Graduation Project Management with Network Optimization for Non-Traditional Students

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Data 4395-Senior Project

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Abstract

While UHD offers four-year degree maps for Data Science majors, these plans require taking heavy course-loads that are impractical for non-traditional students who must work jobs or have children. In this paper, this problem is addressed by using project management techniques known as CPM (Critical Path Method), PERT (Program Evaluation Review Technique), and survey results from 14 current Data Science majors, to build graduation network models to derive optimized graduation paths. Three recommended four-year degree plans, including two summers, were created for students who cannot accommodate more than four courses a semester (on average) but need a minimum of 12 hours to meet financial aid requirements.

Keywords: CPM, PERT, network, graduation, degree, project management

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Acknowledgements

I would like to thank all of those who helped me through this very long and challenging process of my undergraduate career, to you this project is dedicated. To my husband and children, who have been my support system and are affected the most by my completion of this degree. To my mom, without whose help with my household and children I could not have accomplished the grades I made. To my professors, who have been incredibly patient, understanding, and knowledgeable. To my classmates, who have been key for collaborating and studying. Lastly, to my dad, who encouraged me and motivated me to finish my degree by completing his master's in data analytics and being an inspiration to me. I have so much love and gratitude for all of you.

Introduction

Definition of Terms

A *network* consists of a set of *nodes* linked by *arcs* (or *branches*). Associated with each network is a *flow*, generally limited by the capacity of its arcs, which may be finite or infinite. An arc is said to be *directed* if it allows positive flow in one direction and zero flow in the opposite direction. A *directed network* has all directed arcs. A *path* is a sequence of distinct arcs that join two nodes through other nodes regardless of the direction of flow in each arc. A *connected network* occurs if every two distinct nodes are linked by at least one path (Taha, 2017). For this project, I will be using connected networks with directed arcs in order to represent three university graduation planning scenarios in Data Science.

A multitude of projects can be modeled and solved as networks using network optimization algorithms, making them an ideal instrument in project management. *Critical Path Method* (*CPM*) and *Program Evaluation and Review Technique* (*PERT*) are network-based methods designed to assist in the planning, scheduling and control of projects. A *project* is a set of interconnected activities with each activity consuming time and resources (Taha, 2017). The purpose of using CPM and PERT is to provide analytic means for scheduling the activities. In order to create a project, first activities of the project must be defined, along with their precedence relationships and their time requirements (durations). While CPM assumes deterministic activity durations, PERT assumes probabilistic durations. With PERT, each activity will have an optimistic, expected, and pessimistic duration. Next, the precedence relationships among the activities are represented by a network. Then, several specific time computations are made using activity durations to develop the time schedule for the project and determine the overall project duration.

Two of the primary computations made are e*arliest* and *latest start/finish times.* These establish the earliest time at which an activity can start or finish, given that its predecessors are completed, and the latest time at which the activity can be started or completed without delaying the project, respectively for CPM. In PERT, earliest and latest times are a mean of the probabilistic durations. Another informative calculation is the activity *slack time*, which reveals the amount of time an individual activity can be delayed without affecting the overall timeline of the project. Activities that have a slack of time zero are said to be *critical*. The sequence of tasks that have a zero slack time constitute the *critical path,* meaning that any delay in one of these activities will result in a delay in the overall project duration (Taha, 2017). In practice, the critical path is the longest path in the network.

Characteristics of a Network Representation

In a *network representation* of a project, there is a single start and finish node, where the nodes represent *events*, the completion of an activity. Each activity of the project is represented by one single arc pointing in the direction of progress of the overall project, identifiable by two distinct end nodes. The nodes of the network are used to establish the precedence relationships among the different activities. Thus, activities cannot run parallel (Taha, 2017).

In order to maintain the correct precedence relationships within the network, three essential questions must be answered as each activity/arc is added to the network. First, what activities must immediately precede the current activity? Next, what activities must follow the current activity? Finally, what activities *must* occur or *can* occur concurrently with the current activity? In situations where two or more activities both have the same predecessors and precede the same activity, i.e., concurrent activities, a dummy arc must be introduced. A *dummy* arc consumes no time or resources and is used in precedence relationships when the project activity arcs alone cannot represent them properly. By convention, these arcs are represented with dotted lines in the network. Figure A displays how to properly use a dummy arc to represent two concurrent activities A and B in order to satisfy rules of precedence and distinct end nodes.

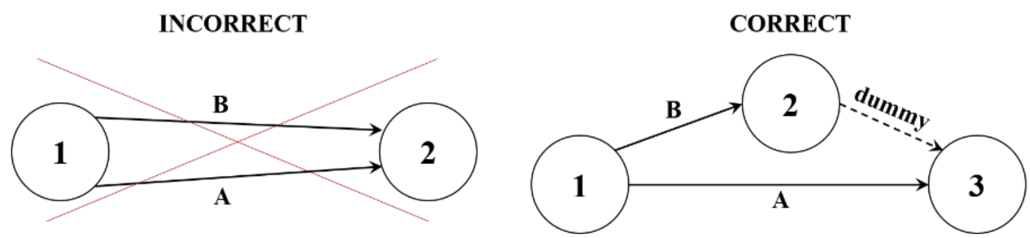


Figure A: Dummy Arc Separating Simultaneous Tasks

Once the network has been constructed, computations can be made to determine earliest and latest times, using either CPM or PERT. PERT is usually calculated backward from a fixed deadline while CPM requires a forward pass and backward pass through the network to determine the earliest and latest occurrence times of the events, respectively (Taha, 2017). These calculations will produce the total time needed to complete the project as well as the classification of critical and noncritical activities. For the purposes of this project, a software program known as *Tora* was used to make computations from an input of all the nodes and arcs in the constructed network.

Project Objectives

By modeling a graduation path in Data Science as a network of tasks, I will be able to use CPM and PERT to identify the longest and most essential sequence of courses to start with, in order to graduate without delays. Using this information, I can then design a degree plan for non-traditional students with additional time constraints in mind. The overall project duration computations will then serve as the *minimum* number of semesters necessary to complete the sequence of critical courses. This degree plan will then be used to answer several key questions. First and foremost, can a non-traditional student with more time constraints than a typical college student still, realistically, graduate in four years? Which classes should and must be taken immediately, and which can wait? How does math placement affect the graduation timeline, and what are the benefits to bypassing lower-level math courses?

These questions my project seeks to answer developed from a personal interest in the subject. By the time I graduate, it will have taken me a total of ten years to complete my bachelor’s degree. Although the UHD Data Science bachelor’s program only requires 120 credit hours, I will be graduating with 189 credit hours. In short, during my undergraduate career at previous schools, I lacked sufficient guidance early on which severely affected my overall graduation timeline. This poses the question: if I had started my undergraduate career at UHD knowing what I know now, how long would it have taken me to graduate? Although UHD currently offers a four-year degree plan for Data Science majors that can be found online, this plan is not one-size-fits-all. The average course load per semester is five classes, and suggests students take as many as six courses or 18 credit hours in a single semester (University of Houston - Downtown: College of Science and Technology, 2021). As a mother of three young children, such a heavy course load is not a feasible time commitment I can make. Therefore, it is my hope and goal that the degree plans I construct can serve as a resource for other students like myself, who are parents, work full-time jobs, or have other time limitations that a traditional student might not.

Modeling a Graduation Project as a Network

Compiling Tasks and Precedence Relationships

The first step in designing a project is compiling the list of activities for the project. The obvious activities to include are the courses required to satisfy the degree requirements, with their pre-requisites as predecessors. To start, I referenced the UHD catalog for core components.

This immediately presented an issue as there are many course options per core component to satisfy the Texas core requirements, with nine different components and 14 courses needing completion. For simplicity, I created a single activity called *Core Components*, consisting of Components 030, 050, 060, 070, 080, and 090, which can be referenced in Appendix A. This activity includes 10 courses and 30 credit hours, with ENG 1301 as a co-requisite, thus these courses can be taken at any given time. Because ENG 1301 is specified as a pre-requisite or co-requisite for every core component and major requirement and must be taken early on, I chose to explicitly include ENG 1301 and 1302 (Component 010). Since PHIL 2305 is included in major requirements and satisfies Component 040, this course is also included in the activity list.

The Mathematics Component 020 is another component included explicitly, as there are many different starting point options for math courses. This presented another set of issues, as advanced math classes are crucial to the data science courses. To resolve this, I opted to construct three different projects/networks based on the different math starting points, instead of a single network. Data science majors are also required to choose a domain focus in order to "gain depth and contextualization in a particular discipline of study in which Data Science skills are used (2021-2022 Undergraduate Catalog: Data Science, BS, 2021)." In accordance, they must choose one of the following areas of study and complete a sequence of four courses: biology, chemistry, computer science, discrete and combinatorial mathematics, finance, operations management/research, psychology, scientific computing or another departmentally approved domain focus.

In order to determine the most likely graduation scenarios for data science majors, I created a survey that was distributed among all current data science majors. The objective of the survey was to gather information from students to determine the most common math starting points as well as most popular domain choices. Additionally, the survey was used to determine what non-curriculum tasks students found necessary in order to graduate, gauge sentiment by identifying how easy or difficult their undergraduate journeys have been, and what information would have made the graduation process easier.

Results from the survey, shown in Figures B and C, are from 14 students' responses. Most students who responded, 84.62%, began math at College Algebra level or higher. Thus, I reasoned to create projects where the student's first math course is College Algebra (MATH 1301), Precalculus with Trigonometry (MATH 1505), or Differential and Integral Calculus with Applications (MATH 2421).

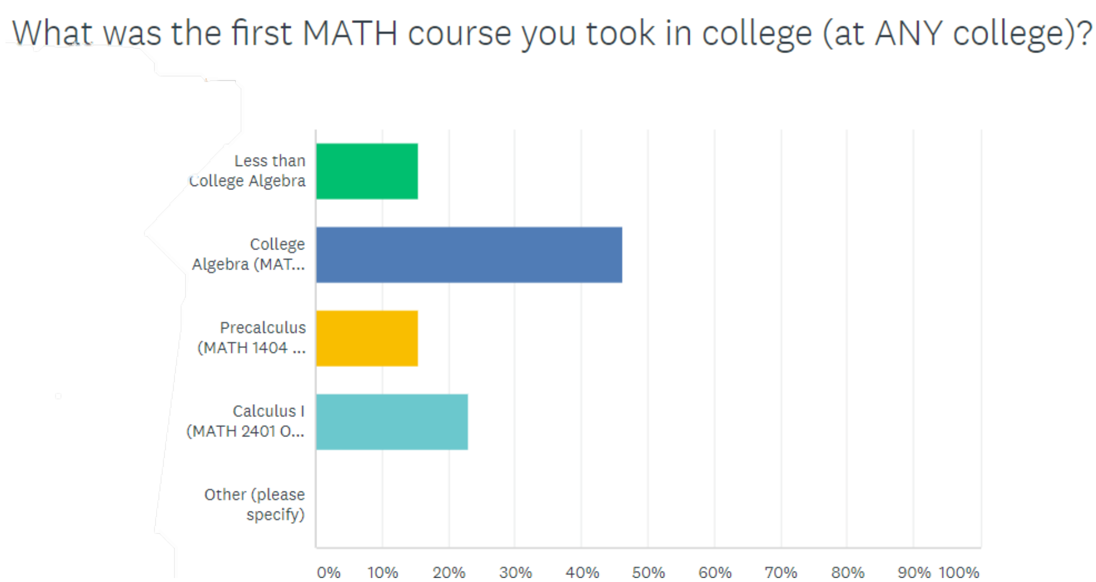


Figure B: Survey Answers for Math Starting Points

Because some of the students who responded were transfer students from other majors at other universities, there are quite a few domain focuses that received special Dean approval and cannot be universalized. Of the remaining eight choices, computer science was the most popular. Additionally, the computer science domain is the only one which leads to a third minor. Thus, students who choose this domain will graduate with minors in mathematics, statistics, and computer science if CS 3321 is taken to fulfill the domain upper-level CS requirement (2021-

2022 Undergraduate Catalog: Computer Science Minor, 2021). Given the enticement of the third minor, as well as its popularity among current majors, all three projects will include the Computer Science domain courses as activities: CS 1410, CS 2410, CS 3304 and CS 3321.

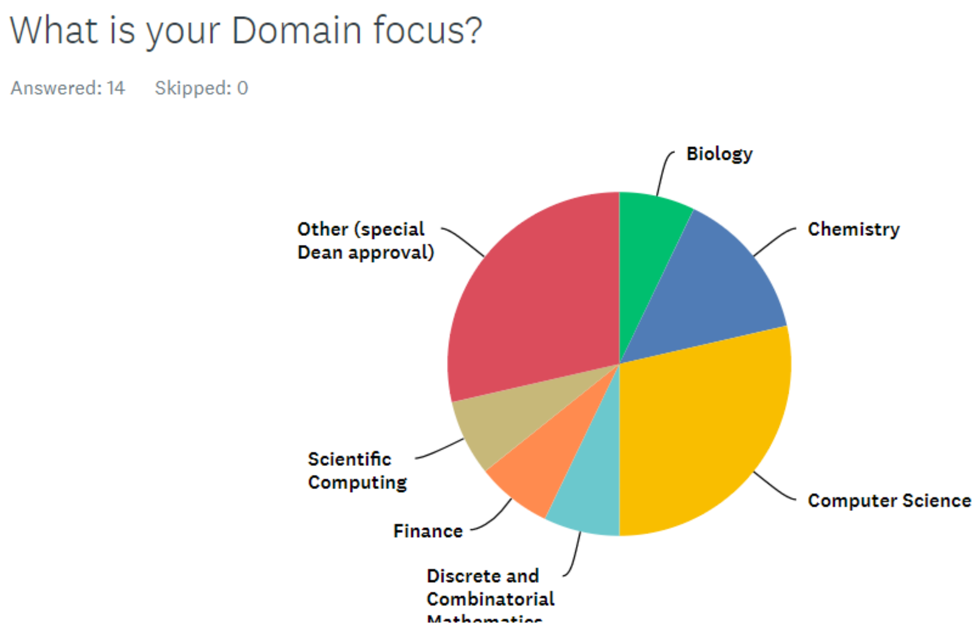
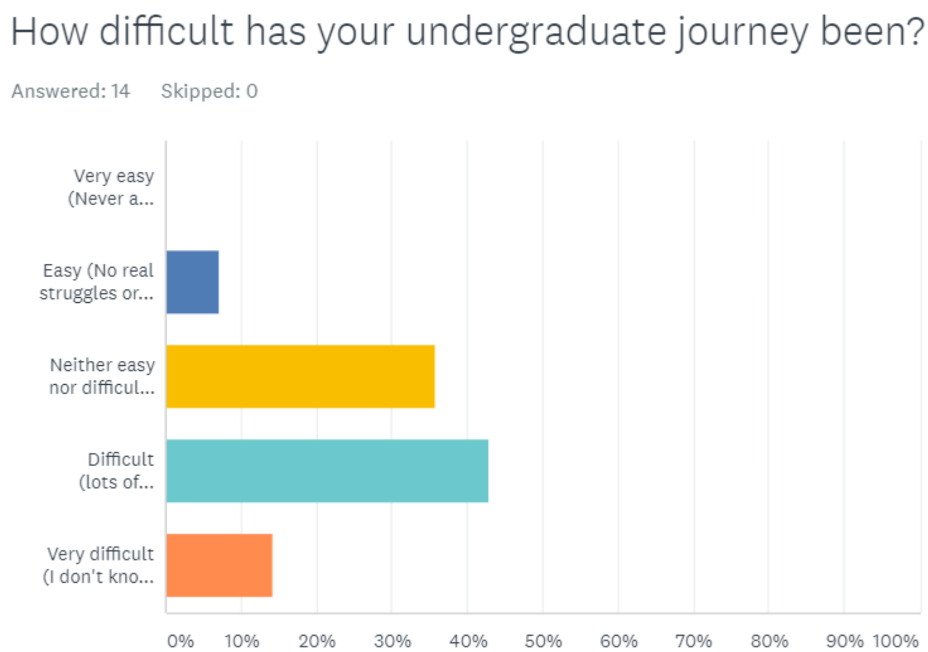


Figure C: Survey Results for Domain Focus Among Data Science Majors

Next, I determined additional activities that are not courses but are necessary for graduation or in the enrollment process, to include in the graduation project. I relied heavily on my personal experiences and the insights of my peers through the survey results to make decisions in this regard. Of survey participants, 71.43% did not take a math placement test in order to bypass College Algebra, possibly because they did not know it was an option or did not see the benefits. Therefore, it seemed necessary to include bypass exams as activities for each of the projects where necessary. Concerning doing a senior project, 57.14% will be opting to take an additional upper-level departmentally approved course instead. Perhaps, this is because 71.43% of these same students were not made aware, prior to their senior years, that DATA 4395 required a senior advisor, project concept, committee members, academic advisor approval and dean approval before you can register for the course. Additionally, 57.14% were not aware that you had to apply for graduation at the beginning of the final semester. Because of this, I felt it essential to include activities such as senior project approval and applying for graduation, as these are also essential to the graduation process. Students were however, for the most part, knowledgeable that scholarship and financial aid applications had to be completed prior to the start of the academic year, with only 21.43% unaware, so I also included a single FAFSA commitment activity to apply to all academic years for financial aid.

Based on the results in Figure D, more students struggled than not in their undergraduate journeys. When asked what information they wish they had known in order to make their undergraduate careers easier and more enjoyable, the following input was given. One student generally wanted to know "What classes *exactly* that we needed to take." I believe my project will address this, as apart from the few core components, explicit courses are named to satisfy degree, domain, and minor requirements. Another suggested "Stat courses should be completed earlier in the curriculum. [Either] before, or in conjunction with Data courses." This will be taken into consideration with the degree plan mapping. Another good point brought to my attention was the comment "I wish it would have been made known to students that some classes are only offered in the fall or spring." This is pertinent information when planning out your degree, as it could potentially delay your completion by an entire year. Therefore, as part of my activity list, I also included the course offering availability as a column of data. In the Data Science degree, there are only two courses that are offered fall or spring only. These courses are STAT 4303/4311 (fall only) and STAT 4310 (spring only). STAT 4303 and STAT 4311 are offered in alternate years, with 4303 being offered in even fall semesters, and 4311 being offered in odd fall semesters. Lastly, another student says "I was lucky enough to discuss my future senior project with my desired professor, but I wonder if others in our degree know to reach out to a professor for their senior project. Some guidance in that regard might push other DS students to push for a senior project." Thus, it is my hope that this project not only bring to light some of the challenges in the graduation process, but also provides a resource in helping resolve the uncertainties many students, like myself, have.



ANSWER CHOICES	RESPONSES	
Very easy (Never a hiccup, everything always as expected!)	0.00%	0
Easy (No real struggles or issues)	7.14%	1
Neither easy nor difficult (maybe a few issues that were easily resolved, nothing that caused delays)	35.71%	5
Difficult (lots of obstacles, fighting for grades/credits/financial aid etc.)	42.86%	6
Very difficult (I don't know how I ever made it/will make it to graduation!)	14.29%	2
TOTAL		14

Figure D: Survey Results on Undergraduate Experience Sentiment

For both projects starting with College Algebra and Precalculus, two free electives are needed to complete the 120-credit hour requirement. Instead of leaving these listed as "free activities" in my tasks list, I opted to designate Spanish 1401 and 1402, for several reasons. First, having a worse-case scenario with one elective being a prerequisite for another would be more beneficial for future students adapting to my model. Should a student wish to take two sequential electives in a completely unrelated discipline, there should be little to no modifications necessary, as Spanish would act as a placeholder. Also, taking languages as electives is very popular, and it would be easy to swap Spanish for French, German, or another language of interest. Having two courses produce eight credit hours instead of only six, also seemed more efficient in achieving 120 credit hours. Lastly, learning Spanish, even at its most basic level would be beneficial given the demand for Spanish speakers since we are in Texas.

Determining Time Durations

After compiling a list of tasks, the next step is to determine the durations of those tasks. Since there are two methods for project management being used, the time durations for these methods will differ.

Using CPM

Time durations using CPM are deterministic, so activities will need a single realistic time estimate. For simplicity, time units of a semester will be used, as the majority of activities which are courses will have a duration of one semester. Activities for bypass exams will be estimated for a week, or $1/16^{th}$ (0.0625) of a semester. Activities such as the TSI registration that are necessary before completing TSI assessments require a day, are computed as $1/7^{th}$ of 0.0625 semesters. For my consolidated core component activity, although the activity represents 10 courses or 30 credit hours, I did not use a duration of 10 semesters. The reason for this, is that some of these courses can be taken concurrently. Since each component consists of only one or two courses, I used the maximum requirement this would entail of two semesters, as the time duration to be used in CPM calculations. Representing the core components in this manner will prevent them from interfering in the determination of the critical path.

Using PERT

PERT can consider scenarios that CPM cannot. Most noteworthy, is that the CPM network calculations for this project assume the student *does not* have any AP credits or credit by examination. CPM also assumes that the student will only need to take a course once to pass. In order to present various best-case and worst-case scenarios, PERT probabilistic time durations are necessary. Thus, three time estimates must be given: optimistic, realistic, and pessimistic. For activities that represent courses for which students have the possibility of transferring in AP credits, the optimistic duration will be zero semesters (Registrar's Office: Credit by Examination (AP/CLEP), 2021). For all courses, the pessimistic duration will be two semesters, meaning a student failed and took the class over. However, there are two courses which are offered only in fall or spring, for which failing would delay the student an entire year for an overall time duration of three semesters. Because I wanted the results from PERT to reflect scenarios regarding the course schedule, I maintained the same durations for all non-curriculum activities. Realistic durations were defined as the same durations used in CPM. The completed three graduation project lists can be found in Appendices D, E and F.

Network Representations

With the completed comprehensive project lists, I was able to construct three networks, shown in Figures E, F and G. The activities are represented on arcs by symbols (letters) and events representing the completion of an activity are dictated by numbers. The start and end nodes are labeled, with the earliest and latest start or finish times underneath, respectively, and were computed using *Tora* software by inputting the set of the nodes, arcs, and durations. The critical path(s) is denoted with red arrows. Notice that the first two networks have multiple critical paths. In large complex projects such as this, there can be more than one critical path.

Multiple critical paths mean these grouped sequences of activities take the same amount of time to complete. For the networks shown in Figures E and F, the critical paths are the same, however the time computations differ due to activity D. In the first network, activity D has a semester duration and represents the course MATH 1301, but in the second network, it represents the bypass exam for MATH 1301 to place into MATH 1505. This has a shorter duration of one week, as opposed to one semester. For these networks, critical courses include: MATH 1301 (or bypass), MATH 1505, DATA 2401, MATH 2305, MATH 2421, DATA 3401, MATH 2422, MATH 3302, DATA 3402, STAT 3333, STAT 4303 or 4311, MATH 3423, STAT 4310, DATA 4300, DATA 4319, CS 1410, CS 2410, CS 3304, and CS 3321. For the third network in Figure G, there is a single critical path consisting of the CS minor courses: CS 1410, CS 2410, CS 3304 and CS 3321.

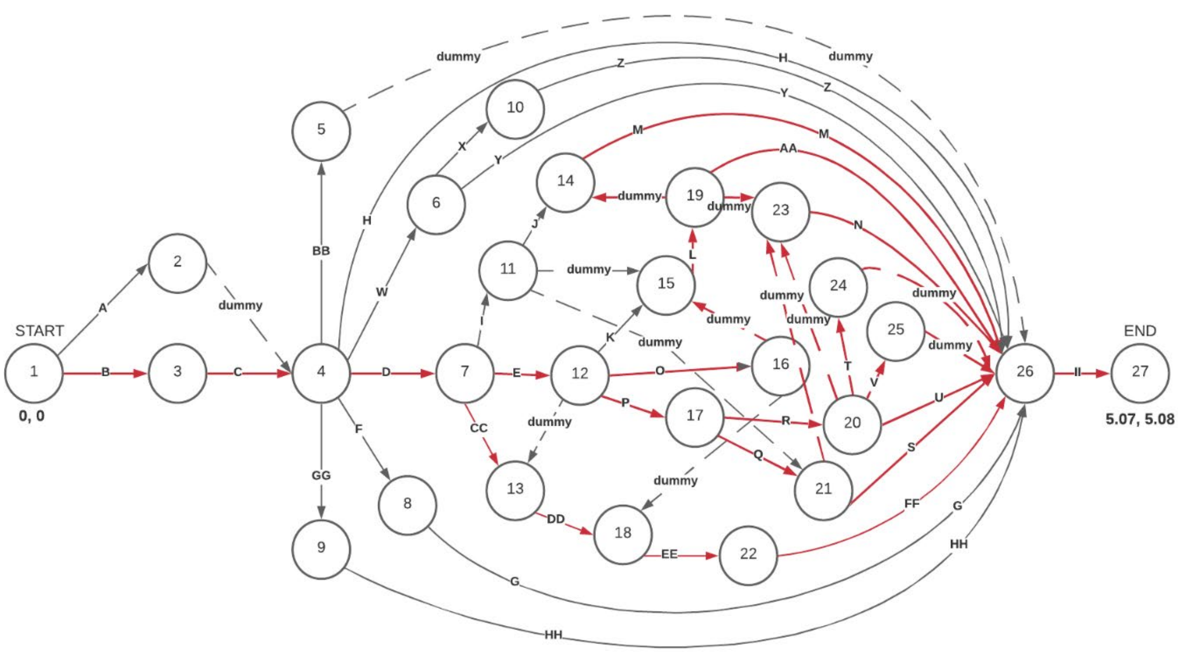


Figure E: CPM Network Modeling Graduation, Starting with MATH 1301

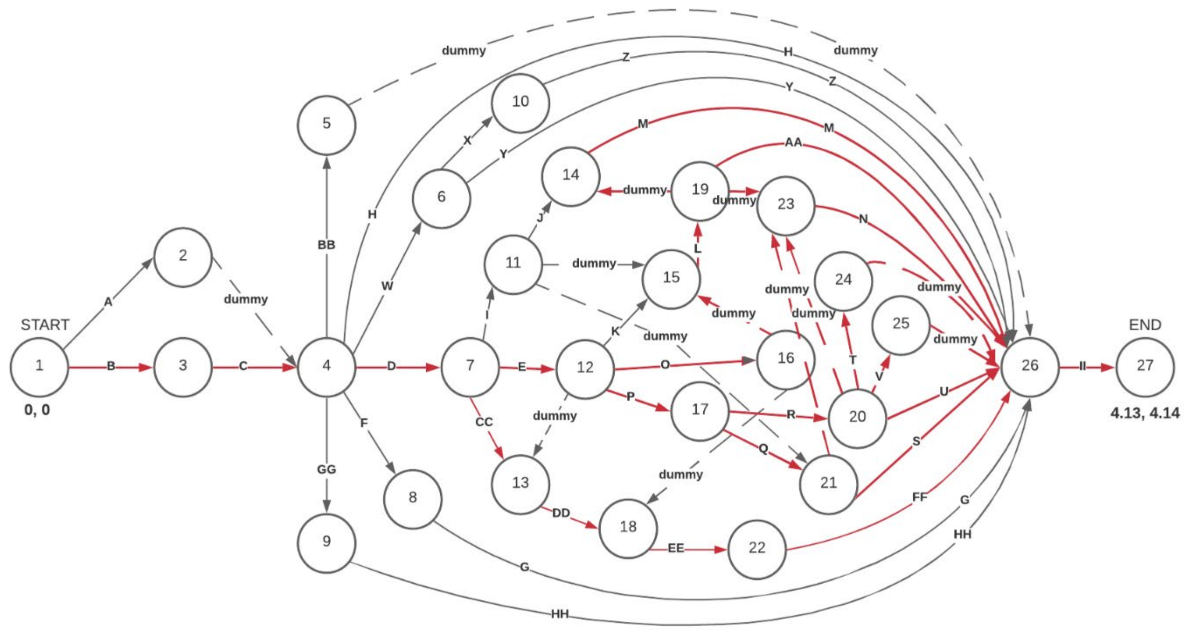


Figure F: CPM Network Modeling Graduation, Starting with MATH 1505

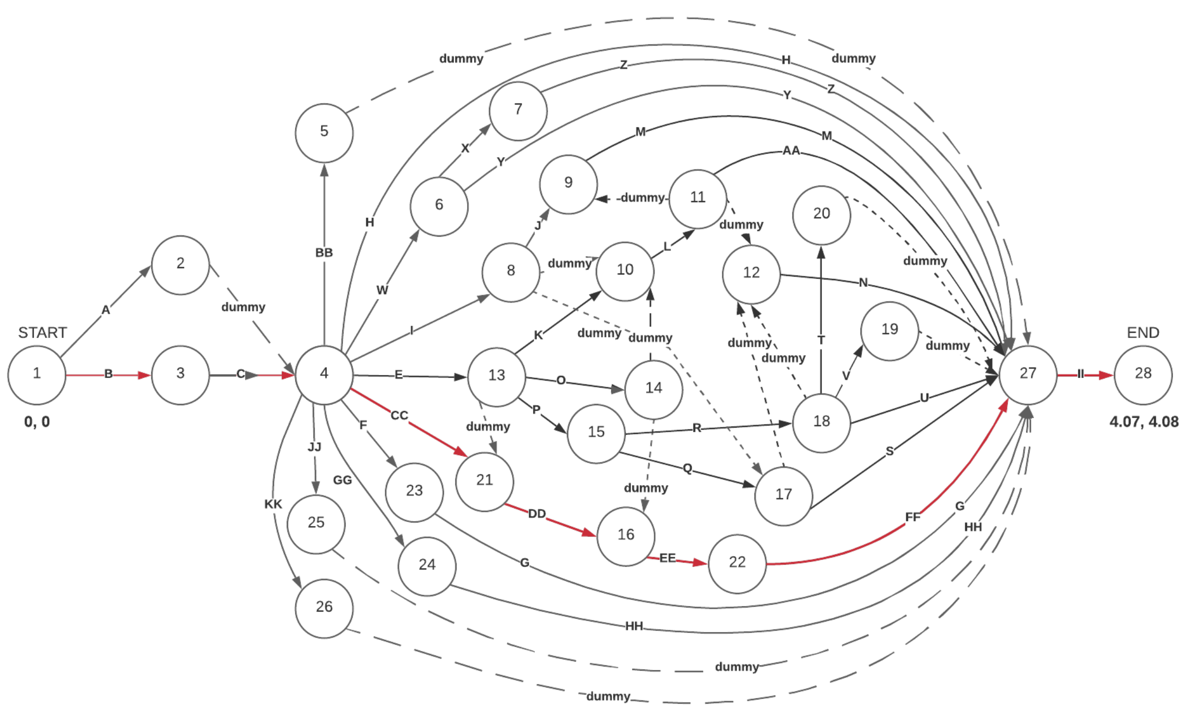


Figure G: CPM Network Modeling Graduation, Starting with MATH 2421

Usually, the latest finish time determines the project duration, as the critical path is the longest path or sequence of activities necessary to complete the project. Since all activities must be completed, the network's latest finish time must be interpreted a bit differently. For example, the first network (Figure E) has a latest finish time of 5.08 semesters. This does *not* mean that the expectation is for a student to graduate in 5.08 semesters. Rather, it means that *if the student were to take all courses concurrently*, the soonest they could graduate is 5.08 semesters. This can be visualized as a stacked bar chart, produced from the *Tora* software in Figure H, where all the courses available to take in a semester, could be taken simultaneously. Obviously, this would not result in a realistic graduation timeline as one would have to take more than 10 courses in a semester. However, there is pertinent information obtained from this calculation that will be used in developing optimal degree plans for non-traditional students. Essentially, the latest finish time correlates to the *minimum number of semesters necessary to complete critical classes*. Again, using the first network as an example, five semesters is the least number of semesters needed to complete the critical sequence of courses. It is likely, however, that these courses will have to be spread over more than five semesters in order to complete, given the additional time constraints imposed as a non-traditional student.

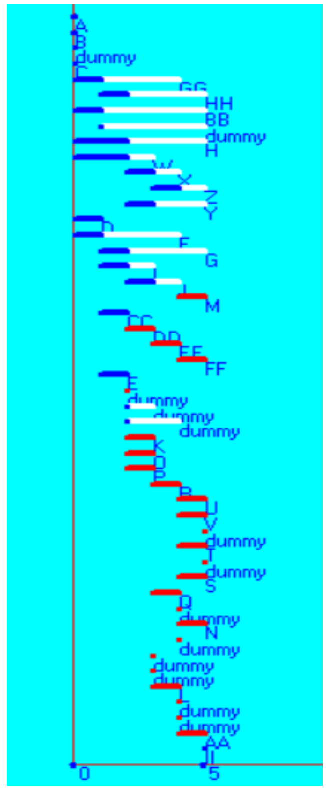


Figure H: Tora Bar Chart for Project 1: MATH 1301

Additional Constraints

As mentioned previously, non-traditional students with families, jobs or other full-time commitments typically have more limitations than your average high-school graduate incoming college student. Because of this, the four-year degree maps UHD already offers require modifications to meet the time needs of busy students. Thus, the degree plans I construct include additional constraints that traditional degree plans do not have. To start, summer semesters are included where necessary. A minimum of 12 credit hours per semester for fall and spring semesters and 6 hours for summer semesters, in order to meet financial aid criteria are also required. Additionally, the average course load per semester is kept to four classes, and a maximum of 15 hours per semester. Limiting the number of classes and hours per semester will dedicate more time per class. This provides the student with an opportunity to make better grades and have a GPA that they are proud of or qualify for scholarships.

Conclusions

Findings

From all three math starting points, it is possible for someone to complete their degree from UHD in Data Science with a domain focus in computer science in four years, with additional time constraints. The caveat is that the student must complete two additional summer semesters. This is displayed by the completed degree plans in Figures I, J and K, constructed from the CPM results. Notice, since

Degree Plan for Non-traditional Students Starting with MATH 1301

Year	Fall	Spring	Summer
1	MATH 1301*	MATH 1505*	TX CORE
	ENG 1301	ENG 1302	TX CORE
	UHD 1302 (TX CORE)	TX CORE	
	TX CORE	CS 1311	
	PHIL 2305		
Semester Total:	**15 hrs**	**14 hrs**	**6 hrs**
2	DATA 2401*	DATA 3401*	TX CORE
	MATH 2305*	MATH 2422*	TX CORE
	MATH 2421*	MATH 3302*	
	CS 2311	CS 1410*	
Semester Total:	**14 hrs**	**15 hrs**	**6 hrs**
3	DATA 3402*	STAT 4310*	
	STAT 3333*	CS 2410*	
	STAT 4303 or 4311*	DATA 4300*	
	MATH 3423*	DATA 4319*	
Semester Total:	**14 hrs**	**13 hrs**	
4	DATA 4395	TX CORE	
	CS 3304*	CS 3321*	
	SPAN 1401	SPAN 1402	
	TX CORE	TX CORE	
Semester Total:	**13 hrs**	**13 hrs**	
		TOTAL:	**123 hrs**
			*** indicates critical task, delay can result in delayed graduation**

Figure I: Degree Plan Starting with MATH 1301

Python is a prerequisite for some of the other critical DATA courses. It must be taken early on, and hence, would make it difficult to transfer into the program from a community college that does not offer Python course. However, taking summer courses from community colleges could still be an option for those who want to save on commute or tuition costs, as those are Texas Common Core courses and have more flexibility than the critical MATH/STAT/DATA courses.

Degree Plan for Non-traditional Students Starting with MATH 1505

Year	Fall	Spring	Summer
1	MATH 1505* ENG 1301 UHD 1302 (TX CORE) CS 1311	DATA 2401* MATH 2305* MATH 2421* CS 2311	TX CORE TX CORE
Semester Total:	**14 hrs**	**14 hrs**	**6 hrs**
2	DATA 3401* MATH 2422* MATH 3302* ENG 1302	DATA 3402* STAT 3333* MATH 3423* TX CORE	TX CORE TX CORE
Semester Total:	**14 hrs**	**14 hrs**	**6 hrs**
3	DATA 4300* DATA 4319* STAT 4303 or 4311* CS 1410*	STAT 4310* TX CORE PHIL 2305 CS 2410*	
Semester Total:	**13 hrs**	**13 hrs**	
4	DATA 4395 CS 3304* SPAN 1401 TX CORE	TX CORE CS 3321* SPAN 1402 TX CORE	
Semester Total:	**13 hrs**	**13 hrs**	
		TOTAL:	**120 hrs**
			*** indicates critical task, delay can result in delayed graduation**

Figure J: Degree Plan Starting with MATH 1505

The first network, beginning with MATH 1301, has the longest path of all three networks, amounting to just over 5 semesters, while the second (MATH 1505) and third (MATH 2421) are just over 4 semesters. This means, taking the Math 1301 bypass exam and beginning the Data

Science degree from Math 1505 will add a semester of flexibility within the degree plan. Moreover, the degree plan in Figure J which starts with MATH 1505 allows the student to take one less course than both MATH 1301 (Figure I) and MATH 2421 (Figure K) degree plans, resulting in 36 overall courses rather than 37. This is interesting, in that by bypassing MATH 1505, the student must compensate for the loss of credits by taking two additional elective courses. Thus, it appears that bypassing MATH 1301 to place into MATH 1505 is certainly worth-while with regards to course load management, while bypassing MATH 1505 is only enticing if the student wishes to have more free elective choices.

Degree Plan for Non-traditional Students Starting with MATH 2421

Year	Fall	Spring	Summer
	MATH 2305*	DATA 2401*	TX CORE
1	MATH 2421*	MATH 2422*	TX CORE
	ENG 1301	MATH 3302*	
	UHD 1302 (TX CORE)	CS 1311	
Semester Total:	**13 hrs**	**14 hrs**	**6 hrs**
	DATA 3401*	DATA 3402*	TX CORE
2	MATH 3423*	DATA 4319*	TX CORE
	STAT 3333*	STAT 4310*	TX CORE
	CS 2311	ENG 1302	
Semester Total:	**14 hrs**	**13 hrs**	**9 hrs**
	DATA 4300*	FREE ELECTIVE	
3	STAT 4303 or 4311*	TX CORE	
	CS 1410*	CS 2410*	
	SPAN 1401	SPAN 1402	
Semester Total:	**14 hrs**	**14 hrs**	
	DATA 4395	FREE ELECTIVE	
4	CS 3304*	CS 3321*	
	PHIL 2305	TX CORE	
	TX CORE	TX CORE	
Semester Total:	**12 hrs**	**12 hrs**	
		TOTAL:	**121 hrs**
			*** indicates critical task, delay can result in delayed graduation**

Figure K: Degree Plan Starting with MATH 2421

The primary difference shown in plans I and J is that the first semester of the second year from the first plan shifts back into the spring semester of the first year in the second plan. This effectively puts the student following the second plan ahead an entire semester in the critical DATA/MATH/STAT courses. Python can also be started sooner by one semester. The last year in both plans starting with MATH 1301 and MATH 1505 are the same. When starting with MATH 2421, there is a greater difference in how the degree plan lays out. One notable difference is the starting and completion of Python courses (CS 1311 and 2311). This occurs a semester later than the MATH 1505 plan. This is due to the necessity in taking ENG 1301 and the availability of UHD 1302 (Freshman Math Seminar) being limited to the fall semester. While this does not delay graduation, it does change the sets of classes being taken together. Also note, ENG 1302 is delayed until the spring semester of the second year, unless the student chooses to take a summer section of the course in the first year (trading with a core class). The most noteworthy distinction of this plan, though, is that Machine Learning (DATA 4319) can be completed as soon as sophomore year. In all plans, apart from the CS domain/minor courses and senior project, the student can have completed all the pertinent major courses by the summer of junior year, making them ideal prospects for a summer internship opportunity.

Using PERT probabilistic durations to consider AP credits and repeating failed courses, computations determined an increase in mean duration between .42 and .5 semesters. This means, that on average, if the student both possessed AP credits and repeated courses, there would be an additional half a semester needed to complete the degree. Thus, AP credits alone could not compensate fully for delays incurred by repeating courses. Most importantly, this does *not necessitate* a delay in graduation if the courses repeated can be done so within a summer semester or a fifth course during a fall/spring semester.

Summary

As a graduating senior, I created three recommended four year degree plans, including summers, for students who cannot accommodate more than four courses a semester, on average, but need a minimum of 12 hours to meet financial aid requirements. In these plans, although there is some flexibility in the fourth year, I recommend completing the majority of major-related courses prior to the final year. This is so the student will have already completed the courses most relevant to data science, making them more appealing prospects for internships in the summer before their senior years. The most balanced plan starts with MATH 1505, requires bypassing MATH 1301, and requires one less course than the other two plan options.

Future Research

There is quite a bit more exploration that can be done with PERT to run personalized graduation scenarios. For instance, a student with only some or all AP credits and no repeated courses may be able to graduate in less semesters, but by how much? Or what if the student only fails one class instead of all of them, what would the graduation delay amount to? These are some realistic situations that can be modeled using PERT.

Additionally, all UHD Data Science majors can benefit from this project. Many did not know of the requirements necessary to take on a senior project, or that certain classes are offered fall or spring only. Data courses are also not currently offered in the summer, making the degree plan inherently less flexible. Also, while fulfilling the computer science minor requirements simultaneously satisfies the domain requirements, merely satisfying the domain requirement *does not* guarantee the minor. These are real issues exhibited by current students that my project address. Thus, making the degree plans from this project a legitimate resource to other students by collaborating with university faculty and advisors is a possibility I am exploring.

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Appendix A

Core Requirements: Foundational Component Areas

6 hours Communication 010
- ENG 1301 – Composition I
- ENG 1302 – Composition II

3 hours Mathematics 020
- MATH 1301 – College Algebra
- MATH 1310 – Contemporary Mathematics
- MATH 1324 – Mathematics for Business and Social Sciences
- STAT 1312 – Statistical Literacy
- *or* Any course for which one of these courses is a pre-requisite.

6 hours Life and Physical Sciences 030
- BIOL 1301 - General Biology I
- BIOL 1302 - General Biology II
- BIOL 1303 - Human Anatomy and Physiology I
- BIOL 1304 - Human Anatomy and Physiology II
- BIOL 1310 - Human Biology
- BIOL 1312 - Ecology and Environmental Biology
- CHEM 1305 - Introductory Chemistry
- CHEM 1307 - General Chemistry I
- CHEM 1308 - General Chemistry II
- GEOL 1304 - Introduction to Meteorology
- GEOL 1305 - Physical Geology
- GEOL 1306 - Historical Geology
- GEOL 1307 - Planet Earth
- GEOL 1308 - History of the Earth
- GEOL 1345 - Oceanography
- MBIO 1305 - Microbiology
- MBIO 1310 - Microbes and Society
- NS 1300 - Emergence of Modern Science
- PHYS 1301 - Introduction to Solar System Astronomy
- PHYS 1302 - Introduction to Stellar and Galactic Astronomy
- PHYS 1307 - General Physics I
- PHYS 1308 - General Physics II
- PHYS 2401 - Physics I
- PHYS 2402 - Physics II

3 hours Language, Philosophy and Culture 040

- ENG 2301 - World Literature I
- ENG 2302 - World Literature II
- ENG 2305 - Literature and Culture
- ENG 2309 - Survey of Film: Beginnings to Present
- ENG 2311 - American Literature I
- ENG 2312 - American Literature II
- ENG 2313 - British Literature I
- ENG 2314 - British Literature II
- HUM 2301 - Foundations of Western Culture
- HUM 2302 - Foundations of Western Culture II
- LATS 1301 - Introduction to Latino Studies
- PHIL 1301 - Introduction to Philosophy
- PHIL 2305 - Contemporary Ethical Issues
- PHIL 2310 - The Meaning of Life
- SPAN 2301 - Intermediate Spanish I
- SPAN 2302 - Intermediate Spanish II

3 hours Creative Arts 050

- ART 1301 - History of Art: Paleolithic to the Middle Ages
- ART 1302 - History of Art: Renaissance to Present
- ART 1308 - Art History: Introduction to World Art
- ART 1310 - Introduction to Visual Arts
- DANC 1301 - Dance in America
- DRA 1301 - Introduction to the Theater
- MUS 2301 - Music Appreciation: Before 1750
- MUS 2302 - Music Appreciation: After 1750

6 hours American History 060

- HIST 1305 - United States History to 1877
- HIST 1306 - United States History after 1877
- HIST 1312 - Texas History
- HIST 1314 - Ethnic Minorities in American History

6 hours Government/Political Science 070

- POLS 2305 - Federal Government
- POLS 2306 - Texas Government

3 hours Social and Behavioral Sciences 080

- ANTH 2302 - Cultural Anthropology
- CJ 1301 - Introduction to Criminal Justice
- CRS 1301 - An Introduction to Critical Race Studies
- ECO 1305 - Contemporary Economic Issues
- PSY 1303 - Introduction to Psychology
- SOC 1303 - Introduction to Sociology
- SOCW 2361 - Introduction to Social Work and Social Welfare
- SOCW 2363 - Introduction to Social Welfare Policy

3 hours Oral Communication 090

- COMM 1302 - Mass Media
- COMM 1304 - Introduction to Communication
- COMM 1306 - Beginning Public Speaking
- COMM 1309 - Communication and Public Decision Making
- COMM 2307 - Intercultural Communication
- COMM 2309 - Interpersonal Communication
- COMM 2311 - Principles of Public Relations
- ENG 1306 - Workplace Presentations

3 hours New Student Seminar*

- UHD 1301 - Freshman Seminar-Communication
- UHD 1302 - Freshman Seminar-Mathematics
- UHD 1303 - Freshman Seminar-Life and Physical Sciences
- UHD 1304 - Freshman Seminar -Language, Philosophy and Culture
- UHD 1305 - Freshman Seminar-Creative Arts
- UHD 1306 - Freshman Seminar-American History
- UHD 1307 - Freshman Seminar-Government/Political Science
- UHD 1308 - Freshman Seminar-Social and Behavioral Sciences
- UHD 2301 - University Seminar-Communication
- UHD 2302 - University Seminar-Mathematics
- UHD 2303 - University Seminar-Life and Physical Sciences
- UHD 2304 - University Seminar-Language, Philosophy and Culture
- UHD 2305 - University Seminar -Creative Arts
- UHD 2306 - University Seminar-American History
- UHD 2307 - University Seminar-Government/Political Science
- UHD 2308 - University Seminar-Social and Behavioral Sciences
- *The student can also take either a course numbered UHD 1301-1308 or UHD 2301-2308.

  Total Core Component Hours: 42

(2021-2022 Undergraduate Catalog: Common Core Requirements, 2021)

Appendix B

Data Science Major Requirements

Major Requirements

- CS 1311 - Introduction to computing with Python
- CS 2311 - Data Structures and Algorithms with Python
- DATA 2401 - Data Science I
- DATA 3401 - Data Science II
- DATA 3402 - Data Collection, Transformation and Curation
- DATA 4319 *or* CS 4319 - Statistical and Machine Learning
- MATH 2305 - Discrete Mathematical Structures
- MATH 2421 - Differential and Integral Calculus with Applications
- MATH 2422 - Linear Algebra & Multivariable Calculus with Applications
- MATH 3302 - Probability and Statistics
- MATH 3423 - Advanced Linear Algebra and Optimization
- STAT 3333 - Statistical Inference
- STAT 4303 - Decision Mathematics or STAT 4311 - Operations Research
- STAT 4310 - Applied Regression
- At least one additional course from the following: DATA 3334, DATA 4395, MATH 3314, MATH 3317, MATH 3318, MATH 3408, MATH 4308, STAT 4300, STAT 4307, STAT 4309, STAT 4318, STAT 4397, CS 3306, or other departmentally approved course.

Ethics Requirements

- DATA 4300 - Ethics for Data Science
- At least one course from the following:
- PHIL 1301 - Introduction to Philosophy
- PHIL 1302 - Critical Thinking
- PHIL 2305 - Contemporary Ethical Issues
- PHIL 3301 - Classical Moral Theory

Domain Focus Requirement (at least 12 SCH)

- To gain depth and contextualization in a particular discipline of study in which Data Science skills are used, the student must complete a sequence of four courses (at least 12 SCH) in the same domain or specialization. Examples include:
- Biology: BIOL 1301/1101 and BIOL 1302/1102, at least 6 additional hours of BIOL (14 SCH)
- Chemistry: CHEM 1307/1107, CHEM 1308/1108, CHEM 3301/3201, and CHEM 3302/3202 OR CHEM 3330/3130 (17-18 SCH)

- Computer Science: CS 1410, CS 2410, CS 3304, at least 3 additional hours of upper-level CS (14 SCH) *
- Discrete and Combinatorial Mathematics: MATH 3309, 3312, 3314, 4308, (12 SCH)
- Finance: ECO 2301, ECO 2302, FIN 3305, FIN 3309 (Approval required from Marilyn Davies College of Business Advising) (12 SCH)
- Operations Management/Research: BA 3300, MGT 3301, MGT 3332, and MGT 3314 OR STAT 4311 (Approval required from Marilyn Davies College of Business Advising) (12 SCH)
- Psychology: PSY 1303 and PSY 3320, at least 6 additional hours of PSY (12 SCH)
- Scientific Computing: MATH 3301, MATH 3408, MATH 4301, STAT 4397 (13 SCH)
- Other departmentally approved domain focus options
- *Together with the Data Science Requirements, this leads to a Minor in Computer Science.

Total Hours: 120 (minimum)

(2021-2022 Undergraduate Catalog: Data Science, BS, 2021)

Appendix C

Computer Science Minor Requirements

Required Courses

- CS 1410 - CS I – Introduction to Computer Science with C++
- CS 2410 - CS II – Introduction to Data Structures and Algorithms
- CS 3304 - Data and Information Structures *
- CS 3321 - Software Engineering* *or* CS 4318 - Database Systems*
- 3 hours beyond CS 1305 – Introduction to Computer Technology
- 3 hours of upper-level Computer Science*
- * Must be completed at UHD for a total of at least 6 hours.

Total Hours: 20 (minimum)

(2021-2022 Undergraduate Catalog: Computer Science Minor, 2021)

Appendix D

Graduation Project List: Starting with MATH 1301

ARC	TASK DESCRIPTION	PREDECESSOR(S)	PREDECESSOR(S) DESCRIPTION	DURATION (semesters)	OPTIMISTIC DURATION (semesters)	PESSIMISTIC DURATION (semesters)	CREDIT HOURS	OFFERED
A	FAFSA Commitment*	None	None	0.0625	0.0625	0.0625	0	Fall, Spring, Summer
B	TSI Pre-Assessment Activity Certification	None	None	0.00893	0.0625	0.0625	0	Fall, Spring, Summer
C	TSI Placement Exams	B	Pre-Assessment Activity	0.0625	0.0625	0.0625	0	Fall, Spring, Summer
D	MATH 1301	A, C	TSI Placement Exams	1	0	2	3	Fall, Spring, Summer
E	MATH 1505	D	MATH 1301	1	0	2	5	Fall, Spring, Summer
F	ENG 1301	A, C	TSI Placement Exams	1	0	2	3	Fall, Spring, Summer
G	ENG 1302	F	ENG 1301	1	0	2	3	Fall, Spring, Summer
H	Core Components	A, C	co-req: ENG 1301	2*	2	3	30	Fall, Spring, Summer
I	CS 1311	D	MATH 1301	1	1	2	3	Fall, Spring, Summer
J	CS 2311	I	CS 1311	1	1	2	3	Fall, Spring
K	DATA 2401	E	MATH 1505	1	1	2	4	Fall, Spring
L	DATA 3401	I, K, O	CS 1311 & MATH 2305 & DATA 2401	1	1	2	4	Fall, Spring
M	DATA 3402	J, L	CS 2311 & DATA 3401	1	1	2	4	Fall, Spring
N	DATA 4319	I, L, Q. R	DATA 3401, co-req: MATH 3423 & STAT 3333	1	1	2	3	Fall, Spring
O	MATH 2305	E	MATH 1505	1	1	2	3	Fall, Spring, Summer
P	MATH 2421	E	MATH 1505	1	0	2	4	Fall, Spring
Q	MATH 2422	P	MATH 2421	1	1	2	4	Fall, Spring
R	MATH 3302	P	MATH 2421	1	1	2	3	Fall, Spring, Summer
S	MATH 3423	I, Q	CS 1311 & MATH 2422	1	1	2	4	Fall, Spring
T	STAT 3333	R	MATH 3302	1	1	2	3	Fall, Spring
U	STAT 4303	R	MATH 3302	1	1	3	3	A
V	STAT 4310	R	MATH 3302	1	1	3	3	Spring only
W	Achieve Senior Status	A, C	FAFSA, TSI Complete	2*	2*	2*	0	N/A
X	Senior Project Approval	W	Achieve Senior Status	1	1	1	0	N/A
Y	Graduation Application	W	Achieve Senior Status	1	1	1	0	N/A
Z	DATA 4395	X	Senior Project Approval	1	1	2	3	Fall, Spring, Summer
AA	DATA 4300	L	DATA 3401	1	1	2	3	Fall, Spring
BB	PHIL 2305	A, C	co-req: ENG 1301	1	1	2	3	Fall, Spring, Summer
CC	CS 1410	D	co-req: ENG 1301 & MATH 1505	1	0	2	4	Fall, Spring, Summer
DD	CS 2410	E, CC	CS 1410, co-req: MATH 2421	1	1	2	4	Fall, Spring, Summer
EE	CS 3304	O, DD	CS 2410 & MATH 2305	1	1	2	3	Fall, Spring, Summer
FF	CS 3321	EE	CS 3304	1	1	2	3	Fall, Spring
GG	(Free Elective) SPAN 1401*	A, C	TSI Placement Exams	1	0	2	4	Fall, Spring, Summer
HH	(Free elective) SPAN 1402*	GG	SPAN 1402	1	0	2	4	Fall, Spring, Summer
II	Commencement Ceremony	G, H, M, N, S, T, U, V, Y, Z, AA, BB, EE, FF, HH	All other tasks	0.00893	0.00893	0.00893	0	N/A
				Total hours =			**123**	
	*FAFSA Commitment * This application has to happen before EACH academic year for which you're getting aid (fall semester)*							
	*Free Elective * May take other electives, does not have to be Spanish*							

Appendix E

Graduation Project List: Starting with MATH 1505

ARC	TASK DESCRIPTION	PREDECESSOR(S)	PREDECESSOR(S) DESCRIPTION	DURATION (semesters)	OPTIMISTIC DURATION (semesters)	PESSIMISTIC DURATION (semesters)	CREDIT HOURS	OFFERED
A	FAFSA Commitment*	None	None	0.0625	0.0625	0.0625	0	Fall, Spring, Summer
B	TSI Pre-Assessment Activity Certification	None	None	0.00893	0.00893	0.00893	0	Fall, Spring, Summer
C	TSI Placement Exams	B	TSI Pre-Assessment Activity Certification	0.0625	0.0625	0.0625	0	Fall, Spring, Summer
D	MATH 1301 Bypass Exam	A, C	TSI Placement Exams	0.0625	0	0.0625	0	Fall, Spring
E	MATH 1505	D	MATH 1301 Bypass Exam	1	0	2	5	Fall, Spring, Summer
F	ENG 1301	A, C	TSI Placement Exams	1	0	2	3	Fall, Spring, Summer
G	ENG 1302	F	ENG 1301	1	0	2	3	Fall, Spring, Summer
H	Core Component	A, C	TSI Placement Exams	2*	2	3	30	Fall, Spring, Summer
I	CS 1311	A, C	MATH 1301 Bypass Exam	1	1	2	3	Fall, Spring, Summer
J	CS 2311	I	CS 1311	1	1	2	3	Fall, Spring
K	DATA 2401	E	MATH 1505	1	1	2	4	Fall, Spring
L	DATA 3401	I, K, O	CS 1311 & MATH 2305 & DATA 2401	1	1	2	4	Fall, Spring
M	DATA 3402	J, L	CS 2311 & DATA 3401	1	1	2	4	Fall, Spring
N	DATA 4319	I, L, Q, R	DATA 3401, co-req: MATH 3423 & STAT 3333	1	1	2	3	Fall, Spring
O	MATH 2305	E	MATH 1505	1	1	2	3	Fall, Spring, Summer
P	MATH 2421	E	MATH 1505	1	0	2	4	Fall, Spring
Q	MATH 2422	P	MATH 2421	1	1	2	4	Fall, Spring
R	MATH 3302	P	MATH 2421	1	1	2	3	Fall, Spring, Summer
S	MATH 3423	I, Q	CS 1311 & MATH 2422	1	1	2	4	Fall, Spring
T	STAT 3333	R	MATH 3302	1	1	2	3	Fall, Spring
U	STAT 4303	R	MATH 3302	1	1	3	3	Fall only
V	STAT 4310	R	MATH 3302	1	1	3	3	Spring only
W	Achieve Senoir Status	A, C	FAFSA, TSI Complete	2*	2*	2*	0	N/A
X	Senior Project Approval	W	Achieve Senior Status	0.0625	0.0625	0.0625	0	N/A
Y	Graduation Application	W	Achieve Senior Status	0.0625	0.0625	0.0625	0	N/A
Z	DATA 4395	X	Senior Project Approval	1	1	2	3	Fall, Spring, Summer
AA	DATA 4300	L	DATA 3401	1	1	2	3	Fall, Spring
BB	PHIL 2305	A, C	co-req: ENG 1301	1	1	2	3	Fall, Spring, Summer
CC	CS 1410	D	co-req: ENG 1301 & MATH 1505	1	0	2	4	Fall, Spring, Summer
DD	CS 2410	E, CC	CS 1410, co-req: MATH 2421	1	1	2	4	Fall, Spring, Summer
EE	CS 3304	O, DD	CS 2410 & MATH 2305	1	1	2	3	Fall, Spring, Summer
FF	CS 3321	EE	CS 3304	1	1	2	3	Fall, Spring
GG	(Free Elective) SPAN 1401*	A, C	TSI Placement Exams	1	0	2	4	Fall, Spring, Summer
HH	(Free elective) SPAN 1402*	GG	SPAN 1402	1	0	2	4	Fall, Spring, Summer
II	Commencement Ceremony	G, H, M, N, S, T, U, V, Y, Z, AA, BB, EE, FF, HH	All other tasks	0.00893	0.00893	0.00893	0	N/A
				Total hours =			**120**	
	*FAFSA Commitment * This application has to happen before EACH academic year for which you're getting aid (fall semester)*							
	*Free Elective * May take other electives, does not have to be Spanish*							

Appendix F

Graduation Project List: Starting with MATH 2421

ARC	TASK DESCRIPTION	PREDECESSOR(S)	PREDECESSOR(S) DESCRIPTION	DURATION (Semesters)	OPTIMISTIC DURATION (semesters)	PESSIMISTIC DURATION (semesters)	CREDIT HOURS	OFFERED
A	FAFSA Commitment*	None	None	0.0625	0.0625	0.0625	0	Fall, Spring, Summer
B	TSI Pre-Assessment Activity Certification	None	None	0.00893	0.00893	0.00893	0	Fall, Spring, Summer
C	TSI Placement Exams	B	TSI Pre-Assessment Activity Certification	0.0625	0.0625	0.0625	0	Fall, Spring, Summer
E	MATH 1505 Bypass Exam	A, C	TSI Placement Exams	0.0625	0	2	0	Fall, Spring
F	ENG 1301	A, C	TSI Placement Exams	1	0	2	3	Fall, Spring, Summer
G	ENG 1302	F	ENG 1301	1	0	2	3	Fall, Spring, Summer
H	Core Components	A, C	co-req: ENG 1301	2*	2	3	30	Fall, Spring, Summer
I	CS 1311	A, C	MATH 1505 Bypass Exam	1	1	2	3	Fall, Spring, Summer
J	CS 2311	I	CS 1311	1	1	2	3	Fall, Spring
K	DATA 2401	E	MATH 1505 Bypass Exam	1	1	2	4	Fall, Spring
L	DATA 3401	I, K, O	CS 1311 & MATH 2305 & DATA 2401	1	1	2	4	Fall, Spring
M	DATA 3402	J, L	CS 2311 & DATA 3401	1	1	2	4	Fall, Spring
N	DATA 4319	I, L, Q, R	DATA 3401, co-req: MATH 3423 & STAT 3333	1	1	2	3	Fall, Spring
O	MATH 2305	E	MATH 1505 Bypass Exam	1	1	2	3	Fall, Spring, Summer
P	MATH 2421	E	MATH 1505 Bypass Exam	1	0	2	4	Fall, Spring
Q	MATH 2422	P	MATH 2421	1	1	2	4	Fall, Spring
R	MATH 3302	P	MATH 2421	1	1	2	3	Fall, Spring, Summer
S	MATH 3423	I, Q	CS 1311 & MATH 2422	1	1	2	4	Fall, Spring
T	STAT 3333	R	MATH 3302	1	1	2	3	Fall, Spring
U	STAT 4303	R	MATH 3302	1	1	3	3	Fall only
V	STAT 4310	R	MATH 3302	1	1	3	3	Spring only
W	Achieve Senior Status	A, C	FAFSA, TSI Complete	2*	2*	2*	0	N/A
X	Senior Project Approval	W	Achieve Senior Status	0.0625	0.0625	0.0625	0	N/A
Y	Graduation Application	W	Achieve Senior Status	0.0625	0.0625	0.0625	0	N/A
Z	DATA 4395	X	Senior Project Approval	1	1	2	3	Fall, Spring, Summer
AA	DATA 4300	L	DATA 3401	1	1	2	3	Fall, Spring
BB	PHIL 2305	A, C	co-req: ENG 1301	1	1	2	3	Fall, Spring, Summer
CC	CS 1410	E	co-req: ENG 1301 & MATH 1505	1	0	2	4	Fall, Spring, Summer
DD	CS 2410	CC	CS 1410, co-req: MATH 2421	1	1	2	4	Fall, Spring, Summer
EE	CS 3304	O, DD	CS 2410 & MATH 2305	1	1	2	3	Fall, Spring, Summer
FF	CS 3321	EE	CS 2410 & MATH 2305	1	1	2	3	Fall, Spring
GG	(Free Elective) SPAN 1401*	A, C	FAFSA, TSI Complete	1	0	2	4	Fall, Spring, Summer
HH	(Free elective) SPAN 1402*	GG	SPAN 1402	1	0	2	4	Fall, Spring, Summer
JJ	Free Elective*	A, C	FAFSA, TSI Complete	1	1	1	3	Fall, Spring, Summer
KK	Free Elective*	A, C	FAFSA, TSI Complete	1	1	1	3	Fall, Spring, Summer
II	Commencement Ceremoy		All other tasks	0.00893	0.00893	0.00893	0	N/A
				Total hours =	**121**			
	*FAFSA Commitment * This application has to happen before EACH academic year for which you're getting aid (fall semester)*							
	*Free Elective * May take other electives, does not have to be Spanish*							