The purpose of this paper is to analyze the retention rate of the Cal Poly Granite Heavy Civil Minor program. This program began in 2020, with the first cohort graduating in Spring of 2022. Throughout the past two years, there have been several students who have joined the program, however they have decided to no longer pursue the minor. Through personal conversations, personal experience, as well as a survey directed to both construction management and civil engineering students, it was identified that scheduling concerns seemed to be a primary factor that was creating apprehensiveness in students. The survey showed that 95% of students believe that an updated flowchart in conjunction with a class supporting document would be beneficial and would assist with scheduling conflicts. After analyzing the survey, two separate deliverables were created; these deliverables consisted of two flowcharts and a supporting classes document with information on the eight minor specific classes to be taken. It is hoped that these documents will be used as a tool for construction management students experiencing scheduling issues after joining the program. These documents will provide increased clarity and aid on these issues and will increase the retention of students in the program.

Key Words:  Minor, Heavy Civil Construction, Construction Management, Schedule, Flowchart

How the Project Came About

The Heavy Civil Engineering and Construction Minor was curated with the support of Granite Construction along with numerous entities to enhance the collaboration between the Construction Management Department from the College of Architecture and Environmental Design and the Civil Engineering Department from the College of Engineering at California Polytechnic State University. Since the beginning of 2021, there has been a total of three cohorts from the minor, each accepting around 24-26 Construction Management (CM) and Civil Engineering (CE) students each recruitment session. To date, there are currently 62 students actively involved in the minor program consisting of 27 Construction Management and 35 Civil Engineering students. The program is comprised of 27% females and 73% males, with minority representation equating to around 53%. The fourth cohort is expected to alter the demographics of the program with full participation of 12 CM’s and 12 CE’s by fall of 2022.
Construction Management students were first introduced to the minor program in late 2020 via email, informational sessions, flyers, and classroom presentations with a known application deadline for the first cohort of January 31, 2021. The codirectors of the minor program portrayed that the benefits associated with enrolling in the program included, “increased experienced in heavy civil engineering and construction, integration of classwork and field experience, increased access to resources such as new courses, summer training, site visits, and future career development, a guaranteed paid summer internship, and interdisciplinary opportunities”. These undergraduate students were also informed that the additional 15 units required of the minor would be easily achievable without having to extend the expected graduation date.

Although there are enormous benefits associated with the completion of the Heavy Civil Minor, the 31% drop rate of the first and second cohorts posed some concerns about long-term engagement from students initially involved in the program. The purpose of this project was to conduct analysis of student’s interest and disinterest in the program to create some potential solutions that may assist with an increased retention rate of the program.

**Processes**

**Preliminary Data Collection**

The initial process involved with this project began by conducting personal conversations with both CM and CE students who were interested in applying in the minor, those that are actively involved in the minor, and those who have chosen to drop from the program. Conversations were also made with CM faculty who have been affected both positively and negatively by the minor program. These conversations helped gauge a better understanding of both students’ and faculty’s opinions on the program. Information collected from students included initial interest in the program as well as basic reasonings behind failing to complete an application or withdrawing permanent enrollment from the program. Information obtained from faculty included positive characteristics associated with their students who were involved in the program as well as any potential class conflicts caused by the program that they may have experienced.

Further information was collected regarding the status of the program during a Granite Construction visit of Cal Poly on March 3, 2022. This day consisted of various meetings, presentations, and tours with Granite executives, the CE and CM department heads, and Cal Poly administrators. This day provided specific information about history of the minor, current enrollment numbers, and industry and staff opinions on success of the program.

Assessment of the information collected during the beginning processes led to a substantial amount of both positive and negative feedback for the program. It was important to understand the positive aspects of the program, however, to make any improvements, it was crucial to fixate on what can be done to improve the flaws. Reoccurring negative observations about the program included issues with the course catalog and scheduling. With that in mind, a survey was then conducted to understand if the majority of students in the program had experienced these scheduling conflicts or not.

**Survey Development**

The survey titled *Heavy Civil Minor Questionnaire*, was sent to all CE and CM majors who had been accepted into the program, regardless of whether they were still involved in the minor or not.
Questions included information regarding major, year, and current status of enrollment as well as reasons why students chose to pursue the minor as well as drop it if applicable. Further questions probed specific struggles encountered with the program and thoughts on the HCM flowchart. The 38 total responses were collected from the survey which represents 50% of students who have ever been enrolled in the minor program. The response distribution was 58% civil engineering students and 42% construction management students, varying from first to fourth years. The survey questions were as follows:

1. What is your major?
2. What year are you?
3. What year were you when you first became enrolled in the minor?
4. What is your status in the HCM program?
5. Are you enrolled in any other minor programs at Cal Poly?
6. What cohort of the HCM are/were you in?
7. Why did you apply to the minor?
8. If you are no longer enrolled in the minor, what was your reasoning? (please select all that apply)
9. If you have encountered any specific struggle with the minor other than those listed in the previous question, please specify them below:
10. Were you on track to graduate within 4 years before applying to the minor?
11. Are you currently on track to graduate within 4 years after joining the minor?
12. Have you ever experienced doubt about graduating within 4 years after joining the minor?
13. Did you ever utilize the HCM flowchart during registration?
14. If you utilized the HCM flowchart during registration, did you find it beneficial?
15. The class description for CE 321 on the Cal Poly catalog is provided in the image below. The information in the asterisk is a scheduling recommendation from a student's point of view. Would you find this information beneficial?
16. If you were given a document with student feedback on each class required of the minor in conjunction with an updated flowchart for your specific major, would you find this beneficial?
17. Do you believe that this information would assist with scheduling conflicts?

Analysis of Scheduling Conflicts

The topic of scheduling conflicts was displayed in various responses throughout the survey. The questions that led to the most insightful information on these conflicts were questions 8-12. Question 8 probed reasoning for dropping the minor with the potential answers to select that varied from scheduling conflicts, lack of interest, rigor of course load, difficulty finding additional career opportunities, financial reasons, inability to graduate within 4 years, and other. Question 8 was, “If you are no longer enrolled in the minor, what was your reasoning?” A summary of the results is displayed in Figure 1.

![Figure 1. Question 8 Results of the Heavy Civil Minor Questionnaire](image_url)
As shown in Figure 1, three out of the seven students who responded to this question who had dropped the minor did so due to scheduling conflicts. Considering these results, finding a useful solution to the scheduling issue has the potential of increasing retention by around 50%.

The scheduling concern is most prominent in the responses from the open-ended question that allowed students to explain any specific struggles they had experienced throughout their time in the program. 14 of the 16 responses highlighted concern with scheduling issues in one way or another. Direct quotes from students include, “not knowing how to take my courses in an appropriate timing to graduate at my expected graduation date”, “the flowchart was not entirely accurate”, “not knowing class schedules in advance made me worried about potential for class conflict” and “disorganization of classes”.

Questions 10-12 were included in the survey to understand whether graduating within four years was an issue for students or not. Questions 10 and 11 revealed that three students’ graduation times were extended due to joining the minor program. Although only three students had to extend their graduation date, many others had some sort of concern that this may happen to them as well. Question 12 is, “Have you ever experienced doubt about graduating within 4 years after joining the minor?” Refer to Figure 2 displaying students’ responses to question 12 of the survey.

Figure 2. Question 12 Results of the Heavy Civil Minor Questionnaire

Figure 2 exhibits that 74% of all students in the program experienced some sort of doubt about graduating within 4 years after joining the minor. When reflecting on the responses from questions 8-12, it is apparent that change needs to happen with course scheduling in the minor program to give students a sense of ease in relation to course load, registration rounds, and graduation times.

Potential Scheduling Solutions

When developing the survey, it was assumed that students would provide similar responses to those displayed above. Keeping potential solutions to scheduling constraints in mind, an updated flowchart that works in conjunction with a class document giving student perspective on scheduling recommendations for courses required was proposed. A draft of these documents was attached in the survey and presented to students for feedback. Questions 13-15 helped grasp an understanding if students used the flowchart if they found it beneficial, etc. and responses varied between the questions. However, the answers to questions 16 and 17 proved that these proposed deliverables will in fact be beneficial to students. Refer to Figure 3 displaying the responses to question 16 of the survey.
100% of the students who responded agreed that these documents would be beneficial if they were provided to them when they join the minor program. Of these students, 95% of them think that the documents will directly assist with scheduling conflicts as well. Deliverables were developed shortly after assessing student concurrence on the helpfulness of it.

**Deliverables**

**Development**

Because the creator of this project was a construction management major, they were most familiar with the conflicts associated with class scheduling for the construction management majors that are minoring in heavy civil engineering. With that being said, the deliverables attached may benefit CE students, but will be most advantageous to CM students. It is proposed that a CM may be able to work with a CE for a future senior project to complete the following deliverables from a CE perspective.

**Flowchart**

The first deliverable that was created was the flowchart. Although there is currently a flowchart on the CM website to assist with scheduling for the minor, there were some changes that needed to be made due to class availability and prerequisites. The necessary changes were identified from personal experience during class scheduling throughout their time at Cal Poly as well as information provided from fellow students.

Because there are several students in construction management who are not on track to graduate within the four years for just the undergraduate degree in CM, I decided it would be best to provide two separate flowcharts: one with a four-year graduation track and one with a four and a quarter graduation track.

The first update made on the first flowchart was changing the academic course catalog year from 2019-2020 to 2021-2022. Although there are no extensive differences between the course catalog years, it will be beneficial to younger students as they are able to navigate through the most recent version of the CM flowchart. In terms of aesthetics, a few changes were made to the colors of each class on the flowchart as well as the legend. Instead of greying out certain classes, I decided to keep the major classes yellow, the support classes orange, and the general education classes green. For the purpose of this analysis, I will call these the “core classes”. The thought behind keeping the core class colors consistent with the updated flowchart is so that students will have more ease with the transition
between the traditional CM major flowchart and the CM major flowchart with the heavy civil minor. Keeping the core colors consistent will also make the new classes required easier to identify. The new colors introduced to the flowchart are blue and purple, which represent the “minor classes”. The additional courses required by the minor (15 units) are represented with a blue color and the elective classes directed by the minor (8 units) are represented with a purple color.

Aside from aesthetic, the two major changes made to the first flowchart are an extra note in the footnotes as well as the movement of the ARCE 421 class. The footnote is as follows: “***Select courses only offered in quarters shown on flowchart”. The asterisks were highlighted in yellow directly on the applicable classes on the flowchart so that students are aware of certain class availability. This information was also provided in the supporting class document information in the following section.

The second major change was moving ARCE 421 from fall of senior year to spring of junior year. ARCE 421 is a prerequisite for CE 429, however in the old flowchart, these were shown as concurrent enrollment in the fall of senior year. Because CE 429 is only offered in the fall, it is best that ARCE 421 is taken spring of junior year so that students do not have to risk a corequisite not being approved their fall of their senior year. Because certain classes had to be moved around slightly, the unit count each quarter varied slightly from the original flowchart. The units needed to graduate within four years requires students to take on average 17 units a quarter adding up to a total of 204 units.

Because there are certain students in the program who are not on track to graduate within four years, a secondary flowchart with one additional quarter was provided: fall quarter of fifth year. Similar to the first flowchart, the “four and a quarter” flowchart contained the same color scheme and legend, the additional footnote, and ARCE 421 taken prior to CE 429. Although taking an extra quarter of college can be financially burdensome and not possible for certain students, I wanted students to understand the per-quarter unit count differences between graduating in four years vs. four and a quarter. Graduating within four years with the CM major and heavy civil minor is certainly not impossible, however it may be challenging for certain students. Students who can take an additional quarter have slightly more flexibility with class scheduling and have a lower per-quarter unit count with an average of 17 units for freshman and sophomore year and 15 units from junior year through fifth year.

**Supporting Class Document**

The second main deliverable that was developed was a supporting class document. This is a class list of all the HCM classes that must be taken in addition to the CM undergraduate program. The classes included in the list are CE 222, CE 321, CE 413, CM 422, CE 429, CE/CM 436, CE/CM 437, CE 474. The basic information like class description, unit count, and prerequisites are taken directly from the Cal Poly Course Catalog and put numerical order. The added information for each class, however, are the notes labeled *Timing and **Student Opinion.

The *Timing note lets students know how many hours a week the class will be based on lecture and lab as well as what quarters they may be offered. An example of a *Timing note for CE/CM 437 is, “2, 1-hour lectures and 2, 3-hour labs a week, ONLY OFFERED IN SPRING”. Although the classes that are only offered one quarter a year are specified on the flowchart, I thought it would be beneficial to include this in the supporting class document as well, so this information does not slip through the cracks. The class availability was also confirmed by the Cal Poly Civil and Environmental Engineering Department Chair.
The **Student Opinion note was created for students to understand more information about what they should expect of the class difficulty as well as any scheduling guidance I have recommended. An example of **Student Opinion for CE/CM 437 is, “The lecture and lab class times are typically offered in 2, 4 hour chunks a week, so it is easier to fit into you schedule than lab and lectures that are broken up. Typically, you can take either morning or afternoon sections of this lab in conjunction with the morning or afternoon section of a CM lab. Keep in mind that this is only offered in the spring when you are scheduling, however”.

The supporting class documents is not a document that I aim to have Cal Poly approve and post on their website, but its primary goal is that it is to be used as a tool for students. Hopefully, students can view this document as advice and support from an older student who was once in their shoes. I foresee this document to be a living document, meaning changes may need to be made as the minor program develops even further. Class lists may change, and other students may also want to add their own opinions or provide further advice.

**Lessons Learned**

Throughout the research and deliverable development this project, I learned many lessons related to data collection as well as problem-solving skills. In my preliminary data collection, I wanted to encourage open conversations and full participation from most entities involved in the minor program to ensure that my information was as all encompassing and as accurate as possible. During my deliverable development, I learned how to research class information and identify clashes with class time based on availability per quarter. I understood how to resolve restrictions based on prerequisites as well and wanted to make sure students were aware of what they need to accomplish to properly schedule their classes. I was able to gain potential new students’ interest in the program throughout this process and have understand what makes a minor program desirable in students’ eyes. It is not easy to develop a brand-new minor program, so the utmost respect goes to all entities that were involved in the funding, curation, and approval of this program. The program has made a lot of progress since I joined in 2020 and I am excited to see what the future holds for the students that will follow behind the first cohort.
Class List of HCM Classes to be Taken in Addition to the CM Undergraduate Program

CE 222. Introductory Experiments in Transportation Engineering  
1 unit  
Application of urban transportation planning, design, and operations principles. Introduction to Engineering Economics in the context of transportation projects. Collect field traffic operations data and conduct analysis and report conclusions from collected data. Field trip required. 1 laboratory.  
*Timing: 3 hour lab once a week.  
**Student Opinion: Could take at any time, recommended to take early as possible as this class is somewhat simple to add into a schedule compared to other classes.

CE 321. Fundamentals of Transportation Engineering  
3 units  
Prerequisite: PHYS 141; CE 250 or CM 113; or graduate standing.  
The characteristics and functions of highway, air, rail, transit and other modes of urban and intercity transportation. Fundamentals of transportation design, operations, and planning. Evaluation of costs, benefits, and environmental considerations. 3 lectures.  
*Timing: 3, 1-hour classes a week.  
**Student Opinion: If there is an opening in your class schedule after taking PHYS 141 and CM 113, try to take this class if you can. It is a prerequisite for CE 413, but you may be able to take this at the same time and get it approved as a corequisite if taken at the same time (approval for corequisite varies depending on the professor).

CE 413. Advanced Civil Computer-Aided Site Design  
2 units  
Prerequisite: BRAE 239; CE 113 or CM 115; and CE 321.  
Apply advanced CAD software to develop design techniques and convey the completed design on a set of plans; site coordination, basic road design, grading, and utility design. 2 laboratories.  
*Timing: 2, 3-hour labs a week.  
**Student Opinion: Shown on flowchart as replacing a tech elective in conjunction with CE 474. These are two separate, 2 unit classes. Make sure you don’t hold off on BRAE 239 in your first two years because it is a lab that is a prerequisite for CE 413.

CM 422. Professional Preparation.  
3 units  
Prerequisite: Third-year standing.  
Professional practice related to the construction management industry. Goals and objectives achieved through analysis, study, and preparation for a particular professional practice. The Class Schedule will list topic selected. Total credit limited to 8 units. 1 to 6 activities.  
*Timing: Meet via zoom 1-3 times over the summer.  
**Student Opinion: This class is taken during your heavy civil internship over the summer. CM 485 may be listed as the class to take, however CM 422 is the correct summer class. Class requirements may vary however in the past, students had to perform daily logs, keep track of progress photos, and complete a research paper by the end of summer term.

4 units  
Prerequisite: CE 250 or CM 113; CE 381 or ARCE 421; and CE 321.  
Theories, principles, and procedures in the structural design of highway pavements. Design of flexible and rigid pavements. Performance of flexible and rigid pavements in the field and the characterization of pavement materials. Practical and direct exposure to laboratory testing of pavement materials. 3 lectures. 1 laboratory. Formerly CE 521.  
*Timing: 2, 1 hour 20 min lectures and 1, 3-hour lab a week, ONLY OFFERED FALL.  
**Student Opinion: More difficult class compared to others in the minor program. Combines physics background with transportation concentration. May be difficult to schedule additional labs in conjunction with this class due to scheduling constraints. Could be a good quarter to complete unfulfilled GEs. Be aware that ARCE 421 is a prerequisite so you must complete that class spring of junior year or before.

CE/CM 436. Heavy Civil Temporary Structures and Shoring.  
4 units  
Prerequisite: ARCE 315 or CE 352; and CM 316.  
Design and construction of retaining walls, concrete formwork, falsework, scaffolding, ramps, platform, bracing, and guy as applied to heavy civil projects. Field trip may be required. 2 lectures, 2 laboratories  
*Timing: 2, 2-hour lectures and 2, 3-hour labs a week, ONLY OFFERED WINTER.  
**Student Opinion: In the past, the lectures and labs have been split into separate days so you may have MW lecture and TTR lab. Be aware that a lecture may be offered in the morning whereas the lab may be offered in later afternoon, conflicting with both the morning and afternoon sections of M-TR CM labs. In the past, students have filled out “time sharing” forms and may have to miss class time in certain classes weekly. May be a good quarter to take GE - keep in mind this is only offered in the winter as well.
CE/CM 437. Heavy Civil Projects and Equipment. 4 units
Prerequisite: CM 314
Heavy civil projects logistics, construction, operations, planning, management, workflow and sequencing, equipment management, fleet configuration and maintenance, equipment productivity and cost optimization. 2 lectures, 2 laboratories.
*Timing: 2, 1-hour lectures and 2, 3-hour labs a week, ONLY OFFERED SPRING.
**Student Opinion: The lecture and lab class times are typically offered in 2, 4 hour chunks, so it is easier to fit into schedule than lab and lectures that are broken up. Typically can take either morning or afternoon session of this lab in conjunction with morning or afternoon section of a CM lab. Keep in mind that this is only offered in the spring, however.

CE 474. Environmental Compliance and Permitting. 2 units
Prerequisite: Senior standing
Fundamentals of State and Federal environmental laws essential to getting Civil Engineering projects permitted. 2 lectures.
*Timing: 1, 2 hr lecture a week. ONLY OFFERED WINTER
**Student Opinion: This class is fairly easy to fit into a schedule that is loaded with labs due to the minimal class time. However, recognize that it is only offered in the winter, so there may be difficulty enrolling if you wait until senior year to take this.

CM 485. Cooperative Education Experience. 1-6 units
CR/NC
Prerequisite: Consent of instructor
Full-time work experience in an area directly related to the construction industry for 2 months. Positions are paid and usually require relocation and registration in course for one quarter. Registration in course is required at start of work experience. Formal report and evaluation by work supervisor required. Credit/No Credit grading only. May be repeated for credit. Major credit limited to 6 units; total credit limited to 12 units. See department for additional requirements.