Incorporating Highway Capacity Software in Undergraduate Teaching of Transportation Courses

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Abstract

The Highway capacity Software (HCS+) provides students with a computer aided engineering software for analysis of traffic engineering cases. This paper presents a description of the software, its existing capabilities and its use as an educational tool in an undergraduate course focusing on traffic engineering. This represents one of the first studies about the use of HCS+ in a Traffic Engineering course at the undergraduate level.

The HCS+ is traffic analysis software that is produced by McTrans Moving Technology. It is used to model signalized intersections, roundabouts, freeway facilities, two-lane two-way highways and multilane highways based on the procedures defined in the Highway Capacity Manual (HCM). With known traffic volumes and many other inputs, this software can determine the current and projected Level of Service (LOS) for all of the above traffic facilities.

An end-of-course survey was implemented to evaluate the benefits of such modification to this existing course. The purpose of the survey was to numerically measure the success rate of this development. The survey included ten questions that compare students learning experience from a classroom-setting to a computer lab-setting, measure how interesting using the computer software was, measure any potential enhancement to students' comprehension of the material explained and whether the software helps students remember main concepts. Ease of operation, linkage between the computer assignments and what is taught in class, students' satisfaction about the tutorial provided, adequacy of the number of problems assigned using the software, how the software ranks among others and the instructor competency in running and teaching the software were other things covered in the survey.

Analysis of results showed that the use of HCS+ software in Traffic Engineering class enhances students' learning experience. Students indicated that HCS+ is a good and easy tool worth learning and could be useful in the future. However, it was shown that any simulation or modeling computer program should not replace regular class instruction. Students suggested more challenging problems and probably projects and also recommended the use of the software for years to come.

Introduction

Ohio Northern University (ONU) is a small (3600 students) institution of higher learning that has undergraduate Colleges of Arts and Sciences, Business Administration, Engineering, and Pharmacy and a College of Law. The core Civil Engineering curriculum consists mainly of Transportation, Structures, Environmental, Geotechnical, and water resources. The Transportation sequence covers a comprehensive spectrum of knowledge; the geometric design of highways, traffic engineering, pavement analysis and design, and highway materials are all

covered. This paper will focus on an undergraduate course within the transportation sequence where the Highway Capacity Software (HCS+) can be implemented. This course is called Transportation II or Traffic Engineering.

Traffic Engineering is a core course in the civil engineering curriculum at Ohio Northern University that is offered once a year. This course is taught by the principal author of this study and is offered to the junior class. The course is divided into three major components; namely: traffic analysis (30%), level of service and capacity analysis (40%) and intersection design (30%). After the completion of this course students should able to:

1. Determine the relationship between traffic stream characteristics.
2. Perform traffic volume, delay, accident, parking, and speed studies.
3. Determine the Level of Service (LOS) for basic freeways, multilane highways and two-lane two-way highways.
4. Analyze and design intersections with different levels of control.

After implementing the HCS+ software the previously mentioned classical topics remained the same. The only difference was the inclusion of the software into the plan of study for many reasons; building knowledge of using viable programs in any field strengthens the comprehension of a material. Furthermore, it saves considerable amount of time after ensuring that students have a good understanding of the material and theory and then the mathematical formulation used in building the computer program. This is more of an issue for complex and iterative processes. In addition, the implementation of such softwares allows conducting parametric and comparison studies to further understand the main controlling factors of a specific phenomenon. Also, knowledge of this kind comes in handy when students are working on their senior design projects besides furnishing their resumes when it is time to look for future jobs. Let's not forget that one of ABET outcomes (outcome-K: an ability to use techniques, skills and modern engineering tools necessary for engineering practice) is fulfilled when such a course improvement is implemented[2]. These benefits could not be attained without implementing and using softwares with modeling and simulation capabilities as can be seen next from the instructor's observations before implementation of HCS+.

All in all students had a good understanding of how to determine the LOS for different classes of roadways, they also were able to analyze and design signalized and unsignalized intersections following a set procedure. In both situations it was lengthy and of course time consuming with large room for mistakes. Additionally, it is always helpful to provide students with ways to double check their final answers, which is one big advantage of using a computerized method for this purpose. Finally, it was obvious that students, in general, lack the ability to identify the most influencing factors or parameters when it comes to using ready mathematical formulas or standardized procedures. This shortcoming could be eliminated, or at least alleviated, by teaching them a computer program that can run the analysis and/or design in a matter of seconds. The aforementioned benefits of using the HCS+ software in Traffic Engineering worth to be investigated more in the following sections.

Several studies were carried out to evaluate and measure the need for using finite element packages or modeling softwares in undergraduate teaching. Abdel-Mohti and Khasawneh[2] studied the benefits of teaching finite element analysis in undergraduate courses. It was found based on their study that students found it rewarding and it is well-received by employers. They

also found that this addition resulted in better learning experience as was validated through students' feedback. Another study by Shaalan[3] concluded that using the Distribution Engineering Workstation as engineering software to teach Electric Power Distribution can serve as an effective educational tool as was illustrated by positive feedback from students participated in his study. A study by Blake and Cornett[4] on Teaching an Object-Oriented Software in Undergraduate Engineering Education resulted in nourishing learning experience by students as this tool helped them in their job interviews and to understand the big picture of their internships. There is a need to conduct a parallel study to investigate the potential benefits of using engineering software(s) in transportation and traffic engineering courses at the undergraduate level.

Highway Capacity Software

Highway Capacity Software (HCS+) is traffic analysis software that is produced by McTrans Moving Technology. It is used to model signalized intersections, roundabouts, freeway facilities, basic freeway segments, freeway weaving segments, freeway merge and diverge segments, two-lane highways and multilane highways based on the procedures defined in the 2000 Highway Capacity Manual (HCM 2000). With known traffic volumes and many other inputs, this software can determine the Level of Service (LOS) for all the above listed facilities. Not only does HCS+ model current conditions, but it can also model future LOS with known growth factors. The software is affordable and a significant discount is offered for education/research license for universities. A laboratory license for up to 10 seats for universities is only at $1000. Figure 1 shows the user interface and all the different options this software has to offer.

Figure 1: Highway Capacity Software Main Menu

Buttons on the Main Menu (Figure 1) provide links to different modules corresponding to the HCM chapters being used for analysis. For more details on how to enter the data and run the analysis, let's consider the module corresponding to signalized intersections. The top of Figure 2 shows the HCS+ Signalized Intersection module Data Entry screen. The bottom of Figure 2 shows the Report Pane. When changes are made to the Data Entry screen, the results are shown immediately in the Report Pane; this is applicable for different types of analyses carried out by HCS+. The first step is to enter general and site information about your intersection and the

analysis that you are performing. Step two is to select the analysis type ("single or multiple period") and the duration (ex. 15 minutes or 0.25 hours). In step three one can enter the lane geometry and volume. An easier method for geometry and volume data entry is via the "Quick Entry", the button on the top of Figure 3. The Quick Entry screen (Figure 4) uses a graphical approach to enter geometry and volume.

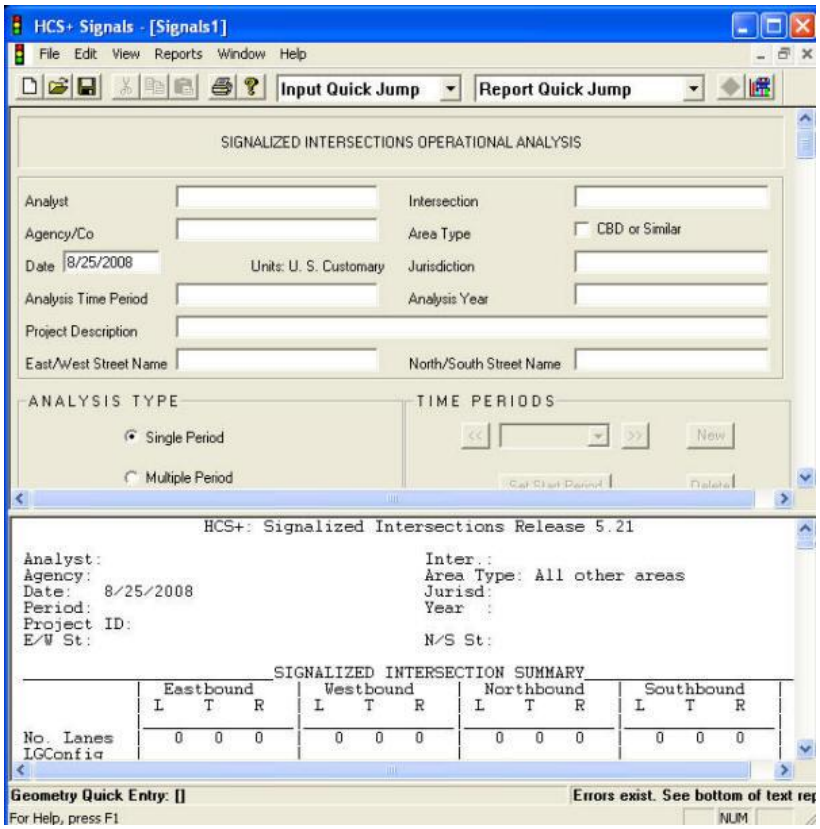


Figure 2: The HCS+ Signalized Intersection Module Entry Screen and Report Pane

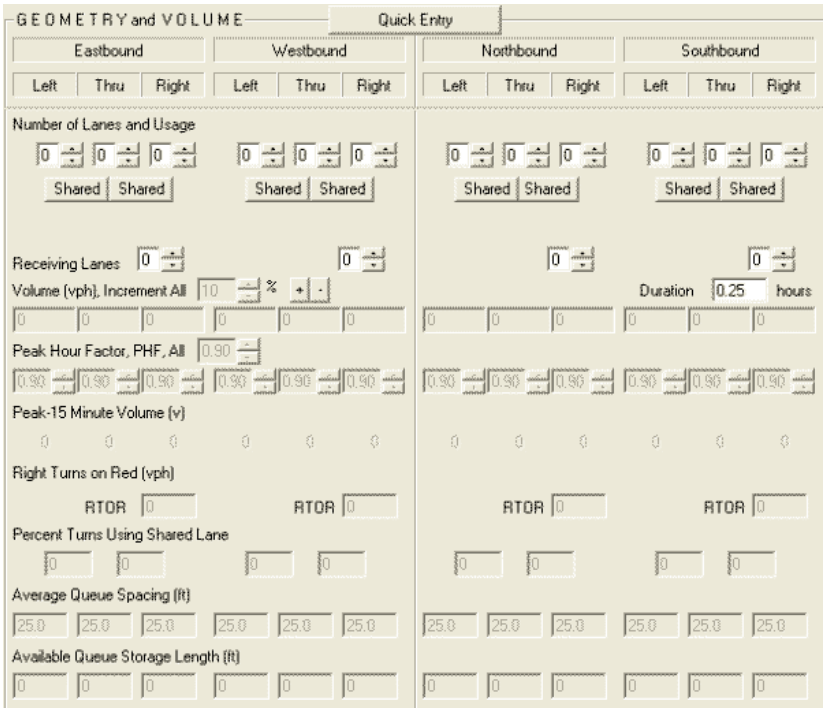


Figure 3: Section for Geometry and Volume

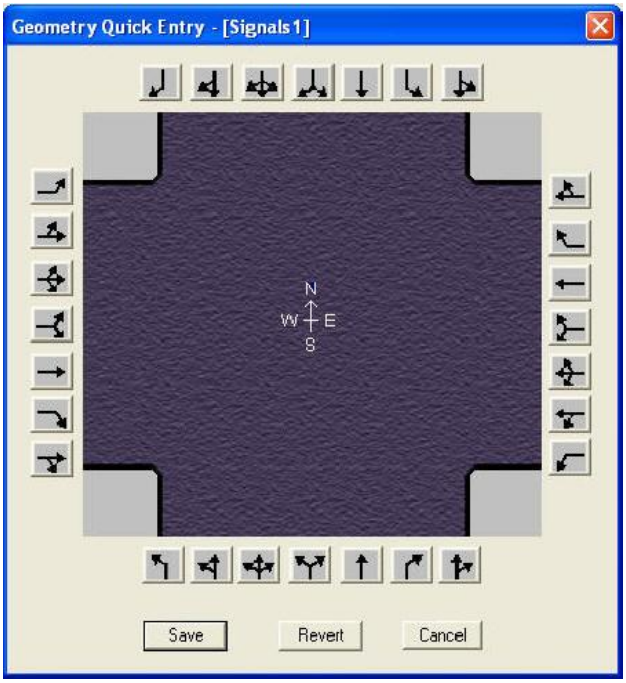


Figure 4: Quick Entry screen

In steps four, five, and six operating parameters, phasing design, saturation flow rate and other parameters are entered, respectively. Step seven is to show results and the final step (step eight) is the operational report; the lower pane of the data entry screen shows a formatted version of the analysis in a dynamic form. The Report portion of the screen can be viewed simultaneously with the Entry pane. All or a portion can be copied to the Windows clipboard for

insertion into other files. The Report pane can also be printed or saved to a text file. If a calculated number is edited, an asterisk (*) will be shown by that field and an asterisk will appear in all results to indicate that an intermediate value was adjusted.

The computer assignments were tailored to touch on some critical learning objectives needed to enhance students learning. These include, but not limited to, effectively collaborate in a team setting and effectively manage projects, apply critical and creative thinking to ambiguous problems, persist through and learn from failure and of course the ethical aspect is always present.

Survey Structure

The incorporation of the HCS+ in the Traffic Engineering course should be assessed to evaluate the benefits of such addition to this existing course. This was completed by having students fill out an end-of-course survey. The purpose of this survey is to numerically measure the rate of success for this course development. The survey is composed of ten questions, each question is to be rated on a scale from 1 to 5 with 1 being described as "strongly disagree", 2 "disagree", 3 "partially agree", 4 "agree" and 5 "strongly agree". Question 1 compares students learning experience from a classroom-setting to a computer lab-setting. Question 2 measures if using computer software makes a class more interesting or not. Any potential enhancement to students' comprehension of specific traffic engineering subjects using the HCS+ is measured by question 3. Question 4 is about whether the software helps students remember main principles more than a class does. Question 5 is about the link, if any, between the computer assignments and what is taught in class. How easy it is to operate the software is covered by question 6 and question 7 deals with students' satisfaction about the tutorial provided to them in class. Questions 8 and 9 touches on the adequacy of the number of problems assigned using the HCS+ and how the HCS+ ranks among other softwares students learned before, respectively. Finally, question 10 is about the instructor competency in running and teaching this traffic analysis software. At the end students were encouraged to provide any additional comments on the usefulness of the HCS+ and/or any suggestions for improvement. Figure 5 shows a complete survey identical to this filled out by Transportation II students.

For the statements below, please circle one number.

1 = "strongly disagree"	2 = "disagree"	3 = "partially agree"	4 = "agree"	5 = "strongly agree"

1. I learn material just as well from a normal lecture/homework/exam class format as I do working in a team using software in a computer lab.

   1 2 3 4 5

2. I enjoyed the Transportation II class more because of the HCS+ software.

   1 2 3 4 5

3. The HCS+ software enhanced my understanding of the traffic engineering principles it employed.

   1 2 3 4 5

4. I remember how to use the traffic engineering principles used in the software better than I remember other principles from this class.

   1 2 3 4 5

5. The computer assignments using HCS+ software were related to the material taught in class.

   1 2 3 4 5

6. The HCS+ software was user-friendly.

   1 2 3 4 5

7. The tutorial provided in class was enough to complete the assigned work using HCS+ software.

   1 2 3 4 5

8. If I were to retake the Transportation II class, I would recommend having more computer assignments using HCS+ software.

   1 2 3 4 5

9. If I were to rank this software among others that I have completed, I would rank it among the best.

   1 2 3 4 5

10. The instructor had enough experience and knowledge to teach this software.

    1 2 3 4 5

Do you have any additional comments on the usefulness of the HCS+ software or any suggestions for improvement?

Figure 5: Survey Structure

Discussion of Results

Total number of junior students participated in this survey is 25. All answers are summarized in a tabular format as shown in Table 1. The average value for each question along with some descriptive statistics is listed in the same table (Table 1). It can be seen that the highest average was recorded for questions 5 and 6 with 4.6/5.0 or students are satisfied up to 92%; question number 5 is "The computer assignments using HCS+ software were related to the material taught in class" and number 6 is "The HCS+ software was user-friendly". This shows that the purpose of incorporating the HCS+ into the course syllabus, which is to reinforce students' understating of the material by having them solve similar problems by hand calculations and using a

computer, is met. This is beneficial to allow students to check their final results and enable them to conduct quick comparisons. Furthermore, results from question 6 show that the software is easy to use to high extent. On the other hand, the lowest average of 3/5 or 60% satisfaction was for question 1 "I learn material just as well from a normal lecture/homework/exam class format as I do working in a team using software in a computer lab". As expected, the vast majority of students prefer the traditional classroom environment to learn a new subject, that is totally reasonable and it was absolutely not the intention to replace classroom instruction by computer sessions in undergraduate teaching. Average values for the rest of the questions were between these two extremes as discussed in the next paragraph.

Question 10 "The instructor had enough experience and knowledge to teach this software" had an average value of 4.4/5; this means that 88% of students were satisfied of the instructor's expertise in using and teaching the HCS+ computer program. In question 7, participating students thought (up to 86%) that the tutorial provided in class was enough to complete the assigned work using HCS+ software, this indicates the ease by which this software can be dealt with. It is recommended to 84% that more HCS+ problems be assigned next time this course is offered, this is indicative that incorporating the HCS+ into transportation topics has made a significant change and could be considered a success as can be seen from question 8. Another measure of the success involved is the fact that participating students highly ranked this software among best 20% compared to others they learned since they started their undergraduate study (see question 9). The average for question 2 "I enjoyed the Transportation II class more because of the HCS+ software" was 3.7/5; this percentage (74%) is a very good result considering that this is the first time this course improvement is being implemented. In addition to what was mentioned above, juniors agreed to 74% that the HCS+ software enhanced their understanding of the traffic engineering principles it employed which is the main objective of using this software (question 3). Finally, a relatively low percentage (68%) thought that implementing the HCS+ did improve their ability to remember how to use the traffic engineering principles used in the software better than they remember other principles from class periods. It is again well established that using a computer program is not sufficient and cannot be used to replace the ordinary classroom instruction. All of these results are graphically shown in Figure 6.

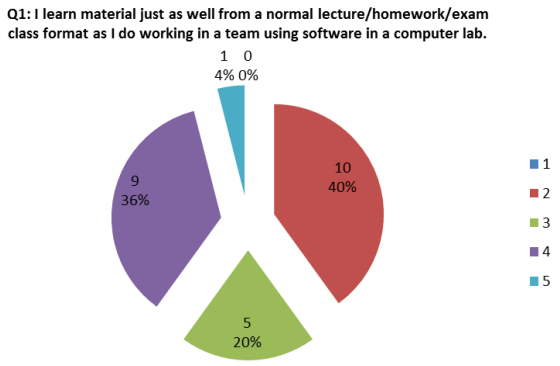
Some of students' comments worthy to be mentioned at this point are listed below:

1. Seems useful in the real world. Good to know how to use it well.
2. Just use more for homework to check yourself.
3. Definitely helped with cutting down on the time of homework problems but at the same time didn't confuse me in wondering "How did they get that number?" or anything like that.
4. The software helped to solidify the methods in class. Everything became clearer when I was able to verify it with a computer program.
5. Assign a few more HCS+ assignments. Helps the understanding of the lecture.
6. It was very useful. When teaching the tutorial on HCS+, have the class in the computer lab so they can follow along on their own computer.
7. I don't think you learn as much using the software but I do think once you understand the principles behind it, the software is a very useful, neat, user friendly program.
8. Definitely implement this into the class.
9. Might see more advantage using it to complete a more complex project.

10. Didn't use it enough to experience a real benefit. Software was quite simple to use for assignment given.
11. Teach us how to use the software earlier in the course so we can use it while performing homework assignments throughout the course when we learned about LOS.
12. Learn more of the software. It gives a better understanding of what we do by hand. With all the calculations and looking at graphs.
13. Easy to use in terms of understanding and how straight forward the program was.
14. It was helpful to use and correspond to the answers you get by the hand calculations.

Table 1: Survey Data

Question #	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	**Average**	**Standard Deviation**	**Maximum**	**Minimum**
1	2	2	3	2	4	3	5	4	3	4	2	2	2	4	4	2	4	2	4	3	2	3	4	4	2	**3.0**	**1.0**	**5.0**	**2.0**
2	3	3	5	4	4	4	4	4	2	4	4	4	4	5	3	4	4	4	4	3	5	2	3	4	3	**3.7**	**0.8**	**5.0**	**2.0**
3	4	3	4	3	3	5	4	5	3	4	4	3	5	5	3	4	4	3	3	3	4	3	4	4	2	**3.7**	**0.8**	**5.0**	**2.0**
4	2	3	4	4	4	5	4	4	2	2	3	4	5	4	3	4	3	4	2	4	3	3	4	3	3	**3.4**	**0.9**	**5.0**	**2.0**
5	5	4	4	5	3	4	5	5	4	5	5	5	5	4	4	5	5	4	5	5	5	5	5	5	4	**4.6**	**0.6**	**5.0**	**3.0**
6	5	4	5	5	4	5	5	5	4	5	5	5	5	5	4	4	4	4	5	5	5	4	5	4	4	**4.6**	**0.5**	**5.0**	**4.0**
7	4	3	4	5	4	5	5	3	4	4	5	5	5	5	4	5	3	4	5	5	5	3	5	4	4	**4.3**	**0.7**	**5.0**	**3.0**
8	3	4	4	5	4	4	5	5	4	4	4	4	5	5	4	4	5	3	3	4	5	4	3	5	4	**4.2**	**0.7**	**5.0**	**3.0**
9	5	4	5	4	3	4	5	4	3	3	4	4	5	5	3	3	4	4	5	5	5	3	4	3	3	**4.0**	**0.8**	**5.0**	**3.0**
10	5	3	4	5	4	4	5	5	4	4	4	5	5	5	2	5	4	5	5	5	5	4	5	5	3	**4.4**	**0.8**	**5.0**	**2.0**
Average	**3.8**	**3.3**	**4.2**	**4.2**	**3.7**	**4.3**	**4.7**	**4.4**	**3.3**	**3.9**	**4.0**	**4.1**	**4.6**	**4.7**	**3.4**	**4.0**	**4.0**	**3.7**	**4.1**	**4.2**	**4.4**	**3.4**	**4.2**	**4.1**	**3.2**				
Standard Deviation	**1.2**	**0.7**	**0.6**	**1.0**	**0.5**	**0.7**	**0.5**	**0.7**	**0.8**	**0.9**	**0.9**	**1.0**	**1.0**	**0.5**	**0.7**	**0.9**	**0.7**	**0.8**	**1.1**	**0.9**	**1.1**	**0.8**	**0.8**	**0.7**	**0.8**	Sample Size = 25			
Maximum	**5.0**	**4.0**	**5.0**	**5.0**	**4.0**	**5.0**	**5.0**	**5.0**	**4.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**4.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**4.0**				
Minimum	**2.0**	**2.0**	**3.0**	**2.0**	**3.0**	**3.0**	**4.0**	**3.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**4.0**	**2.0**	**2.0**	**3.0**	**2.0**	**2.0**	**3.0**	**2.0**	**2.0**	**3.0**	**3.0**	**2.0**				



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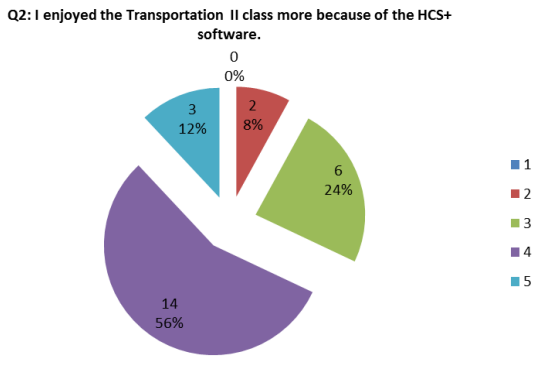

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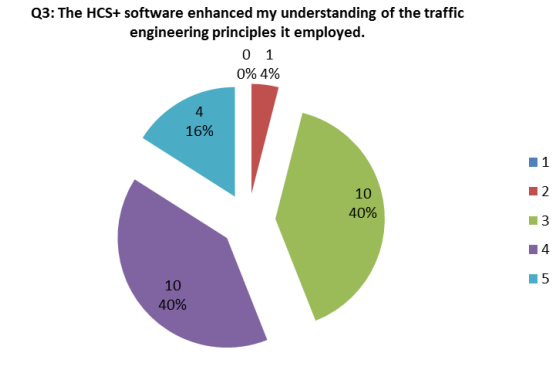

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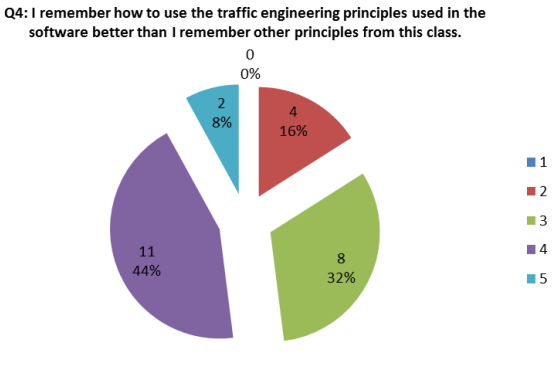

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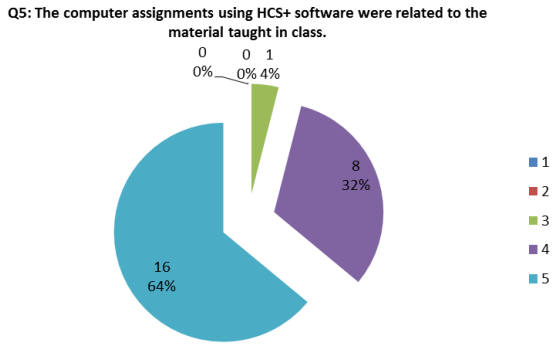

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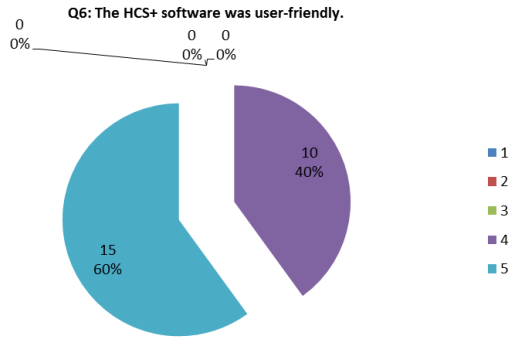
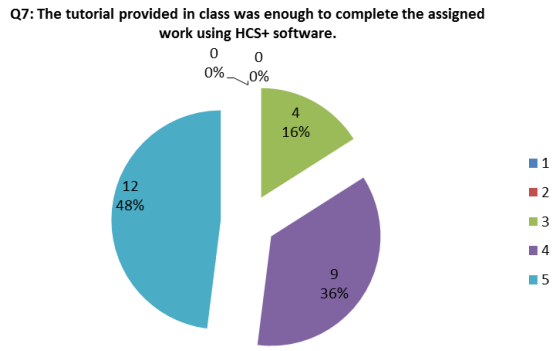


(f)

Figure 6 (a-j): Survey Results



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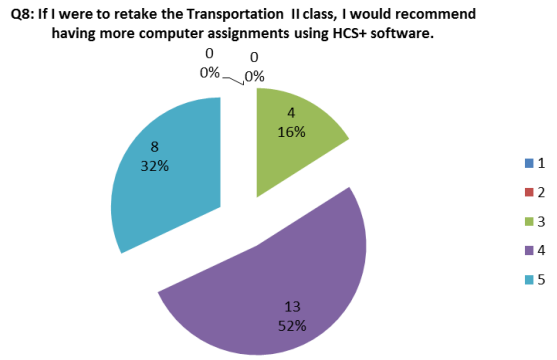

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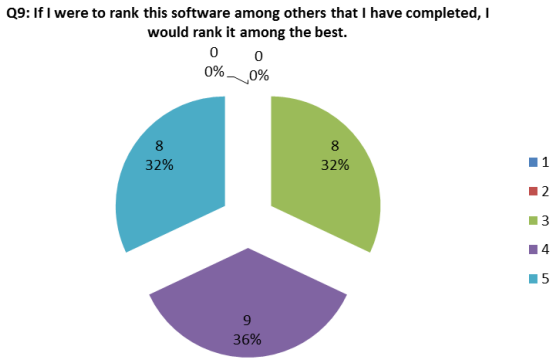

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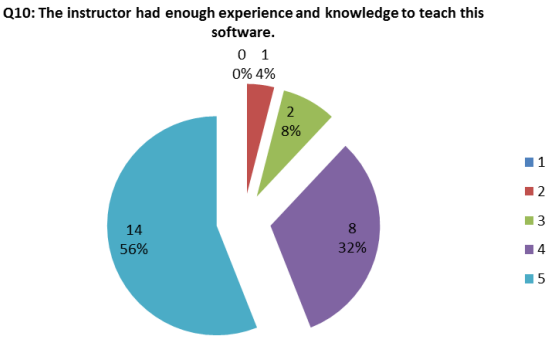

(j)

Figure 6 (a-j): Survey Results, continued

Conclusions and Future Work

The specific conclusions that can be drawn from the study presented in this paper are enumerated as follows:

1. After the theoretical background is completely covered and students are proficient in running hand calculations, the use of HCS+ software in Transportation II was found to enhance students' learning experience, solidifies methods presented in class and better clarifies the details taught in class.
2. From students' standpoint, HCS+ is a good and easy engineering tool to know, as early in the course as possible, that does not require much help or extensive tutorial. It is so to double check your hand calculations, practical and could be useful later in future jobs and possibly in completing a senior design project.
3. Caution must be taken not to use the HCS+ software or any simulation or modeling computer program in place of regular class instruction. These are only supplementary tools that are helpful after a topic is clearly presented in a classroom setting.
4. The assignment of more challenging and complex problems/projects is recommended besides providing the tutorial in a computer lab rather than using snapshots from the program. It is also recommended to implement the software for years to come.

I recommend that some studies on the same subject be conducted on students after they finish their senior design project then after one, three and five years of graduation for those in the transportation filed. Such studies could help further understand the benefits of teaching HCS+ software, or any newer version, in undergraduate courses on the long term.

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