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Crowdsourcing an Outline for a Model Introductory Infrastructure Course Using a Modified Delphi Process

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Background

The Center for Infrastructure Transformation and Education (CIT-E) is a community of civil and environmental engineering faculty members from more than 30 institutions interested in the scholarship of infrastructure education. CIT-E activities have evolved in a short period of time, starting with sharing materials from existing infrastructure courses at University X and the University of Y [1, 2, 3], to collaboratively creating sample "showcase" course materials, to the current effort of creating a crowd-sourced model infrastructure course outline.

This paper will describe the steps taken to create the course outline for a model infrastructure class using a modified Delphi process. The Delphi process utilizes a panel of experts to iteratively address a question or task. It effectively builds consensus using a series of questionnaires administered iteratively over time.[4] In our case, the expert panel consisted of members of the CIT-E community.

Consensus is at the heart of the Delphi process, and we defined consensus as:

1. Few participants objected to the inclusion of a lesson outcome or topic.
2. Almost all participants agreed that each lesson topic was relevant to the course material, even if that participant would later choose not to use that lesson.

For example, some participants suggested inclusion of a lesson on foundations and structures, but many other participants did not see this as relevant to an infrastructure course so by criterion 2 it was not included. In this way, we assembled the outcomes and outline for a model course where all topics were agreeable and not objectionable to nearly all participants.

The process was carried out entirely online during summer and fall semesters in 2015. More than 35 people from more than 30 universities participated over seven rounds. The rounds are described in the remainder of the paper and are summarized in Figure 1.

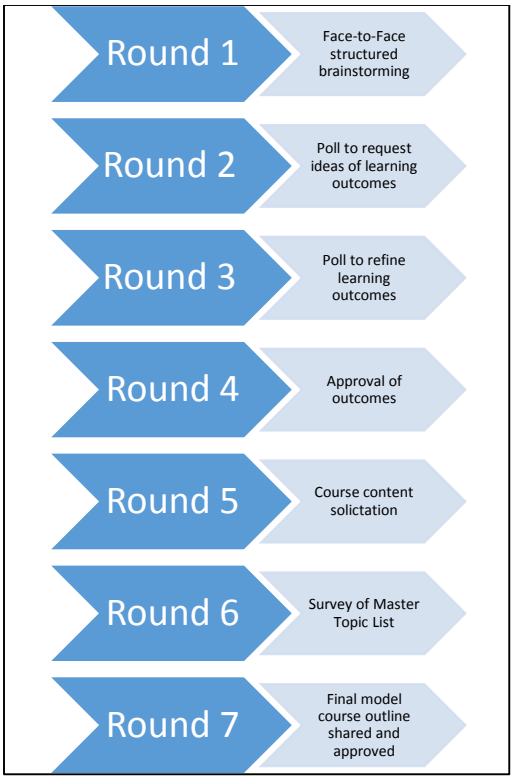

Figure 1: Summary of Delphi Process used

Round 1: Face-to-Face Structured Brainstorming.

- Process – A structured brainstorming technique was used at the second annual Infrastructure Education Workshop held in Salt Lake City in May 2015. Participants brainstormed outcomes for an infrastructure course by placing Post-it® notes on the wall and grouping them (a sample of one such grouping is shown in Figure 2). An experienced facilitator was used to prompt the process and moderate the discussion. Twenty-one participants and one facilitator took part in this exercise.
- Lessons learned about the process – The process was successful and generated 123 ideas that were later grouped into six learning outcomes. The use of the experienced facilitator was particularly important as was her messaging to the participants that this step was a starting point for future work and did not need to be perfect or complete to begin with.
- Findings/Results – A list of proposed learning outcomes was generated that served as a starting point for developing final course outcomes. These initial outcomes completed the sentence "At the end of this course, students will attain the knowledge, skills, and attitudes that will enable them to…":

    1. develop skills and knowledge to become analytic problem solvers as they address complex infrastructure challenges and problems

2. apply systems thinking to describe infrastructure interconnections that impact people's lives
3. collaborate effectively and communicate infrastructure concepts clearly and persuasively in oral and written formats
4. acquire an open minded perspective and dispositions that will help them make a positive impact on the world, country, state, and local levels
5. articulate how policy influences infrastructure decisions, funding and social change
6. consider the triple bottom line as they learn to design and manage sustainable infrastructure

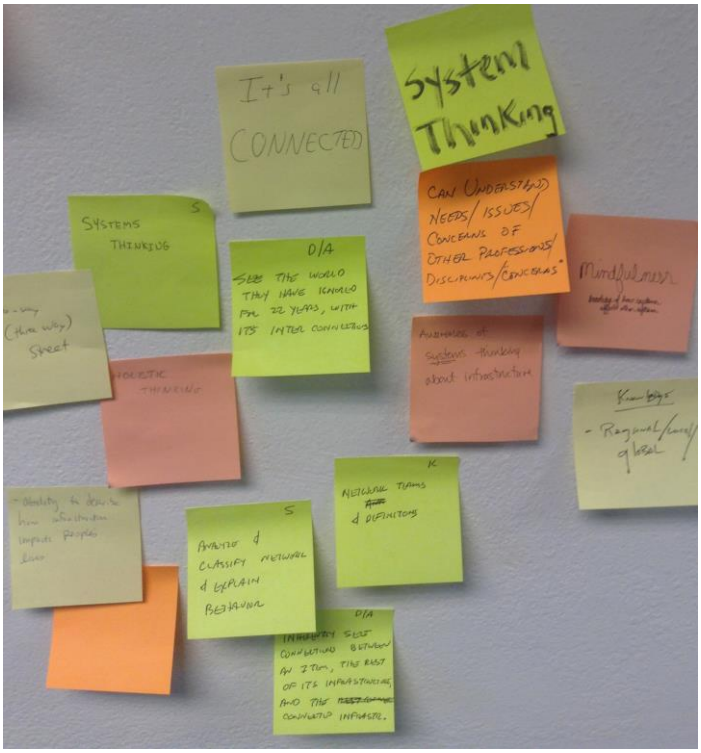

Figure 2: Sample of grouping of "stickie" notes

Round 2: Online poll to request ideas of learning outcomes

- Process – Five members of the CIT-E community, all of whom were PIs on the NSF grant that funded the project, are members of the "management team." This management team simplified the wording of the outcomes from Round 1 and split the original outcome 3 into two distinct outcomes (3 and 4 in the new list). Furthermore, one additional outcome was added to coincide with exercises that been successfully conducted at University Y in which students go out into the local area and inspect real infrastructure (number 8 in the list below):

1. solve open-ended infrastructure challenges and problems
2. describe and analyze infrastructure using systems and network approaches
3. collaborate effectively
4. communicate clearly and persuasively in oral and written formats
5. desire to make a positive impact on the world, country, state, and local levels and face infrastructure problems with an open-minded perspective
6. describe the influence of political, social, technological, and economic factors on infrastructure decisions
7. consider the triple bottom line as they learn to design and manage sustainable infrastructure
8. evaluate the condition of existing infrastructure and recommend improvements

This revised list was then shared with the CIT-E community and feedback was requested using an online survey (Survey Monkey). For each of the outcomes, respondents were asked to select "Retain as Written," "Do Not Retain," or "Retain with Modifications"; for the latter response, respondents were requested to provide alternate wording. Participants were also asked if they would like to suggest any new outcome that wasn't addressed. The survey was distributed to 61 people and 28 responded.

- Lessons learned about the process – In order to maintain the momentum of the Delphi process, a short turnaround time of about one week was mandated. The participants were not forewarned of this requirement ahead of time which resulted in some grievances concerning this step. Some participants did not have access to email or faced other obstacles that caused them to miss the turnaround deadline, excluding their participation. In retrospect, the process later slowed down and there was no need to hurry through these early rounds. Furthermore, participants should have been presented with a master timeline of the process and important deadlines at the beginning; however as the management team was coordinating this type of process for the first time, they did not have the experience to provide a reliable timeline at those early stages.
- Findings/Results – Following a conference call in which all of the outcomes were discussed, the initial eight outcomes were agreed upon and a ninth outcome was added: "Students will be able to define and describe the components of an infrastructure system and their functions." This particular outcome was added after an observation that the eight outcomes from the start of the round targeted higher-level Bloom's functions and that there were no low-level outcomes targeted towards basic knowledge acquisition. The discussion also included debate about the overlap between the selected outcomes and university level outcomes required for general education; however the overlap was eventually regarded as unimportant as there is no problem with the course fulfilling multiple roles.

Round 3: Poll to refine the learning outcomes

- Process –Survey Monkey was used again for this round; each of the participants were presented with the nine outcomes, one of which was new. For all of the eight "old" outcomes, participants were provided with the new wording and a brief commentary on the reason for the wording changes, based on input from the Round 2 surveys. Participants were then asked to keep the wording as is, to modify the wording, or to eliminate it from the survey. Two examples will illustrate this process; the commentary is verbatim from the surveys, and was written in a casual voice that was appropriate for the overall tone of the survey.

  Outcome 1

  Old wording: solve open-ended infrastructure challenges and problems
  New wording: analyze and propose solutions to ill-defined infrastructure problems
  Commentary: "solve" is viewed as too presumptive and expecting too much out of freshmen or sophomores; "ill defined" might be better than "open ended" to describe problems that don't have answers "in the back of the book."

  Outcome 5

Old wording: desire to make a positive impact on the world, country, state, local levels and face infrastructure problems with an open-minded perspective
New wording: desire to make a positive impact on the world, country, state, local levels and face infrastructure problems with an open-minded perspective (unchanged)
Commentary. Oh boy! Lots of comments on this one, mostly centered on the word "desire," and specifically focused on the ability to assess it. But for now we feel it is important to have one affective/attitudinal outcome, as this type of outcome might be the most important, regardless of whether it can be assessed. As we continue the integrated course design, and if we find it difficult to align activities with this outcome, we will drop it. Or, if the community of practice votes on this page to not keep it - that will also be reason to drop it!

- Lessons learned about the process – It proceeded with very few problems, however, the response rate to the survey (19 participants) during this round diminished. In many ways, this step was a "polishing" step—the CIT-E community had reached consensus on the course learning outcomes and now we were "wordsmithing" to make sure our wording was precise and achievable in the course. This round highlighted the fact that complete agreement by all participants on all of the wording was not going to be possible, but that consensus was possible.
- Findings/Results – After completing the first three rounds, the learning outcomes were defined as follows.

  At the end of this course, students will attain the knowledge, skills, and attitudes that will enable them to:
  1. solve open-ended infrastructure challenges and problems
  2. describe and analyze infrastructure using systems and network approaches
  3. collaborate effectively
  4. communicate clearly and persuasively in oral and written formats
  5. desire to make a positive impact on the world, country, state, local levels and face infrastructure problems with an open-minded perspective
  6. describe the influence of political, social, technological, and economic factors on infrastructure decisions
  7. consider the triple bottom line as they learn to design and manage sustainable infrastructure
  8. evaluate the condition of existing infrastructure and recommend improvements
  9. define and describe the components of an infrastructure system and their functions.

Round 4: Webinar for approval of outcomes

- Process – For this round, all CIT-E community members were invited to an online webinar using Blackboard Collaborate. However only 11 members participated. Outcomes were shared and participants were given the opportunity to vote to retain, reword, or delete each outcome.
- Lessons learned about the process – This round was a valuable in allowing some "give and take" dialogue about the outcomes. While full community participation was never expected, the sharply diminished participation in this round seems to either a) indicate fatigue with the

process which had proceeded for about 2 months at this time, or b) highlight the difficulty in arranging high turnout for synchronous online meetings.

- Findings/Results – the findings are summarized in the following table.

Outcome Wording	A Retain	B Reword	C Delete	D Abstain
1) Analyze and propose solutions to infrastructure problems	10	0	0	1
2) Describe and analyze infrastructure using systems and network approaches	7	3	0	1
3) Identify traits of effective team members and apply these traits to course assignments	7	3	0	1
4) Identify traits of effective spoken and written communication, and be able to apply these traits to make clear and compelling arguments	7	4	0	0
5) Desire to make a positive impact on the world, country, state, local levels and face infrastructure problems with an open-minded perspective	10	0	1	0
6) Describe the influence of political, social, technological, environmental, and economic factors on infrastructure decisions	11	0	0	0
7) Explain how infrastructure solutions affect society, the environment, and finances (i.e. the "triple bottom line")	10	1	0	0
8) Evaluate the condition of existing infrastructure and recommend improvements	9	0	2	0
9) Define and describe the components of an infrastructure system and their functions	7	3	1	0

Round 5: Course content solicitation

Process – A spreadsheet was created containing a matrix with the 9 learning outcomes as column headings and course content modules as rows. For the purposes of organization, the management team decided that a course organized around the major infrastructure sectors of water (including drinking water, waste water, and stormwater), transportation, and energy made the most sense. Added to these three was a column for "cross-cutting" (or synthesizing) topics and "miscellaneous" (a catch-all for anything that did not fit elsewhere). This spreadsheet was distributed to the CIT-E community and participants were asked to provide ten lecture topics, activities, or assessments that would each align with one of the five listed modules and nine learning outcomes. Adding a topic/activity/assessment to the list did not require ownership (i.e. the person adding the content was not expected to already have expertise in the area nor were they required to actually develop it). Nineteen responses were collected. After examination of the responses and some discussion among the management team, the content modules were renamed and some of the participant responses reorganized. The content modules used at the start of Round 5 were:

- Fundamentals – the critical knowledge, skills, and attitudes necessary to succeed in the remaining modules.
- One Water – a descriptor for the cumulative water management infrastructure including “natural” or “environmental” water, drinking water, wastewater, and stormwater.
- Transportation – the transportation sector including all modes and intermodal components.
- Energy – the energy sector including energy generation, transmission, and usage.

All of the responses were compiled in a spreadsheet, with one worksheet tab for each module. A screen capture of a portion of one of the worksheets with a compilation of all submitted information is provided in Figure 3. This screen capture provides some of the topics/activities/assessments that were generated for the first five outcomes for the Transportation module and hints at the wealth of material that was collected.

Transportation - Roads; Rail; Shipping; Intermodel Connection Points; Mass Transit; Bridges; Etc.				
List and describe the components of an infrastructure system and their functions	Analyze and propose solutions to infrastructure problems	Describe and analyze infrastructure using systems and network approaches	Identify traits of effective team members and apply these traits to course assignments	Identify traits of effective spoken and written communication, and be able to apply these traits to make clear and compelling arguments
[Lesson] Mode Focus with [Activity] Passenger train use country comparison, identify funding mechanism, avg. person miles traveled/year, total mileage of track per country, interconnectivity of routes through different countries (Kristina Fields)	[Lesson] Analyze the Hoover Dam and the Hoover Dam By-Pass. (Lauren McBurnett)	[Lesson] Describe the concept of system appraoch to infrastructure management. (Behzad Esmaeili)	(Activity) work out a model road design project that demand expertise from survey, geometric design, traffic analysis, pavement desgn and bridge design. (Moses Tefe)	(Activity) Apply the traits of effecitve spoken and written communication to a final team term paper and/or presentation dealing with the failure of a specific bridge during Hurricane Katrina. (Ralph Dusseau)
(Lesson) List and describe the main components of the transportation System. (Moses Tefe)	[Lesson] Remote transport: how to remote mountain villages/huts/islands transport goods (milk, food, beverages, recyclables, people, vehicles, cows/herds) [Activity] Students research a remote location and identify how infrastructure/transport is provided (Kristina Fields)	Describe a logistics system by developing a VENSIM model. Use this to analyse management issues (e.g., size of warehouse). (Mark Milke)		[Lesson] Multi-language/Cultures Infrastructure Use with [Activity] Explore how users understand how to use the infrastructure in other languages/importance of common symbols used in signage, train itineraries, communicating with conductors/police/staff/public - within and across borders of the same system (i.e. cross-border passenger train travel) (Kristina Fields)
[Lesson] Railroad. (Led Klosky)	Part A. Analyze traffic patterns on your campus - foot, bicycle, and vehicle traffic - identify problem areas, then use the engineering design process to develop solution(s) (Liz Adams)	[Lesson] Unique Multi-modal Transport with case study of Denmark/Sweden train/ferry transport; Kandersteg Switzerland car transport on train; Malmo/Copenhagen bridge/tunnel (Kristina Fields)		[lesson]&[activity] Describe the Highway funding issues in the government (postponed 36 times). Then have teams of 2 or 4 develop and then debate arguments for and against an increase gas tax to fund the infrastructure needs of the country. (Eric Steward)

Figure 3: Sample of compilation of one portion of the Round 5 submittals

- Lessons learned about the process – This was a very effective process. However, it did take some follow-up e-mails to encourage a sufficient number of people to respond. The task of contacting people was split up among the management team, which may have helped so that people weren't being contacted by the same person repeatedly. The additional contact may have been necessary for several reasons:
    - Participants were getting "burned out" or felt that the group was "close enough" to a solution.
    - This was an activity unlike any activity participants had probably completed in the past.
    - Consequently, respondents may have had some doubts (e.g. "Wow, I could dump in lots of stuff here…I wonder what they would want from me?" or "Are my ideas really good enough others would want them?")
    - This was a sizeable amount of work that we asked the respondents to complete.
- Findings/Results - 178 lesson topics, activities, and assessments were submitted. The large amount of material submitted was most likely due to the fact that approximately half of the participants had taught a similar course in the past; thus some material was already developed.

  One additional module was added ("Capstone") in response to the many activities that were cross-cutting and that built on a variety of materials in the class. Thus, the course design at the end of Round 5 consisted of five modules: Fundamentals, One Water, Transportation, Energy, and Capstone.

  The many topics from Round 5 were reviewed and then used to create an outline with a total of 78 lessons within the five modules. Within each of the five modules, topics were split into three levels: Foundational, In-depth, and Synthesis. Clearly, 78 lessons is more than a semester's worth of material but we did this because we wanted to get a completely comprehensive, all-encompassing list of possible content that our CIT-E community could eventually contribute to. We called this compilation the Master Topic List.

Round 6: Survey of Master Topic List

- Process – Participants were asked to comment on the Master Topic List by editing a spreadsheet template. The following questions were asked for each module on different tabs of the worksheet. Each tab (module) contained: a list of foundational, in-depth, and synthesis topics; and for each topic, a list of activities (e.g. in-class exercises, homework, case studies), all of which were gleaned from the Round 5 submittals. Participants were first asked "What do you think about our proposed course layout (i.e. the list of modules and the hopes that users will choose content such that it builds to at least one synthesis lesson per module)?" The following questions were asked for each module.
    - Module 1 (Fundamentals)
        - Are there any topics missing? Please list them. (It may be easier to answer this question after visiting the other tabs.)
    - Module 2 (One Water), Module 3 (Transportation) and Module 4 (Energy)

        - Are there any Foundational topics missing? Please list them.
        - Are there any In-Depth topics missing? Please list them.
        - As a result of reviewing this page, are there any additional activities or assessments that come to mind? If yes, please list them.
        - Please share any additional comments.
    - Module 5 (Capstone)
        - As a result of reviewing this page, are there any additional activities or assessments that come to mind? If yes, please list them.
        - Please share any additional comments.
- Lessons learned about the process – The respondents approved of the three levels (Foundational/In-Depth/Synthesis). We provided more Synthesis lessons than would be needed in a single course because multiple synthesis lessons allow flexibility for instructors based one which In-Depth topics they cover.
- Findings/Results – 17 participants submitted spreadsheet responses and 12 participants participated in the summary webinar. A model course outline was created from the list of 78 topics, retaining the modules and three levels of content within each module. An attempt was made to balance between the three discipline-specific modules (One Water, Transportation, and Energy). Furthermore, the model syllabus utilized several of the most useful sets of materials from University X and University Y and four "showcase lessons. The showcase lessons were developed collaboratively at the Second Annual Infrastructure Education Workshop held in 2015 at the University of Utah.

Round 7: Final outline was created and shared

The final outline is included as Appendix A.

- Process – The outline was shared with the community of practice via e-mail and then summed up with an online meeting. We used a Doodle poll to find the best time for interested parties.
- Lessons learned about the process – We found it was difficulty to get a large number of collaborators together for this final webinar (~10 participants) which highlights the difficulty in synchronous web meetings for large groups.
- Findings/Results

Consensus was reached on the course outline. For this webinar, there was not a lot of discussion solicited, as the focus was to get the final outline approved.

Overall assessment/reflection

Each member of the management team was asked to share their reflection on the process, and some of these reflections are shared in the following list.

- "The biggest challenge in the process was remembering we were writing a model course for new infrastructure instructors, not the *Best Infrastructure Course Ever* (which, of course, each participant believes she or he had already written and is currently teaching!)."

- "Remaining focused on the objective helped prevent "my way or the highway" attitudes from intruding. This is not a process for stubborn people. Compromise and consensus requires each participant acknowledge that someone else might be right on this issue and accept that."
- "We had to remember that no one actually teaches the model course; each professor will add, delete, and modify content. Accordingly, the lessons had to be loosely coupled where they were all interrelated but not so tightly woven together that removal, modification, and addition would change the nature of the overall course."
- "To me, as an outside observer of this process, [submitted by the program's external evaluator], this was an excellent example of a Community of Practice coming together around a purposeful activity. From the Community of Practice Design Guide for Higher Education,[5] I see these elements:
  - Provided a shared context for people to communicate around a topic in a way that built understanding and insight
  - Enabled dialogue to "create new, mutually beneficial opportunities"
  - Stimulated collective learning and shared existing knowledge
  - Was a collaborative process to "encourage the free flow of ideas and exchange of information"
  - Helped people organize around purposeful actions that deliver tangible results"
- "I doubt this could have worked if we hadn't previously done lots of meetings online previously, and especially if several of us had not met and worked (the majority) face to face previously. If we randomly had 20 professors out of the blue, it would have failed more than likely."
- "I think the objectives were clearly articulated and the fact that the goal was a pool of information from which to pick and choose helped the process go more smoothly and made it much less likely to have standoffs over any given topic."
- "There is a lot of "behind the scenes" work and leadership needed to keep a process like this moving along."
- "It would have been helpful to have a framework ahead of time to share with the participants (e.g., short deadlines!), but that wasn't really possible for us the way this work evolved."

Additionally, participants were invited to share their reflections which are provided below.

- "It appeared to me that you were intentional about involving junior and senior faculty from all over the country to ensure the topics, lessons, and assessment tools were diverse. With that, the course outline is actually much larger than a standard 3 credit semester course to allow each instructor to alter or adjust the course content depending on the region they are located, the style in which it is taught, and/or the resources available. I learned various techniques on how to develop a course (and also curriculum/specialty path within a department) from being involved in this process."
- "We teach our students about the need to work collaboratively, and it's about time that engineering teachers walk the talk."
- "…The process has been very effective at generating ideas and discussion. I know that I will look to push ahead with a somewhat related course here."

- “It is a great idea to create curriculum with input from multiple people. I liked being a part of a larger effort and am excited about the possibilities... I liked seeing how my interests fit in with the larger goal of the course.”
- “The Delphi process provided a fair and democratic method for determining the intermediate and final lists of modules for the model course. I felt that all of my opinions and suggestions were given serious consideration for inclusion in the list of modules at each stage of the Delphi process.”

Summary

The process, as described in this paper, was successful in meeting its objective: to create an outline for a model introductory infrastructure course in a collaborative method that collected input from infrastructure education experts from around the world.

Acknowledgements

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Appendix A – Model Introductory Infrastructure Course Outline

#	Module	Topic	Level
1	Fundamentals	What is infrastructure and why do we care?	
2	Fundamentals	Basic infrastructure functions	
3	Fundamentals	Systems/network analysis	
4	Fundamentals	TBL/Sustainability	
5	Fundamentals	Social Impacts of Infrastructure	
6	Fundamentals	Teamwork	
7	Fundamentals	Ethics I	
8	Fundamentals	Ethics II	
9	Fundamentals	Traits of effective written and oral communication	
10	Fundamentals	Financing public works	
11	Fundamentals	Safety/licensure	
12	Fundamentals	Land Use and Planning/Growth/Forecasting	
13	Fundamentals	Resilience and risk	
14	One Water	Enviro I	Fundamentals
15	One Water	Drinking water supply and treatment	Fundamentals
16	One Water	Wastewater sources and treatment	Fundamentals
17	One Water	Stormwater infrastructure and basic calculations	In-Depth
18	One Water	Green Infrastructure	In-Depth
19	One Water	Water Security	Synthesis
20	One Water	Water Re-use	Synthesis
21	One Water	Global water topics	Synthesis
22	Transportation	Transportation I	Fundamentals
23	Transportation	Intro to rail, water, roads, air, and pipelines	Fundamentals
24	Transportation	Bridges - life cycle	Fundamentals
25	Transportation	Roadways	Fundamentals
26	Transportation	Complete Streets	In-Depth
27	Transportation	Parking	In-Depth
28	Transportation	Mass Transit	In-Depth
29	Transportation	Route analysis and layout	Synthesis
30	Transportation	Hoover Dam Bypass	Synthesis
31	Energy	Sustainability and Energy	Fundamentals
32	Energy	Energy use	Fundamentals
33	Energy	Generation	Fundamentals
34	Energy	Transmission	Fundamentals
35	Energy	Distribution	Fundamentals
36	Energy	Renewable energy	In-Depth
37	Energy	Air Pollution	In-Depth
38	Energy	Energy/food and Energy/transportation nexi	Synthesis
39	Energy	Water/Energy nexus	Synthesis
40	Capstone	"Very Current" topic	Synthesis
41	Capstone	Infrastructure user fee	Synthesis
42	Capstone	Dams	Synthesis
43	Capstone	Hazardville	Synthesis