2.80</td>
</tr>
<tr>
<td>Hazardous Waste</td>
<td>D</td>
<td>2.73</td>
</tr>
<tr>
<td>Inland Waterways</td>
<td>D-</td>
<td>3.09</td>
</tr>
<tr>
<td>Levees</td>
<td>D-</td>
<td>2.40</td>
</tr>
<tr>
<td>Ports</td>
<td>C</td>
<td>3.08</td>
</tr>
<tr>
<td>Public Parks &amp; Recreation</td>
<td>C-</td>
<td>3.00</td>
</tr>
<tr>
<td>Rail</td>
<td>C+</td>
<td>2.77</td>
</tr>
<tr>
<td>Roads</td>
<td>D</td>
<td>2.88</td>
</tr>
<tr>
<td>Schools</td>
<td>D</td>
<td>2.19</td>
</tr>
<tr>
<td>Solid Waste</td>
<td>B-</td>
<td>3.00</td>
</tr>
<tr>
<td>Transit</td>
<td>D</td>
<td>2.80</td>
</tr>
<tr>
<td>Wastewater</td>
<td>D</td>
<td>3.00</td>
</tr>
<tr>
<td>Overall GPA</td>
<td>D+</td>
<td>2.92</td>
</tr>
</tbody>
</table>

Conclusions

Two instruments have been developed to assess student learning and views of infrastructure. The concept map instrument is used to assess student learning gains as they relate to the interconnectedness between civil engineering disciplines, civil infrastructure, and non-technical and societal aspects of engineering. The concept map instrument has been used for several years at multiple universities and has been helpful in visualizing student understanding of civil engineering and infrastructure. The IVS was developed just recently, and has so far been used in only one class. Initial results indicate that the IVS can be used to answer interesting research questions. As more data are collected, the IVS should help to better understand how students’ perceptions of infrastructure change as they are exposed to infrastructure topics. Furthermore, administering the IVS to non-engineers may be helpful in determining public perception of infrastructure and could be helpful for policymakers and infrastructure planners.

Acknowledgements

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expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. The authors also wish to thank the reviewers for their comments, which were helpful in improving the final version of the paper.

Bibliography


Appendix 1

Concept Map Rubric Instructions

There are six dimensions to the concept map rubric. Follow the instructions below to determine the “score” for each dimension. Then plot the dimensions on a radar chart. A sample concept map that has been “graded” is provided at the end of this document.

It is imperative that someone with content expertise score the rubrics. It would be very difficult for a non-expert to judge the correctness of links on the concept map.

1. Infrastructure Components – Sum the total number of infrastructure components included on the concept map. The components listed below are certainly not an all-inclusive list.
   a. Transportation Sector
      Components: Streets, rail, non-motorized infrastructure, highways, aviation infrastructure, parking, ports, mass transit, waterways, lighting, signs, signals, markings
   b. Structures Sector
      Components: Bridges, buildings, foundations, towers, retaining walls, tunnels
      Note: schools, hospitals, courthouses, etc. should be counted as buildings even though they hint at government as a part of infrastructure.
   c. Hazardous Waste Sector
      Components: Landfills, transfer/storage facilities, incinerators, contaminated sites
   d. Solid Waste Sector
      Components: Landfills, transfer stations, incinerators, composting, recycling
   e. Stormwater Sector
      Components: Detention ponds, infiltration basins, inlets, gutters, catch basins,
   f. Energy Sector
      Components: Power plants, transmission lines, transformers,
   g. Wastewater Sector
      Components: Waste water treatment plant, conveyance system (e.g., sewer systems)
   h. Parks and Recreations Sector
      Components: City parks and recreation facilities, national parks, state parks
   i. Water Supply Sector
      Components: Reservoirs, conveyance channels and pipelines, treatment, storage
   j. Telecommunications Sector
      Components: Telephone, television, cable, Internet, cell-phone towers, satellites
   k. Flood Control Sector
      Components: Dams, levees
   l. Support of Natural Environment Sector
      Components: Source of natural resources, sink for pollution

2. Sectors – For each infrastructure component mentioned above determine the sector to which the component belongs and sum the total number of sectors represented. Note:
   a. The sector (transportation, structures, etc.) does not need to be specifically mentioned to be counted.
Appendix 1

b. Sectors that are specifically mentioned are always counted even if there are no corresponding infrastructure components. (See the “Notes” section below for more guidance.)
c. Do not count the civil engineering sub-disciplines (construction, environmental, geotechnical, structural, transportation) unless

3. CORRECT Technical Links – Sum the total number of links made between technical concepts.
   a. Component to component
   b. Sector to Sector
   c. Sector to component from a different sector (see “Notes”)
   d. Engineering concepts to components/sectors

4. Non-technical concepts – Sum the total number of non-technical concepts such as:
   a. Communication
   b. Emergency response
   c. Economic Growth
   d. Economy
   e. Energy
   f. Ethics
   g. Funding
   h. Government
   i. People-serving
   j. Politics
   k. Pollution
   l. Public health
   m. Public safety/Security
   n. Social impacts
   o. Teamwork

5. CORRECT Non-technical links – Sum the total number of links between technical and non-technical concepts.

6. Engineering concepts such as:
   a. Assessment (e.g., PASER)
   b. Code of Ethics
   c. Constructability
   d. Decision-making
   e. Design
   f. Environmental Impact
   g. Green Infrastructure
   h. Life cycle costs
   i. Maintenance
   j. Materials (see Figure 1)
   k. Planning
   l. Resilience
   m. Risk management
   n. Safety factors
   o. Sustainability

Figure 1 - Engineering materials. Note that in this example the student has identified multiple materials that can be used to construct roads. The four concepts (concrete, gravel, timber, and dirt) together would count as one engineering concept.
Appendix 1

p. Systems

These six categories become the dimensions for a radar chart.

Note: links between two non-technical concepts are not counted.

On the last page is a sample concept map that has been graded using the rubric and the resulting radar chart.

Notes

1. Links originating from the main concept (e.g., “infrastructure”) are not considered in the scoring of the concept map.
2. Do not count any concepts without linking words.
3. Do not count civil engineering subdisciplines (e.g., transportation, geotechnical, etc.) as concepts.
4. Links to examples of a concept also not counted (see Figure 2), although links from such examples to other concepts should be counted.

5. If the Infrastructure Sectors (transportation, structures, etc.) are identified on the concept map, then links from sectors to components are counted as “infrastructure components” and are not also counted as technical links (see Figure 3). Also, if the component is listed under the wrong sector (as in Figure 3) the component is still counted along with its corresponding sector.

6. Apart from the exceptions in items 1 - 5, all correct concepts and links should be counted.
7. Each concept should only be counted once, no matter how many times it is mentioned on the concept map.
Student Infrastructure Survey

Thank you for participating in this survey. The questions were designed to measure your knowledge and opinions about various issues and challenges that face society today. Your responses are completely anonymous and you may skip any question you do not wish to answer. Your responses will not be linked to any identifying information provided to your university. You may discontinue your participation at any time without any penalty. The questions pose minimal risk to you. The study has been reviewed by the Institutional Review Board at Southern Utah University and complies with all policies and regulations. Results may be reviewed by contacting Professor Matthew Roberts at Southern Utah University after May 2015. If you are under 18 years old, please do not complete this survey.

In your own words, define infrastructure:

_________________________________________________

Please review your definition before proceeding with the survey as you will not be able to return to this page to change it.

Below are several different programs and systems. Please rate how important you think each one is to our current American society, on a scale of 1 to 10 with 1 being not at all important and 10 being extremely important.

Hover your mouse over the word definition to find out more.
Transportation Systems

Roads and Bridges *Definition:* Roads are the U.S. interstate system, state highways, farm roads, and all other streets. Bridges are used to cross waterways and for highway interchanges.

Not at all important

1 2 3 4 5 6 7 8 9 10

Extremely important

Non-motorized Transportation *Definition:* Bike lanes, sidewalks, etc.

Not at all important

1 2 3 4 5 6 7 8 9 10

Extremely important

Public Transit *Definition:* Busses, subways, etc.

Not at all important

1 2 3 4 5 6 7 8 9 10

Extremely important

Rail Lines *Definition:* Railroads, trains, etc.

Not at all important

1 2 3 4 5 6 7 8 9 10

Extremely important

Aviation *Definition:* Airports, runways and air traffic control systems.

Not at all important

1 2 3 4 5 6 7 8 9 10
Extremely important

**The Built Environment**

**Dams** *Definition: Dams in the US provide drinking water, irrigation, hydropower, flood control, and recreation.*

Not at all important

( ) 1   ( ) 2   ( ) 3   ( ) 4   ( ) 5   ( ) 6   ( ) 7   ( ) 8   ( ) 9   ( ) 10

Extremely important

**Drinking water** *Definition: Facilities to treat drinking water and the pipes that deliver the water to houses and businesses.*

Not at all important

( ) 1   ( ) 2   ( ) 3   ( ) 4   ( ) 5   ( ) 6   ( ) 7   ( ) 8   ( ) 9   ( ) 10

Extremely important

**Sewage/Wastewater Collection and Treatment** *Definition: Pipes and treatment facilities for sewage from domestic and commercial sources.*

Not at all important

( ) 1   ( ) 2   ( ) 3   ( ) 4   ( ) 5   ( ) 6   ( ) 7   ( ) 8   ( ) 9   ( ) 10

Extremely important

**Solid Waste (trash) Disposal** *Definition: Landfills, recycling, and composting of garbage.*

Not at all important

( ) 1   ( ) 2   ( ) 3   ( ) 4   ( ) 5   ( ) 6   ( ) 7   ( ) 8   ( ) 9   ( ) 10

Extremely important

**Public Schools** *Definition: Elementary and secondary schools (in the U.S.: Kindergarten through 12th grade)*

Not at all important
Extremely important

Public Colleges and Universities *Definition: Institutions of higher learning funded by public means*

Not at all important

Prisons and Jails *Definition: Secure facilities that house people who have been convicted of criminal offenses*

Not at all important

The Natural Environment

Public Parks and Recreation *Definition: Recreation areas managed by the National Parks System, the US Forest Service, and state and municipal governments.*

Not at all important

Energy *Definition: The electric grid (including power plants and transmission lines) and oil and gas pipelines.*

Not at all important
**Agriculture** *Definition: Occupation concerned with cultivating land, raising crops, and feeding, breeding, and raising livestock*

Not at all important

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10

Extremely important

**Government Agencies and Services**

**Income Taxes** *Definition: Taxes levied by government directly on income*

Not at all important

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10

Extremely important

**Police and Law Enforcement** *Definition: People and processes that discover, deter, rehabilitate or punish people who violate the law*

Not at all important

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10

Extremely important

**Public Postal Service** *Definition: The department of government charged with the transportation of mail*

Not at all important

( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10

Extremely important

**Social Systems and Programs**

**Welfare Assistance Programs** *Definition: Food stamps, housing, etc.*
Not at all important
( ) 1   ( ) 2   ( ) 3   ( ) 4   ( ) 5   ( ) 6   ( ) 7   ( ) 8   ( ) 9   ( ) 10
Extremely important

**Social Security** Definition: A federal insurance program that provides benefits to retired and disabled people

Not at all important
( ) 1   ( ) 2   ( ) 3   ( ) 4   ( ) 5   ( ) 6   ( ) 7   ( ) 8   ( ) 9   ( ) 10
Extremely important

**Unemployment Programs** Definition: A federal insurance program whereby eligible unemployed persons receive cash benefits for a specified period of time

Not at all important
( ) 1   ( ) 2   ( ) 3   ( ) 4   ( ) 5   ( ) 6   ( ) 7   ( ) 8   ( ) 9   ( ) 10
Extremely important

**Accessibility of Medical Care** Definition: Availability and adequate supply of medical services

Not at all important
( ) 1   ( ) 2   ( ) 3   ( ) 4   ( ) 5   ( ) 6   ( ) 7   ( ) 8   ( ) 9   ( ) 10
Extremely important

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For the remaining items in this survey, “infrastructure” is defined as the large physical networks necessary for the functioning of modern industrial societies and economies (roads and bridges, water management, communication, etc).
Infrastructure challenges and solutions will be important to my future career. Select the answer that best represents your opinion.

( ) Strongly disagree
( ) Disagree
( ) Neither agree nor disagree
( ) Agree
( ) Strongly agree

Please rate your familiarity with the American Society for Civil Engineering (ASCE) Report Card for America’s Infrastructure:

( ) Not at all familiar
( ) A little familiar
( ) Somewhat familiar
( ) Familiar
( ) Very familiar

For each of the infrastructure components below, please select a grade to represent how well you think each is doing in meeting the demands of American society today.

Hover your mouse over the word *definition* to read a definition of each component.

<table>
<thead>
<tr>
<th></th>
<th>Failing (F)</th>
<th>Poor (D)</th>
<th>Mediocre (C)</th>
<th>Good (B)</th>
<th>Exceptional (A)</th>
<th>Don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Schools</strong> Definition: Public K-12 schools.</td>
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<td><strong>Transit</strong> Definition: Public transportation such as buses,</td>
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<tr>
<td>Infrastructure Type</td>
<td>Definition</td>
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<tr>
<td><strong>Rail</strong></td>
<td><strong>Definition:</strong> Track, bridges, and tunnels for passenger and freight rail service.</td>
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<tr>
<td><strong>Inland Waterways</strong></td>
<td><strong>Definition:</strong> Facilities, such as locks and harbors, that enable freight services on rivers and canals.</td>
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<tr>
<td><strong>Aviation</strong></td>
<td><strong>Definition:</strong> Airports, runways and air traffic control systems.</td>
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<tr>
<td><strong>Solid Waste</strong></td>
<td><strong>Definition:</strong> Landfills, recycling, and composting of garbage.</td>
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<tr>
<td><strong>Hazardous Waste</strong></td>
<td><strong>Definition:</strong> Pesticides, heavy metals, and other waste that is harmful to health or the environment.</td>
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<tr>
<td><strong>Dams</strong></td>
<td><strong>Definition:</strong> Dams in the US provide drinking water, irrigation, hydropower, flood control, and</td>
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<td><strong>recreation.</strong></td>
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<td><strong>Roads</strong> <strong>Definition:</strong> The U.S. interstate system, state highways, farm roads, and all other streets.</td>
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<td><strong>Ports</strong> <strong>Definition:</strong> Harbors and ports that process U.S. imports and exports on oceangoing vessels.</td>
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<tr>
<td><strong>Bridges</strong> <strong>Definition:</strong> Used to cross waterways and for highway interchanges.</td>
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<td><strong>Wastewater</strong> <strong>Definition:</strong> Pipes</td>
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</tbody>
</table>
and treatment facilities for sewage from domestic and commercial sources.

| Levees Definition: Man-made structures along the edge of rivers to control flooding. | () | () | () | () | () | () |
| Drinker Water Definition: Facilities to treat drinking water and the pipes that deliver the water to houses and businesses. | () | () | () | () | () | () |

If you were to grade the infrastructure of the United States on how well it is meeting the demands of American society today, what overall grade would you give?

( ) A = Exceptional
( ) B = Good
( ) C = Mediocre
( ) D = Poor
( ) F = Failing
( ) Don’t know

The questions below describe possible solutions for infrastructure challenges. Select the answer that best matches your feelings about each question.
Income taxes should be raised in the U.S. to construct and maintain infrastructure.

( ) Strongly Disagree ( ) Disagree ( ) Neither Agree nor Disagree ( ) Agree ( )
Strongly Agree

Funding for roads and bridges generally comes from fuel taxes. Those who use more fuel generally pay more for maintenance and upkeep. However, newer cars using hybrid or electric power systems are using the same roads, but not paying as much in taxes. How willing would you be to approve a system that pays for road and bridge maintenance using a mileage fee charged to each driver instead of a fuel tax?

( ) Very Unwilling ( ) Unwilling ( ) Neutral ( ) Willing ( ) Very Willing

Most electrical utility companies charge people for the amount of power they use regardless of the time of day. However, peak use occurs when the grid is under heavy strain and electricity is more expensive. One potential solution is to charge more for electricity during peak usage times (like when the temperature is highest and more people are using air conditioning) and less during off-peak times. How willing would you be to pay a higher rate for electricity during peak usage times?

( ) Very Unwilling ( ) Unwilling ( ) Neutral ( ) Willing ( ) Very Willing

I would be willing to pay an extra toll to drive on roads during peak traffic times if it meant less traffic.

( ) Strongly Disagree ( ) Disagree ( ) Neither Agree nor Disagree ( ) Agree ( )
Strongly Agree

What percentage of your tax dollars would you like to go to each of the following categories? The total must equal 100%}

______Health Care
______Infrastructure
_____Public Education
_____Military
_____Social Security

Please enter your 4 digit ID code:* 

_________________________________________________

What is your university?*

_________________________________________________

What is your academic level?

( ) Freshman
( ) Sophomore
( ) Junior
( ) Senior
( ) Graduate student

What is your gender?

( ) Male
( ) Female

What is your age?

( ) 18-21
( ) 22-25
() 26-29
() 30 or older

**What is your race/ethnicity?**

() American Indian/Alaskan Native
() Asian
() Black/African American
() Hispanic
() White/Caucasian
() Some Other
() Prefer not to answer

Thank you for completing the survey.