FACULTY SENATE ISSUE FORM

Date Submitted: September 25, 2018

Title of Issue (a short descriptive title by which the issue may be referenced)

Proposal for a Master of Science in Data Science and Analytics

Description of Issue:

Old Dominion University (ODU) seeks approval to initiate a Master of Science in Data Science and Analytics degree program. The proposed program will be administered by the Graduate School at ODU. The target date of the program's initiation is fall semester 2019.

Rational for Submission:

The purpose of the proposed Master of Science in Data Science and Analytics degree program is to address the need for an expanding workforce that will help companies analyze data and integrate the outcomes with business processes to make them more productive. Data science and analytics is a multidisciplinary field that combines computer science, business analytics, and statistics to understand and leverage data to make advances and decisions that were not possible within previous organizational tools.

The curriculum will provide students with the skills and competencies that will make them successful in today's competitive, data-driven world. The proposed program will prepare students to develop proficiencies in the fields of computational data analytics or in business intelligence and analytics. Specifically, they will be prepared to use state-of-the-art programming languages, tools, and software packages to perform analytics on complex data, develop statistical and machine-learning models, and organize, manage, and clean data for its maximum effectiveness in analysis and visualization.

The proposed MS in Data Science and Analytics will offer two concentrations – computational data analytics and business intelligence and analytics – both of which are designed to prepare students to apply knowledge and skills acquired in the program to specific areas of data science.

Name: Judy Bowman, submitted on behalf of Austin Agho and the Provost's Council
Department: Academic Affairs
Date: September 25, 2018
Signature:
For Faculty Senate Use Only
Assigned to Committee:
Date Assigned:

SUMMARY FROM CMTE C

Cmte C recommends approval of the proposed MS in Data Science and Analytics. The Cmte discussed the resource needs for a new graduate program like this MS program and, based on input from the University Libraries, acknowledge that library resources already exist to support this graduate program and no new library resources are needed. In the same discussion the Cmte agrees that this the MS in Data Science and Analytics builds on an existing expertise base at ODU and is a degree that will be needed in the future workforce. The proposal reflects the work of an interdisciplinary team from Computer Science, Math, Statistics, IT, and Business Analytics to develop an academic program that was responsive to the needs of future employers and that is distinctly different from other data science programs in the state.

STATE COUNCIL OF HIGHER EDUCATION FOR VIRGINIA

PROGRAM PROPOSAL COVER SHEET

1. Institution Old Dominion University	2. Academic Program (Check one): New program proposal ☒ Spin-off proposal ☐ Certificate document ☐
3. Name/title of proposed program Data Science and Analytics	4. CIP code 11.0802
5. Degree/certificate designation Master of Science	6. Term and year of initiation Fall 2019
7a. For a proposed spin-off, title and degree designation of existing degree program 7b. CIP code (existing program)	
8. Term and year of first graduates Spring 2021	9. Date approved by Board of Visitors
10. For community colleges: date approved by local board date approved by State Board for Community Colleges	
11. If collaborative or joint program, identify collaborating institution(s) and attach letter(s) of intent/support from corresponding chief academic officers(s)	
12. Location of program within institution (complete for every level, as appropriate and specify the unit from the choices). Departments(s) or division of _____ School(s) or college(s) of The Graduate School Campus(es) or off-campus site(s) Main campus, Norfolk	
Mode(s) of delivery: face-to-face ☐ hybrid (both face-to-face and distance) ☒	Distance (51% or more web-based) ☐
13. Name, title, and telephone number(s) of person(s) other than the institution's chief academic officer who may be contacted by or may be expected to contact Council staff regarding the modified program. Dr. Jeanie Kline, SCHEV Liaison, 757.683.3261	

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Description of the Proposed Program

Program Background

Old Dominion University (ODU) in Norfolk, Virginia seeks approval to initiate a Master of Science in Data Science and Analytics degree program. The proposed program will be administered by the Graduate School at ODU. The target date of the program's initiation is fall semester 2019.

The purpose of the proposed Master of Science in Data Science and Analytics degree program is to address the need for an expanding workforce that will help companies analyze data and integrate the outcomes with business processes to make them more productive. Data science and analytics is a multidisciplinary field that combines computer science, business analytics, and statistics to understand and leverage data to make advances and decisions that were not possible within previous organizational tools. With the growth in computing hardware and software technologies, along with advancements in statistical and machine learning methods, industries are increasingly data driven. Organizations can now perform advanced analytics on large amounts of data and are able to move out of the arena of traditional business intelligence built around databases and data warehouses.

Faculty developed a curriculum that will provide students with the skills and competencies that will make them successful in today's competitive, data-driven world. The proposed program will prepare students to develop proficiencies in the fields of computational data analytics or in business intelligence and analytics. Specifically, they will be prepared to use state-of-the-art programming languages, tools, and software packages to perform analytics on complex data, develop statistical and machine-learning models, and organize, manage, and clean data for its maximum effectiveness in analysis and visualization.

The proposed MS in Data Science and Analytics will offer two concentrations, both of which are designed to prepare students to apply knowledge and skills acquired in the program to specific areas of data science. Those in the computational data analytics concentration will possess the core background knowledge in computer science and statistics fields and will be able to apply this knowledge to different types of data, and to structured and unstructured text, pictures, and videos. They will be able to perform predictive and prescriptive analytics. Not only will the program educate graduates in data analysis, it will also provide skills for graduates to extend results to broader interpretations of data in real-world contexts. The faculty will do this by teaching different methods to explore and visualize data and having graduates develop the ability to summarize and present the results of their analysis to both technical and non-technical audiences.

Graduates in the business intelligence and analytics concentration will learn the tools and methods used for the storage, access, and analysis of data to support informed business decision-making. Students will develop competencies in descriptive, predictive, and prescriptive analytics in a business context. They will be able to identify, collect, manage and analyze appropriate organizational data and use the resulting information to make informed business recommendations.

Mission

The mission of the university states: Old Dominion University, located in the City of Norfolk in the metropolitan Hampton Roads region of coastal Virginia, is a dynamic public research institution that serves its students and enriches the Commonwealth of Virginia, the nation, and the world through rigorous academic programs, strategic partnerships, and active civic engagement.

The proposed MS in Data Science and Analytics aligns with this mission by providing a "rigorous academic program" that will prepare the next generation of data scientists to gain key analytic knowledge and skills in their respective fields, and ultimately to "enrich" the Commonwealth of Virginia, the nation, and the world with data-driven decision-making.

Online Delivery

The proposed Master of Science in Data Science and Analytics will be offered in a hybrid format, combining on-campus and online instruction. For online classes, Blackboard is Old Dominion University's learning management system, which will be used for the proposed program, with extensive use of synchronous meetings in the Adobe Connect platform. Additionally, faculty utilize Adobe Connect or WebEx for weekly synchronous office hours and other real-time communication throughout each semester.

Old Dominion University has a robust distance learning network that supports faculty in web-based course development and delivery. Faculty who teach in the program are trained in course development and delivery through the Center for Learning and Teaching (CLT). Instructional designers, technologists, and other staff work with the library faculty to assist in implementing technology into classes and providing the latest in course development strategies.

Admission Criteria

The criteria for acceptance into the Master of Science in Data Science and Analytics will include the following:

- A completed online application and associated application fee
- A baccalaureate degree in computer science, electrical and/or computer engineering, mathematics, statistics, information system and technology or a related field from a regionally-accredited institution or an equivalent institution outside the U.S.; students holding bachelor's degrees in an unrelated field will need the competency in topics related to basic statistics and computer science such as: differentiation and integration, vectors and matrices, determinants and matrix inverse, elementary statistics and probability, basic programming, software development and testing, and C++/java concepts.
- Official copies of transcripts of all regionally-accredited institutions attended (or equivalent non-U.S. institutions)

- Two letters of recommendation from individuals familiar with the applicant's professional and/or academic background
- A current resume
- A statement of professional goals
- GRE scores, with a 50% or better attainment on quantitative reasoning

Current scores on the Test of English as a Foreign Language (TOEFL) of at least 550 on the paper-based test (or 79- 80 on the iBT) are required for non-native English speakers.

Students with previously completed work at a regionally-accredited institution may submit a request for a maximum of 9 graduate credit hours to be transferred into a concentration or research area of the program. If approved by the graduate committee—the Graduate Program Director and faculty members representing each department associated with the degree—they will be added to their transcripts.

Target Population

The proposed Master of Science in Data Science and Analytics degree program will target undergraduates at ODU in various disciplines, including computer science, information technology, engineering, and health sciences. The program will also target those in the military and individuals working for federal, state, or local government or for government contractors who wish to gain advanced expertise in data science.

Curriculum

The proposed Master of Science in Data Science and Analytics is a 30-credit hour non-thesis degree program. The curriculum will offer two concentrations: computational data analytics and business intelligence and analytics.

The focus of the curriculum is to provide students with a solid foundation in data analytics. It will consist of a core, two concentrations, and a capstone project. The objective of the core is to lay the foundation that is required by data scientists working in any field. The core will establish proficiency in data discovery, collection, processing, and cleaning; competency in exploratory data analysis using statistics and visual analytics; and aptitude in statistical modeling implementation for predictive analytics.

The concentration in computational data analytics will provide students with opportunities to learn about different aspects of computational data analysis, such as machine learning, data visualization, web science, and natural language processing. Courses in this concentration are also offered to address relevant data analytics topics such as video analytics, algorithms and data structures, and information retrieval. The concentration in business intelligence and analytics will provide students with knowledge about database management systems, business intelligence, information and communications technology, business analytics, and simulation modeling for business systems.

The capstone project brings together students in their final semester of study to synthesize knowledge from their coursework and apply it to solve real-world data analytics problems.

New courses are noted with an asterisk.

Program Requirements

Core Courses (15 Credits)

DASC 600	Introduction to Data Science	(3 credits)
STAT 603*	Statistical/Probability Models for Data Science	(3 credits)
CS 625*	Data Visualization	(3 credits)
STAT 604*	Statistical Tools for Data Science	(3 credits)
CS 624*	Data Analytics and Big Data	(3 credits)

Computational Data Analytics Concentration (12 credits)

Four of the following courses to be selected in consultation with the faculty advisor.

CS 521*	Machine Learning I	(3 credits)
CS 601*	Algorithms and Data Structures for Data Science	(3 credits)
CS 626*	Visual Analytics: Exploring and Analyzing Data Visually	(3 credits)
CS 632*	Web Science	(3 credits)
CS 721*	Machine Learning II	(3 credits)
CS 727*	Large Scale Video Analytics	(3 credits)
CS 733*	Natural Language Processing	(3 credits)
CS 735*	Information Retrieval	(3 credits)

Business Intelligence and Analytics Concentration (12 credits)

Two of the following courses to be selected in consultation with the faculty advisor

BNAL 503	Data Exploration and Visualization	(3 credits)
BNAL 515	Advanced Business Analytics with Big Data Applications	(3 credits)
BNAL 721	Simulation Modeling for Business Systems	(3 credits)

Two of the following courses to be selected in consultation with the faculty advisor

IT 650	Database Management Systems	(3 credits)
IT 651	Business Intelligence	(3 credits)
IT 652	Information and Communications Technology for Big Data	(3 credits)

Capstone Project

DASC 690*	Capstone Project	(3 credits)

Capstone Project

The culminating course in the proposed MS in Data Science and Analytics degree program will bring students together with faculty and external partners. In consultation with a faculty advisor, along with a business or industry or government representative, students will be required to develop a project that aims to solve a data science problem in a real-world business, industry or government setting. Faculty and business/industry/government representatives will serve as external mentors for the students during this experience.

Students will learn how to identify problems, gather data and information, understand the business system, define hypotheses, analyze and visualize the data, develop solutions, and effectively articulate and communicate ideas and results. The capstone course offers valuable experiences—through the collaborative efforts—to develop design thinking in data science and to exercise leadership in a team environment.

Appendix A provides sample schedules for full-time and part-time students. Course descriptions may be found in Appendix B.

Student Retention and Continuation Plan

The Graduate School, along with faculty who oversee this program will offer programming designed to ensure student success. Faculty will require new students to attend an orientation session, in person or online, which introduces the program, curriculum, requirements, expectations, faculty, facilities and other relevant resources students may access. In addition, faculty will publish an up-to-date curriculum and a long-range course schedule to help students plan their enrollment and time to completion. They will also hold advising sessions each semester and provide personalized advising throughout students' program of study. Finally, faculty, in collaboration with government/industry/business partners, will mentor students in curricular content and career opportunities.

When individual student performance demonstrates a lack of success, faculty will meet with the student to explore ways that will lead to success. These include holding additional advising sessions with the student, using peer mentors to connect students to each other and to their academic work, and having an external partner meet with the student to discuss areas of career interest.

Continuation within the program is contingent upon maintaining a 3.0 average in all academic coursework. Students who are unable to maintain the GPA requirements will meet with the Graduate Program Director and their academic advisor to develop a remediation plan designed to assist the student with academic success within the program.

Faculty

This proposed interdisciplinary degree program will have faculty members from the College of Sciences (Department of Computer Science and Department of Mathematics and Statistics) and from the Strome College of Business (Department of Information Technology and Decision Sciences). There will be six faculty members who will teach core and capstone classes. All hold PhDs and are tenured or tenure-track faculty members. They are active in research, publications, and teaching in areas related to data science and analytics. Combined, they have over 80 years' experience in postsecondary teaching.

Abbreviated CVs of faculty members are included in Appendix C.

Program Administration

The proposed Master of Science in Data Science and Analytics will be administered by the Graduate School, in collaboration with faculty from the College of Sciences and the Strome College of Business. A faculty member from Computer Science will be appointed as the Graduate Program Director (GPD). She or he will teach in the program and will have responsibility for setting class schedules, coordinating student meetings and activities, providing admission and enrollment information to the Graduate School, and meeting with the faculty, and dean or associate dean of Graduate School to discuss program matters.

A graduate committee, to include the GPD and faculty members representing each department associated with the degree, will be formed to review applicants for admission, evaluate the curriculum to ensure it meets student and employer needs, and conduct regular program assessments.

An administrative assistant in the Graduate School will support faculty and students in this program, with approximately 20% of his/her time devoted to the proposed degree program. The administrative assistant will help with class scheduling and coordination of appropriate paperwork for the program, including assessment materials that are provided to the dean, associate dean, and the Office of Academic Affairs.

Student Assessment

Students will be evaluated throughout the program using formative assessments, such as quizzes, tests, cases studies, papers, research projects, and presentations. Student learning outcomes cover many of the technical and management competencies required for the area of data science. Specifically, students graduating from the proposed program will have specific skills/knowledge in the area of data science and analytics. They will be able to:

1. Use statistical analyses to solve data analytics problems and make decisions.
2. Utilize descriptive and predictive analytics to identify a problem and improve business productivity.
3. Create visual representations of complex real world data that helps to identify patterns.
4. Apply modern programming languages and open source tools and packages to solve data science problems.
5. Employ effective communication skills to defend data analysis results and conclusions to both technical and non-technical audiences.
6. Explore and develop data models in order to recommend optimal solutions facing organizations.

Assessment Map for Core Courses in Proposed Program

Student Learning Objectives	Measures
1. Statistical Methodology for Exploring Data Use statistical analyses to solve data analytics problems and make decisions.	DASC 600 – Introduction to Data Science Assessment: 85% of students will attain target on the statistical analysis final assignment rubric. DASC 690 – Capstone Assessment: 85% of students will attain target on the Capstone Project rubric – related to statistical exploration.
2. Data Analytics Utilize descriptive and predictive analytics to identify a problem and improve business productivity.	STAT 603 – Statistical/probability models for data science Assessment: 85% of students will attain target on the statistical modeling assignment rubric. DASC 690 – Capstone Assessment: 85% of students will attain target on the Capstone Project rubric – related to statistical modeling
3. Data Visualization Create visual representations of complex real world data that helps to identify patterns.	CS 625 – Data Visualization Assessment: 85% of students will attain target on the data visualization project rubric. DASC 690 – Capstone Assessment: 85% of students will attain target on the Capstone Project rubric – related to data visualization
4. Computer Programming Apply modern programming languages and open source tools and packages to solve data science problems.	CS 624 Data Analytics and Big Data Assessment: 85% of students will attain target on the final data science programing project rubric. CS 690 – Capstone Assessment: 85% of students will attain target on the Capstone Project rubric – related to programming.
5. Communication Skills Employ effective communication skills to defend data analysis results and conclusions to both technical and non-technical audiences.	CS 625 – Data visualization Assessment: 85% of students will attain target on the data visualization presentation rubric.

	DASC 690 – Capstone Assessment: 85% of students will attain target on the Capstone Project rubric – related to communication skills
6. Research Explore and develop data models in order to recommend optimal solutions facing organizations.	STAT 604 - Statistical Tools for Data Science Assessment: 85% of students will attain target on the final data modeling assignment rubric. DASC 690 – Capstone Assessment: 85% of students will attain target on the Capstone Project rubric – related to final recommendations.

Employment Skills/Workplace Competencies

Graduates of the Master of Science in Data Science and Analytics will have the skills, ability, and workplace competencies needed for employment in the field of data science. Specifically, they will have:

- Proficiency in using state of the art programming languages, tools, and software packages to perform analytics on complex data including big data.
- Capability to develop statistical and machine learning models.
- Ability to organize, manage, and clean data for its maximum effectiveness in analysis and visualization.
- Proficiency in visually representing complex data to better understand the data and to effectively communicate to higher management the intricacies of data and its relationship with the organization processes.
- Ability to write professional code adhering to industry standard for building data science applications.
- Ability to lead teams in working various aspects of data science from retrieving and cleaning data to exploring and modeling data.

Program Assessment

The program will be assessed by faculty and administrators in the Graduate School, the College of Sciences, the Strome College of Business, and the Provost's office. The review will be completed annually in the fall starting in the second year after the program is launched and will consist of:

- Analyzing retention and attrition rates in order to maximize the positive influences and improve the negative ones that affect program completion
- Analyzing the results of the ODU Graduate Student Satisfaction Survey for areas where additional student support is needed

- Analyzing graduate job placement to assess if the program is preparing students with the knowledge, skills and abilities for jobs in data science and evaluating the program's ability to meet market demands (following initial graduates' completion)

The results of these assessments will be used to evaluate the quality of the program, to stimulate program development, and to assess the role of the program in fulfilling ODU's institutional mission. The program review may (a) result in strategic decisions about the program, (b) identify areas of improvement, (c) make resource recommendations, (d) articulate considerations for expansion or consolidation, and/or (e) consider other aspects of programmatic quality with respect to policies and practices relative to:

- Student recruitment, admissions, advising, and retention;
- Enrollment projections including consideration of the context of the SCHEV 5-year benchmark and other on-going enrollment targets;
- Course descriptions and implementation;
- Curriculum changes and development;
- Faculty development and research activities;
- Facilities;
- Internal and external funding; and
- Description of strengths and weaknesses with attention to action items for the future.

The dean and associate dean in the Graduate School will read the program review each year to ensure that benchmarks are met and excellence is maintained. The Graduate School's annual evaluation of the program will be sent each year to the Vice Provost for Academic Affairs for review. The Vice Provost will offer guidance, as needed, for improvement, and will provide updates about the review to the Provost.

Old Dominion University maintains a robust program review process for graduate programs; as such, this master's program will have an internal review conducted by external faculty after five years (i.e., in fall of year 6). This review will include a self-study, a visit from faculty external to the program, and an action plan developed in concert with the Graduate Program Director, program faculty, and dean and associate dean of Graduate School.

Benchmarks of Success

Benchmarks of success for the proposed Master of Science in Data Science and Analytics degree program include the following student enrollment and graduate goals:

- 25-30 new students will be admitted when the program is launched, and will continue through the target year
- The program will graduate a minimum of 12 students annually by the completion of the target year
- 80% of the students who begin the program will successfully complete the program within five years of matriculation

- 80% of graduates will be employed in data science positions using knowledge acquired in their graduate studies within one year of program completion
- 80% of students will be satisfied with the program as determined by the university's Graduate Student Satisfaction Survey
- 80% of alumni will be satisfied with the program as determined by the university's Graduate Alumni Survey, administered within one year of program completion
- 80% of employers will be satisfied with the level of education and skill of graduates, as measured by an employer survey administered within one year of hire.

After the first year and subsequent years, periodic evaluations of the success of the program in meeting these benchmarks will be undertaken. If program benchmarks are not achieved, the Dean of the Graduate School, along with the Graduate Program Director and the program faculty, will examine the program's admissions policies, curriculum, instructional methods, advising practices, and course evaluations to determine where changes need to be made.

Expansion of an Existing Program

The proposed program is not an expansion of an existing certificate, concentration, emphasis, focus, major, minor, or track at Old Dominion University.

Relationship to Existing ODU Degree Programs

The proposed program is not similar or related to any existing master's program at Old Dominion University.

Compromising Existing Programs

No degree programs will be compromised or closed as a result of the initiation and operation of the proposed degree program.

Collaboration or Standalone

This is a standalone program. No other organization was involved in its development, and no other organization will collaborate in its operation.

Justification for the Proposed Program

Response to Current Needs
(Specific Demand)

Data science and analytics is being recognized as the key discipline in utilizing ever-growing data to solve challenging problems facing multiple economic sectors. The latest U.N. E-Government Survey 2018[1] concludes that the fourth industrial revolution and convergence of big data technologies and machine learning is making a dramatic shift towards more data and machine-driven societies. The survey report states: "Data is being currently referred to as the new oil, the new raw material driving innovation and growth in both the private and public sectors. Indeed, data use will grow exponentially in the next decade and will offer the ability to systematically analyze and act in real time in solving more complex business problems, creating more competitive advantage and making better-informed decisions in a tightly connected world."

Amazon CEO, Jeff Bezos, in a recent letter to shareholders, highlights the importance of data analytics and machine learning and how it impacts every part of the company. He wrote: "Machine learning drives our algorithms for demand forecasting, product search ranking, product and deals recommendations, merchandising placements, fraud detection, translations, and much more. Though less visible, much of the impact of machine learning will be of this type – quietly but meaningfully improving core operations."[2]

Data is growing exponentially at all levels of human activity. Just in the past two years, for example, more data has been generated than in the entire previous history of the human race.[3] According to one estimate, by the year 2020, approximately 1.7 MB of data will be created every second for every person on the planet.[3] With the growth in computing hardware and software technologies, along with advancements in statistical and machine learning methods, it is becoming feasible to work with this ever-growing data and address big challenges facing the society in various economic sectors. In general, multiple economic sectors can benefit from using a data-centered approach to reduce costs, make better and faster decisions, and develop new products and services.

Impact of Data Science and Analytics on Various Economic Sectors

Health. According to the American College of Cardiology,[4] the aggregation of large quantities of structured and unstructured health information coupled with advanced data analytics will lead to a more patient-centered health care model that improves outcomes and reduce cost. That report claims that applying emerging computational data analytics techniques such as machine learning, natural language processing, and artificial intelligence to a large-scale biological, radiological, and translational bioinformatics datasets will help in defining dynamic patterns of health and disease. This will result in sustainable healthcare models that are driven by data and technology.

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[1] https://publicadministration.un.org/egovkb/en-us/Reports/UN-E-Government-Survey-2018
[2] https://www.sec.gov/Archives/edgar/data/1018724/000119312517120198/d373368dex991.htm
[3] https://www.forbes.com/sites/bernardmarr/2015/09/30/big-data-20-mind-boggling-facts-everyone-must-read/#ee9256c17b1e
[4] http://www.onlinejacc.org/content/70/21/2696

Finance and Banking. The financial and banking sector is using data to reduce fraudulent transactions, reduce customer churning, find new areas of growth, and reduce risk. With increased access to online transactions, bank frauds have become more sophisticated. According to a McKinsey report,[5] banking data along with machine learning techniques can help institutions to fight against bank frauds. The finance and banking industry can use machine learning techniques to predict customers that are likely to reduce their business with the bank. This information can be used by the banks for target campaigning to reduce churn.[6] Data analytics techniques can be used for risk assessment, stress testing, and developing early-warning systems.[6]

Defense. The Defense Logistics Agency created a new Strategic Data and Analysis office in March 2018 to help in making data-driven decisions.[7] The new office will harness emerging tools and technology in the area of data analytics for reducing costs, making faster decisions, and offering new services. The office plans to use advanced predictive analytics approaches to forecast deployment needs. For example, by analyzing data from past deployments it is possible to predict the need of supply items by a unit in the future so as to supply the required items to the unit more efficiently, and at a cost reduction by avoiding emergency orders.

Retail. This is one of the sectors which is heavily utilizing data-centric approaches to enable targeted and personalized marketing. The data analytics, on a large scale, is enabling retailers to gain an innovative edge over the competition by using customer behavior analytics, optimize advertising and promotional investment, optimize supply with demand, detect fraud, and personalizing the in-store experience.[8] For example, Starbucks' mobile app has more than 13 million active users who are creating a significant amount of data reflecting their purchasing habits.[9] These data, along with data analytics approaches, are being used for personalizing the Starbucks experience, targeted and personalized marketing, determining new store locations, and updating menu options.

Skills Required and Shortage

Data science and analytics core skills are built upon statistics and computing fundamentals, which are acquired as part of an undergraduate curriculum. At the graduate level, students are prepared to solve real-world problems that require advanced analytics coupled with complex problem-solving skills. There is a growing need for training students at a graduate level where they obtain hands-on experience in data science and analytics techniques and methodologies to solve actual problems. More specifically, the skills required for most of the data scientists jobs are machine learning, big data, data visualization, predictive analytics, and problem-solving.

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[5] https://www.mckinsey.com/business-functions/mckinsey-analytics/our-insights/applying-analytics-in-financial-institutions-fight-against-fraud

[6] https://www.mckinsey.com/industries/financial-services/our-insights/analytics-in-banking-time-to-realize-the-value

[7] http://www.dla.mil/AboutDLA/News/NewsArticleView/Article/1454856/dla-creates-new-office-to-help-data-drive-decisions/

[8] https://www.morganmckinley.co.uk/article/data-opportunities-and-challenges-within-retail-sector

[9] https://www.forbes.com/sites/bernardmarr/2018/05/28/starbucks-using-big-data-analytics-and-artificial-intelligence-to-boost-performance/#45939b0065cd

A report from the career and hiring company, Paysa,[10] found that over 36% of data analytics and machine learning positions require a graduate level degree. Another report from IBM found that over 40% of data scientist positions require candidates to have a graduate degree.[11]

According to the report from Paysa, the top 20 machine learning recruiters are investing over $650M annually to hire data scientists.[10] The recruiters' list includes Amazon, Google, Microsoft, Nvidia, Facebook, Intel, Rocket Fuel, GE, Cylance, and Oculus. The top annual investment is by Amazon of over $200M with over 1100 jobs posting for machine learning. This is followed by Google with an annual investment of $130M and the posting of over 550 jobs in machine learning. All this investment by various industries is disrupting the job market where current demand is far exceeding the supply. To make matter worse the growth in data scientists jobs is note leveling and it will put the demand for data scientists' skills in a dangerous zone. The IBM report written in collaboration with the Higher Education Forum and Burning Glass Technologies predicts that by 2020 the number of Data Science and Analytics job listing is projected to grow by 364,000.[11]

The consulting firm, PricewaterhouseCoopers—or PwC—recently published a report that makes a case for investing in America's data science and analytics (DSA) talent.[12] The report claims that as companies in all sectors are becoming data-driven, there is an emergence of a hybrid economy. "The hybrid economy generates considerable demand for highly trained data scientists and an even greater demand for analytics-enabled professionals who possess hybrid skills: deep knowledge in a particular domain with strong ability in the use of data, analytics, and visualization tools. Despite this broad demand across all sectors, the US faces a significant shortfall in the number of data scientists and 'data-enabled' professionals. Closing this DSA talent gap—and enabling organizations to take full advantage of the value of data—will require significant expansion of strategic partnerships between business and higher education as well as investments in new talent development strategies."

A report from 2011 published by the McKinsey Global Institute predicts that data-driven technologies will bring an additional $300 billion of value to the U.S. healthcare sector alone, and by 2020, 1.5 million more "data-savvy managers" will be needed to capitalize on the potential of data[13]. The rise of data is creating similar opportunities/challenges in fundamental science. This report goes on to warn that in spite of a strong push in the U.S. at the federal, state, and local levels for more STEM education and more graduates who are underrepresented, the need for deep analytical talent is more specific even than this – more graduates with advanced training in statistics and machine learning will be necessary.

[10] https://www.paysa.com/press-releases/2017-04-17/6/us-companies-raising-1-billion
[11] https://www-01.ibm.com/common/ssi/cgi-bin/ssialias?htmlfid=IML14576USEN&
[12] https://www.pwc.com/us/en/publications/assets/investing-in-america-s-dsa-talent-bhef-and-pwc.pdf
[13]https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/Big%20data%20The%20next%20frontier%20for%20innovation/MGI_big_data_exec_summary.ashx

Federal Initiative to Address Shortage of Talents

The Federal Big Data Research and Development Strategic Plan, published in May 2016 by the Executive Office of the President, National Science and Technology Council,[14] emphasizes the importance of the emerging multidisciplinary field of data science for the overall economic development of the U.S. It concludes that the public-private partnerships, together with the education and training of future data scientists will be the key to improving the country's economy. According to the report, there are 60 institutions that offer a master's degree in data science, which is insufficient in addressing the workforce challenge. "The need is for both domain [concentration] experts who are trained in data science and "core" data scientists who focus on data science as their primary field of expertise. Individuals educated in data science at the undergraduate and graduate levels are vital to meeting needs across all sectors—industry, government, and academia."

The National Science Foundation report, "Realizing the Potential of Data Science," published in December 2016,[15] highlights the importance of the emerging area of data science, the potential impact it will have on the U.S. economy, and the workforce requirements it will generate. "The ability to manipulate data and understand data science is becoming increasingly critical to current and future discovery and innovation." The report recognizes the role of National Science Foundation programs such as IGERT (Integrative Graduate Education and Research Traineeship) in the development of graduate program related to data science, and emphasizes the need for additional mechanisms to support the development of graduate programs in data science at various institutions.

The National Science Foundation sponsored a workshop in April 2016[16] to identify research and workforce development challenges in this area. The workshop report recognizes that it is essential that computer scientists and statisticians collaborate to achieve significant progress in the emerging area of data science. It also highlights the challenges of developing new graduate data science programs to address the workforce development. "A successful foundational undergraduate and post-graduate data science education program should capitalize on cultural differences between disciplines that intersect the science of collection, conditioning, modeling, compression, and analysis of data. Such a program should combine the best practices of training in un-programmed learning (empirical experimentation labs, Kaggle competitions) and programmed learning (fundamental principles, analytical tools, formal methods, etc.)."

The challenge of producing a properly trained workforce with data science skills is enormous and higher education institutions will play an essential role in meeting this challenge. New graduate programs are needed to train both domain experts in the techniques of data science, and "core" data scientists who will be making advancements in the field of data science itself. Integrating data science as a discipline is paramount to developing a productive workforce that can address the needs across different sectors, and to ensuring that the United States remains economically competitive. To meet the explosive growth in demand for data scientist skills,

[14] https://www.nitrd.gov/pubs/bigdatardstrategicplan.pdf
[15] https://www.nsf.gov/cise/ac-data-science-report/
[16] http://www.cs.rpi.edu/TFoDS/

several institutions in the U.S., including Virginia, have launched master's programs, but they will not meet the current and future demand in the field.

Why Old Dominion University?

The economy in Hampton Roads is driven, in large part, by federal resources, with many organizations increasingly analyzing data for critical decision making. Among these entities are national research laboratories, large military organizations and government contractors, including the NASA Langley Research Center, Naval Station Norfolk, and Booz Allen Hamilton. NASA is collecting data from hundreds of satellites about Earth, the solar system, and the universe, utilizing big data analytics approaches to work with this significant amount of data.[17] Naval Station Norfolk is looking at data analytics to predict when the fleet might be in danger of committing a major mishap, so that it can avoid a possible failure.[18]

Besides federal organizations, there are local industries such as Sentara Healthcare and Automatic Data Processing (ADP) that are becoming more data centered. Big data is essential to delivering sustainable, high quality, value-based healthcare; it is also critical to the success of new models of care such as clinically integrated networks (CINs) and accountable care organizations. Sentara Healthcare, based in Norfolk, is leading the way by leveraging big data analytics to build telehealth-supported electronic intensive care units and telehealth primary care support.[19] In the burgeoning cloud-based computing enterprise, ADP, a fortune 500 company that provides business process outsourcing solutions, opened a new facility in Norfolk in 2016. ADP uses big data analytics at the core of its operations; one of their products, DataCloud, provides data analytics tools to help HR professionals gain insights from ADP workforce data.[20]

Old Dominion University aims to meet the needs of these and other local entities—government and private industry—by providing the Master of Science in Data Science and Analytics to those who seek to become highly trained and skilled data scientists in their respective fields.

Employment Demand

The Bureau of Labor Statistics published a document that highlights career opportunities for data scientists.[21] Some of the fields where graduates of the proposed program can be employed are business, E-commerce, finance, government, healthcare, science, social networking, telecommunication, politics, and utilities.

A recent report by IBM, Burning Glass Technologies, and the Business-Higher Education Forum suggests that the demand for data science skills is disrupting the job market.[22] Key highlights from this report are:

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[17] https://digit.hbs.org/submission/nasa-big-challenges-require-big-data-solutions/

[18] https://news.usni.org/2017/11/13/navy-struggling-balance-training-maintenance-deployment-needs-service-looking-data-analysis-warn-readiness-problems

[19] https://www.ncbi.nlm.nih.gov/pubmed/28199238

[20] https://www.adp.com/why-adp/data-cloud/overview.aspx

[21] https://www.bls.gov/careeroutlook/2013/fall/art01.pdf

[22] https://www.ibm.com/analytics/us/en/technology/data-science/quant-crunch.html and http://www.burning-glass.com/research-project/quant-crunch-data-science-job-market/

- Twenty-five percent of employers hiring analysts prefer or require candidates to have a graduate degree, according to research from job market analytics firm, Burning Glass Technologies.
- In 2015 the number of job postings for data scientist and advanced analysts was 1629, 30% above the national average for all occupations.
- Among these job postings in 2015, the number of job posting that required a master or higher-level degree was 612. This number will grow to 678 by 2020.
- By 2020 the number of job openings requiring data science skills will reach 2.7 million.
- Data science jobs pay an average annual salary of $105,000.
- Data science jobs remain open an average of 45 days, five days longer than the market average.
- The greatest demand for data science skills are in three sectors: information technology, finance and insurance, and professional services.
- By 2020, only 10% of the demand for employees skilled in data science, analytics and business analytics will be filled if there is not significant growth in advanced degree programs in these fields.

The number of "big data" jobs increased 63% during 2012, and some predictions estimate that 1.9 million new jobs will have been created by 2017 in the United States. Industry is currently facing a shortage of skilled workers. According to McKinsey,[23] "By 2018, the United States alone could face a shortage of 140,000 to 190,000 people with *deep analytical skills*." The objective of the proposed Master of Science in Data Science degree program is to address this shortage.

Old Dominion University organized a workshop in December 2016 to assess the feasibility, demand, and requirements for a new graduate program in Data Science. Members of local industry and organizations such as Booz Allen Hamilton, Sentara Healthcare, and NASA Langley Research, more than 50 in all, participated in the workshop and were overwhelmingly supportive and encouraging that ODU should quickly establish an interdisciplinary graduate degree in Data Science, or Data Analytics. This new program should include a project-based Capstone course and emphasize critical thinking and problem solving in addition to quantitative skill in statistics, machine learning and visualization.

According to the BLS, employment of computer and information research scientist occupations is projected to grow 19% from 2016 to 2026,[24] "much faster than the average" for all occupations. The BLS reports that the "typical entry-level education" for computer and information research scientist occupations is a master's degree. Demand for these workers will stem from greater emphasis on cloud computing, the collection and storage of big data, and information security.

[23] http://www.mckinsey.com/business-functions/business-technology/our-insights/big-data-the-next-frontier-for-innovation

[24] https://www.bls.gov/ooh/computer-and-information-technology/computer-and-information-research-scientists.htm

The BLS also reports that overall employment of mathematicians and statisticians is projected to grow 33% from 2016 to 2026, "much faster than the average" for all occupations.[25] The "typical entry-level education" for mathematicians and statisticians occupations is a master's degree. Businesses will need these workers to analyze the increasing volume of digital and electronic data. The average growth rate for all occupations is 7%.

According to the BLS Geographic Profile for Computer and Information Research Scientists, the Commonwealth of Virginia has the second highest employment level in this occupation, second to California:[26]

State	Employment (in thousands)	Employment per thousand jobs	Location quotient	Hourly mean wage	Annual mean wage
California	4,950	0.31	1.64	$60.39	$125,620
Virginia	2,550	0.68	3.59	$60.96	$126,800
Maryland	2,490	0.94	4.99	$54.38	$113,110
New Jersey	1,530	0.39	2.04	$60.52	$125,880

The Commonwealth of Virginia is among the top states with the highest concentration of jobs and location quotients for this occupation. The location quotient is the ratio of the area concentration of occupational employment to the national average concentration. A location quotient greater than one indicates the occupation has a higher share of employment than average, and a location quotient less than one indicates the occupation is less prevalent in the area than average.

In the June 2018 Bureau of Labor Statistics publication called Beyond the Numbers,[27] the employment change for mathematical science occupations projected for 2016-2026 follows (with numbers in thousands).

Occupational title	Employment		Change, 2016–26	
	2016	2026	Number	Percent
Total, all occupations	156,063.8	167,582.3	11,518.6	7.4
Mathematical science occupations	180.7	231.0	50.4	27.9
Actuaries	23.6	28.9	5.3	22.5
Mathematicians	3.1	4.0	0.9	29.7
Operations research analysts	114.0	145.3	31.3	27.4
Statisticians	37.2	49.8	12.6	33.8

[25] https://www.bls.gov/ooh/math/mathematicians-and-statisticians.htm
[26] https://www.bls.gov/oes/current/oes151111.htm#st
[27] https://www.bls.gov/opub/btn/volume-7/big-data-adds-up.htm

Commonwealth of Virginia

The Commonwealth of Virginia recognizes the importance of data science and is already investing in this area. One of the initiatives, Virginia Longitudinal Data System,[28] enables data analysis on a diverse set of large datasets. Executive Directive 7 (2016) makes the case for leveraging the use of shared data and analytics.[29] The directive states:

> In order to continue the Commonwealth's advancement towards a New Virginia Economy that draws on all of the Commonwealth's vast resources, it is important that state agencies have access to all information necessary to better provide services to our citizens. Increasing the use of shared data and analytics among Virginia agencies through a comprehensive and coordinated effort will improve the provision of services and outcomes, maximize the use of resources, and increase the return on investment of our citizens' tax dollars in their government. Increasing data sharing, correlation, and analysis capacity will enable the state to achieve efficiencies in the administration of state programs and services, and allow state government to more efficiently and effectively address issues related to public health, public safety, education, and quality of life.

Recently, The Commonwealth started GO Virginia, which provides funds to diversify the economy of regions.[30] Data analytics has been identified as the best opportunity for increasing the economic prosperity of Regions 5,[31] which is comprised of the cities of Chesapeake, Franklin, Hampton, Newport News, Norfolk, Poquoson, Portsmouth, Suffolk, Virginia Beach, and Williamsburg; and the counties of Accomack, Isle of Wight, James City, Northampton, Southampton, and York. Additionally, the Commonwealth of Virginia has made a number of non-sensitive datasets available in the public domain.[32] This will enable data scientists to build useful applications around the open data set potentially leading to economic opportunities.

A recent report from the Center for Data Innovation evaluates different states, including Commonwealth of Virginia, in terms of a series of indicators in three categories: the availability of high-value datasets, the creation of important technologies, and the development of human and business capital.[33] For one of the metrics, "Data Science Job Listings," which is a measure of job postings for data scientists as a share of total posted job listings, the Commonwealth of Virginia is ranked #4.

Virginia Labor Market Information

The Virginia LMI[34] website provides long term (2016-2026) projected employment information about occupations that require skills in Data Science and Analytics such as:

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[28] https://vlds.virginia.gov/
[29] https://governor.virginia.gov/media/6007/ed-07-leveraging-the-use-of-shared-data-and-analytics.pdf
[30] http://www.dhcd.virginia.gov/index.php/go-virginia.html
[31] http://www.dhcd.virginia.gov/images/GoVA/Region%205%20G&D%20Plan.pdf
[32] http://data.virginia.gov/
[33] https://www.datainnovation.org/2017/07/the-best-states-for-data-innovation/?mc_cid=876e528114&mc_eid=ad73800a40
[34] https://data.virginialmi.com/

Occupation	Total change for 2016-2026 (%)	Annual Average Growth (%)
Operations Research Analysts	36.53	3.16
Mathematical Scientists	35.94	3.12
Statisticians	43.36	3.67
Computer Systems Analysts	12.95	1.23
Software Developers	32.71	2.87

The annual average percent change for computer and mathematical occupations for 2016-2026 is 1.69% as compared to the 0.89% for all occupations during that time period. The total percent change for Computer Mathematical occupations from 2016-2026 is 18.23% as compared to 9% change for all occupations.

Hampton Roads
The Hampton Roads area includes organizations that are keenly interested in this program. Letters of support from several of these employers may be found in Appendix D.

Employer Survey

The results of survey among employers are provided in Appendix E.

Appendix F contains current job announcements demonstrating a need for prospective employees with the knowledge that this data science degree program would provide.

Student Demand

Evidence of student demand is available with the following data:

1. Student Survey:

https://odu.co1.qualtrics.com/jfe/preview/SV_afy4dgxJokEzvjD?Q_CHL=preview

The results of student survey are presented in Appendix G.

2. Alumni survey or second student survey

Projected enrollment:

Year 1		Year 2		Year 3		Year 4 **Target Year (2-year institutions)**			Year 5 **Target Year (4-year institutions)**		
2020 - 2021		2021 - 2022		2022 - 2023		2023 - 2024			2024 - 2025		
HDCT 25	FTES 15	HDCT 28	FTES 18	HDCT 28	FTES 18	HDCT 28	FTES 18	GRAD _____	HDCT 30	FTES 22	GRAD 14

Assumptions
Retention percentage: 80%
Percentage of full-time students: 25% Percentage of part-time students: 75%
Full-time student credit hours per semester: 12
Part-time student credit hours per semester: 6
Full-time students graduate in 1.5 years
Part-time students graduate in 3 years

Duplication

The Commonwealth of Virginia currently has six public institutions—College of William and Mary, George Mason University, Radford University, University of Virginia, Virginia Commonwealth University, and Virginia Tech—that offer master's programs that are similar or related to the proposed Master of Science in Data Science and Analytics degree program.

The College of William & Mary (WM) offers a Master in Science in Business Analytics that requires 30 credit hours.

Similarities to ODU: The WM program is similar to the proposed program in many respects. Both require 30 credit hours (though the online version requires 32 hours) and both include a 3-credit hour capstone project. Several courses in the WM program cover comparable content as that in the proposed program. These include Intermediate Probability and Statistics at WM and Statistical/Probability Models for Data Science at ODU and Data Visualization (WM) and Data Visualization (ODU).

Differences from ODU: The WM program has no electives and focuses entirely on business analytics. In contrast, the proposed program at ODU is interdisciplinary, and it offers both a core component and the choice of two concentration areas. The WM core component consists of 18 credits including a three credit hour capstone project. In addition, ODU's proposed program consists of 12 elective credits from one of the two concentrations. Some core courses in the WM program, such as Optimization, Heuristics Algorithms, have no counterparts in the ODU program. On the other hand ODU's core course, Introduction to Data Science, is not available in the WM program.

George Mason University (GMU) offers a Master of Science in Data Analytics Engineering that requires 30 credits of graduate course work.

Similarities to ODU: This MS degree has a similar structure as the proposed program at ODU. It has two components: a core consisting of 15 credits and a concentration consisting of 15 credits. Content covered in two GMU core courses is similar to content in the proposed core. The GMU course, Analytics: Big Data Information, overlaps with ODU's Data Analytics and Big Data. Also, the GMU course Applied Statistics and Visualization for Analytics covers comparable content in two ODU courses, Statistical Tools for Data Science and Data Visualization. Another similarity is the capstone project that is required in both programs.

Differences from ODU: Unlike the proposed program, the GMU program does not have an Introduction to Data Science. In addition, there are variations in content in core courses between the two programs. For example, the GMU program has a core course option in operation research. Such a course is not part of the proposed program core.

Radford University (RU) offers a Master of Science in Data and Information Management, requiring 30 credit hours.

Similarities to ODU: The emphasis of this program is on the use of technology for data management for both traditional and big data. The program has a fixed set of courses and a capstone project.

Differences from ODU: There are major differences between the two programs. The ODU program is interdisciplinary and the RU program focuses on one discipline. None of the ODU core courses are taught in the RU program. Data Visualization, Algorithms and other data science topics that are in the proposed program are absent from the MS program at Radford University. Instead, RU offers core courses that cover database administration, data warehousing, and data mining.

University of Virginia (UVA) offers a Master of Science in Data Science consisting of 30 credit hours.

Similarities to ODU: The UVA program is a one-year professional degree and is interdisciplinary in nature (similar to the ODU program), with the Departments of Computer Science, Statistics, and Systems and Information Engineering providing the coursework. It also has a similar structure as the proposed program, consisting of nine core courses with varying number of credit hours, two capstone projects and two electives. Core courses in the proposed program cover much of the content as that of the UVA program.

Differences from ODU: The UVA program requires two capstone projects each carrying one credit, in comparison to one 3-credit capstone project in the ODU program. At UVA, a core course, Ethics of Big Data II, has no common content with core courses of the ODU program. At ODU, core courses, Statistical/Probability Models for Data Science and Data Analytics and Big Data, have no equivalents in the UVA curriculum.

Virginia Commonwealth University (VCU) offers a Master of Decision Analytics that requires 30 credit hours.

Similarities to ODU: The VCU School of Business offers the Master of Decision Analytics degree. It has a similar structure as the proposed MS in Data Science: a core consisting of five courses (15 credit hours) and five approved electives (15 credit hours) offered by several departments in the college. The VCU course, Statistical Analysis and Modeling, is similar to the proposed ODU course, Statistical Tools for Data Science.

Differences from ODU: There are major differences between the VCU program and the proposed program. The ODU program is interdisciplinary, with a core in the proposed program combining computer science and statistics; the VCU program consists of core courses in business that are not part of the ODU core. Other than the statistical analysis course in the core, there is almost no overlap in content between the VCU program and the ODU program.

Virginia Tech (VT) offers two graduate programs related to data science, one of which is a stand-alone master's program; the other is a concentration within the MS in Business Administration.

(1) Master of Arts in Data Analysis and Applied Statistics, 33 credit hours.

Similarities to ODU: The structure of the Data Analysis and Applied Statistics program is similar to the proposed program. The VT program has a core consisting of 21 credit hours and 12 credit hours in electives. Comparable content is covered in the VT course, Theoretical Statistics, and the ODU course, Statistical/Probability Models for Data Science. In addition, VT's Statistics in Research I-II courses have content in common with ODU's Statistical Tools for Data Science. Both programs require a capstone project.

Differences from ODU: The VT program consists of 33 credit hours and the proposed program at ODU is 30 credit hours. The proposed program at ODU is interdisciplinary, and VT's program is offered by the statistics department at Virginia Tech; thus, it is predominantly a program in statistics and applications. There are no computer science courses in the VT program, whereas computer science is a key component of the ODU core.

(2) Master of Science in Business Administration with a concentration in Business Analytics

The concentration in business analytics requires the completion of 30 credit hours. It is designed to give students the necessary business knowledge, technical expertise, and professional skills to be effective business analytics practitioners. It teaches students quantitative modeling techniques for descriptive, predictive, and prescriptive analytics.

The MSBA-BA concentration covers content that is similar to the proposed MS in Data Science, and both require a capstone project. However, the concentration is not a stand-alone program, and does not offer the full depth and breadth of the coursework offered in the proposed ODU degree program.

Location
Old Dominion University is in south Hampton Roads and will be the only program in this area.

Enrollments[35]	**Fall 2013**	**Fall 2014**	**Fall 2015**	**Fall 2016**	**Fall 2017**
College of William and Mary				47	84
George Mason University		38	125	236	294
Radford University				3	11
University of Virginia		47	53	49	37
Virginia Commonwealth University				60	88
Virginia Tech				3	2
Graduates[36]	**2012-2013**	**2013-2014**	**2014-2015**	**2015-2016**	**2016-2017**
College of William and Mary					45
George Mason University			1	27	67
Radford University					
University of Virginia			43	49	50
Virginia Commonwealth University					40
Virginia Tech					4

Projected Resource Needs for the Proposed Program

Resource Needs

The Graduate School and Old Dominion University have sufficient resources to initiate and sustain the proposed program. The institution has existing faculty, staff, equipment, space, and library resources that will support the program. The proposed program allocates 1.0 FTE of instructional effort for every 9.0 FTE of enrollment. The proposed program will therefore require a total of 2 FTE of instructional effort in 2020-2021 when it is launched and 2.25 by the target year, 2024-2025.

Full-time faculty
One faculty member whose course load represents 50% or more of their teaching requirements will teach in the proposed MS in Data Science and Analytics. The faculty load will be .75 FTE when the proposed program is launched and through the target year.

Part-time faculty
Five faculty members in the Departments of Computer Science, Mathematics and Statistics, and Information Technology and Decision Sciences have part-time teaching loads (below 50%) in the proposed program. These faculty will contribute 1.0 FTE when the program is launched and 1.5 by the target year.

[35] http://research.schev.edu/enrollment/E16_Report.asp
[36] http://research.schev.edu/Completions/C1Level2_Report.asp

Adjunct faculty
No adjunct faculty are required to launch and sustain the proposed degree program.

Graduate Assistants
No graduate assistants are required to launch and sustain the proposed degree program.

Classified Positions
There is currently a full-time classified position within the Graduate School, an Administrative Assistant, who will assist faculty who teach in the proposed MS in Data Science and Analytics. The program will require .20 FTE of classified support to initiate and this level of effort will remain constant through the target year. Salary for the administrative assistant will be $7,500 in salary and $2,893 in benefits.

Targeted financial aid
No targeted financial aid is required or designated to initiate and sustain the proposed degree program.

Equipment (including computers)
No new equipment, including computers, is necessary to launch and sustain the proposed degree program.

Library
No new library resources are required to launch and sustain the proposed degree program.
The University Libraries will be able to fully support the MS in Data Science and Analytics. Major journals in the field, including *International Journal of Data Science and Analytics*, *ACM Transactions on Knowledge Discovery from Data*, *Statistical Analysis and Data Mining*, *Big Data*, and many others, are available in the University Libraries. Obtaining articles is extremely easy through (1) online subscriptions held by the university, (2) physical subscriptions for some journals, and (3) rapid delivery via Interlibrary Loan.

Telecommunications
No new telecommunications resources are required to launch and sustain the proposed degree program.

Space
No new space is required to launch and sustain the proposed degree program.

Other Resources (specify)
No additional resources are required to launch and sustain the proposed degree program.

Resource Needs: Parts A - D

Part A: Answer the following questions about general budget information.

- Has the institution submitted or will it submit an addendum budget request to cover one-time costs? Yes ☐ No ☒
- Has the institution submitted or will it submit an addendum budget request to cover operating costs? Yes ☐ No ☒
- Will there be any operating budget requests for this program that would exceed normal operating budget guidelines (for example, unusual faculty mix, faculty salaries, or resources)? Yes ☐ No ☒
- Will each type of space for the proposed program be within projected guidelines? Yes ☒ No ☐
- Will a capital outlay request in support of this program be forthcoming? Yes ☐ No ☒

Part B: Fill in the number of FTE and other positions needed for the program

	Program Initiation Year 2020- 2021		Expected by Target Enrollment Year 2024- 2025	
	On-going and reallocated	**Added (New)**	**Added (New)*****	**Total FTE positions**
Full-time faculty FTE*	0.75			0.75
Part-time faculty FTE**	1.00		0.50	1.50
Adjunct faculty				0.00
Graduate assistants (HDCT)				0.00
Classified positions	0.20			0.20
TOTAL	1.95	0.00	0.50	2.45

*Faculty dedicated to the program. **Faculty effort can be in the department or split with another unit.

*** Added **after** initiation year

Part C: Estimated resources to initiate and operate the program				
	Program Initiation Year		Expected by Target Enrollment Year	
	2020- 2021		2024- 2025	
Full-time faculty	0.75	0.00	0.00	0.75
salaries	$84,642			$84,642
fringe benefits	$32,646			$32,646
Part-time faculty (faculty FTE split with unit(s))	1.00	0.00	0.50	1.50
salaries	$112,856		$56,428	$169,284
fringe benefits	$43,529		$21,764	$65,293
Adjunct faculty	0.00	0.00	0.00	0.00
salaries				$0
fringe benefits				$0
Graduate assistants	0.00	0.00	0.00	0.00
salaries				$0
fringe benefits				$0
Classified Positions	0.20	0.00	0.00	0.20
salaries	$7,500			$7,500
fringe benefits	$2,893			$2,893
Personnel cost				
salaries	$204,998	$0	$56,428	$261,426
fringe benefits	$79,068	$0	$21,764	$100,832
Total personnel cost	$284,066	$0	$78,192	$362,258
Equipment				$0
Library				$0
Telecommunication costs				$0
Other costs				$0
TOTAL	**$284,066**	**$0**	**$78,192**	**$362,258**

Part D: Certification Statement(s)

The institution will require additional state funding to initiate and sustain this program.

_____ Yes _____
Signature of Chief Academic Officer

X_____ No _____
Signature of Chief Academic Officer

Please complete Items 1, 2, and 3 below.

1. Estimated $$ and funding source to initiate and operate the program.

Funding Source	Program initiation year 2020 - 2021	Target enrollment year 2024 - 2025
Reallocation within the department *(Note below the impact this will have within the department.)*		
Reallocation within the school or college *(Note below the impact this will have within the school or college.)*		
Reallocation within the institution *(Note below the impact this will have within the institution.)*	$284,066	$362,258
Other funding sources *(Specify and note if these are currently available or anticipated.)*		

2. Statement of Impact/Funding Source(s). A separate detailed explanation of funding is required for each source used and a statement of impact on existing resources.

Reallocation within the Institution
The College of Sciences will be the primary funding source to launch and sustain the proposed degree program. In addition, the Graduate School and the Strome College of Business will also contribute to the operation of the program. College of Sciences funding includes reallocation and sharing of faculty resources used for computer science and mathematics/ statistics graduate programs. Specifically, faculty who teach in those programs will also teach in the proposed program. No adverse impact is anticipated on academic programs in the College of Sciences as a result of opening the proposed program.

The Graduate School will provide operational funding for the program, and the Department of Computer Science and Department of Information Technology and Decision Sciences will provide faculty for course offerings in the concentrations. No adverse impact is anticipated on academic programs in either department or the Graduate School as a result of opening the proposed program.

3. Secondary Certification.

If resources are reallocated from another unit to support this proposal, the institution will **not** subsequently request additional state funding to restore those resources for their original purpose.

X_ Agree _____

Signature of Chief Academic Officer

___ Disagree _____

Signature of Chief Academic Officer

APPENDICES

APPENDIX A
PLANS OF STUDY

Sample Schedule for Full-Time Students

Course	Credits	Category
Fall I		
DASC 600 Introduction to Data Science	3	Core
STAT 603 Statistical/Probability Models for Data Science	3	Core
CS 625 Data Visualization	3	Core
Concentration I	3	Concentration
TOTAL 12 credits		
Spring I		
STAT 604 Statistical Tools for Data Science	3	Core
CS 624 Data Analytics and Big Data	3	Core
Concentration II	3	Concentration
Concentration III	3	Concentration
TOTAL 12 credits		
Fall II		
DASC 690 Capstone Project	3	Core
Concentration IV	3	Concentration
TOTAL 6 credits		

Total Required for Degree—30 credits

Sample Schedule for Part-Time Students

Course	Credits	Category
Fall I		
DASC 600 Introduction to Data Science	3	Core
STAT 603 Statistical/Probability Models for Data Science	3	Core
TOTAL 6 credits		
Spring I		
CS 625 Data Visualization	3	Core
Concentration I	3	Concentration
TOTAL 6 credits		
Fall II		
STAT 604 Statistical Tools for Data Science	3	Core
CS 624 Data Analytics and Big Data	3	Core
TOTAL 6 credits		
Spring II		
Concentration II	3	Concentration
Concentration III	3	Concentration
TOTAL 6 credits		
Fall III		
DASC 690 Capstone Project	3	Core
Concentration IV	3	Concentration
TOTAL 6 credits		

Total Required for Degree—30 credits

APPENDIX B
COURSE DESCRIPTIONS

New courses developed for this degree program are indicated with an asterisk (*).

Core Courses

CS 624 Data Analytics and Big Data* (3 credits)

This course introduces the essential data science tools to work with different types of data including streaming data and big data, including static and streaming data using Python software packages; modeling and predictive analysis using basic machine learning techniques; work with real sample data sets from different disciplines, e.g., health sciences, and finance industry; and how to work with big data using emerging technology such as Apache Spark.

CS 625 Data Visualization* (3 credits)

This course covers the theory and application of data visualization. This includes issues in data cleaning to prepare data for visualization, theory behind mapping data to appropriate visual representations, introduction to visual analytics, and tools used for data analysis and visualization. Modern visualization software and tools will be used to analyze and visualize real-world datasets to reinforce the concepts covered in the course.

DASC 600 Introduction to Data Science* (3 credits)

This course will explore data science as a burgeoning field. Students will learn fundamental principles and techniques that data scientists employ to mine data. They will investigate real life examples where data is used to guide assessments and draw conclusions. This course will introduce software and computing resources available to a data scientist to process, visualize, and model different types of data including big data.

STAT 603 Statistical/Probability Models for Data Science* (3 credits)

This course will serve as an introduction for modeling data using probability and statistical methods. Topics include basic concepts of probability, Bayes theorem, frequently-occurring discrete (e.g., Binomial, Hypergeometric and Poisson) and continuous (e.g., Normal, Gamma, Beta and Chi-square) probability distributions, as well as how to simulate data from these distributions using R or Python.

STAT 604: Statistical Tools for Data Science* (3 credits)

This course will cover statistical tools for data exploration. Topics taught during the course include descriptive statistics, correlation, confidence intervals, linear and logistic regressions, t-test for one and two samples, and analysis of variance (ANOVA). For analyzing categorical data we will study contingency tables, odds ratios for measuring association, goodness of fit tests and chi-square tests for testing independence.

Capstone

DASC 690 Capstone Project* (3 credits)

The capstone course brings together students in their final semester of study to synthesize knowledge from their previous coursework and apply it to solve a real-world data science problem.

Restricted Electives—Computational Data Analytics Concentration

CS 521 Machine Learning I (3 credits)
This course provides a broad introduction to machine learning and its applications in data science. Topics include supervised learning (discriminative learning, support vector machine, hidden Markov chain, etc.), unsupervised learning (clustering, dimension reduction, kernel methods, etc.), and reinforced learning. We will also discuss applications on data mining, text processing, pattern recognition, and bioinformatics.

CS 601 Algorithms and Data Structures for Data Science (3 credits)
Working with large data poses several challenges in terms of designing algorithms, data structures, and performing analysis. The course aims to develop the mathematical foundation for working with large data. This includes topics in algorithms for very large graphs, heuristics, randomized algorithms, counting and combinatorics, data structures for big data, design and analysis of algorithms.

CS 626: Visual Analytics: Exploring and Analyzing Data Visually (3 credits)
This course covers the theory and application of visual analytics, which is the science of combining interactive visual interfaces and information visualization techniques with automatic algorithms to support analytical reasoning through human-computer interaction. Modern visualization software and tools will be used to analyze and visualize real-world datasets.

CS 632 Web Science (3 credits)
This course will focus mainly on computational aspects of the Web. We will examine a number of topics including: web architecture, web characterization and analysis, web archiving, social media, social networks, collective intelligence, search engines, machine learning, web mining, information diffusion on the web, and the Semantic Web. This is a programming intensive course, and students will perform projects with material extracted from the live web, including Twitter, blogs, newsfeeds, and movie ratings.

CS 721 Machine Learning II (3 credits)
This course provides students with the understanding and practice of advanced machine learning techniques, including deep neural networks for computer vision/speech recognition, reinforcement learning, unsupervised learning, generative adversarial networks.

CS 727 Large Scale Video Analytics (3 credits)
In this course, students will learn how to gather analytics from pervasive cameras by using real datasets, and state-of-the-art software tools. Video analytics can have very high resource demands. Keeping this in mind, they will also be exposed to various stages of gathering, storing, and querying video data.

CS 733 Natural Language Processing (3 credits)
This course provides an introduction to the field of Natural Language Processing (NLP), which is the study of computing systems that can process, understand, or communicate in human language. There will be a focus on statistical learning algorithms that train on (annotated) text corpora to automatically acquire the knowledge needed to perform the task. The course will include analysis of real-world datasets.

CS 735 Information Retrieval (3 credits)
This class will explore the theory and engineering of information retrieval in the context of developing web-based search engines. We will explore issues related to crawling, ranking, query processing, retrieval models, evaluation, clustering, machine learning, and other aspects related to building web search engines. The class will feature a mix of hands-on development and coding (including local installation of an open source search engine as well as interaction with existing commercial search engines), as well as theoretical exploration of the existing literature on these topics.

Restricted Electives—Business Intelligence and Analytics Concentration

BNAL 503 Data Exploration and Visualization (3 credits)
This course introduces students to processes, technologies, and methodologies that are commonly used in understanding data to be able to effectively analyze the data. Emphasis is placed on data visualization.

BNAL 515 Advanced Business Analytics with Big Data Applications (3 credits)
This course addresses advanced business analytics techniques and the application of such techniques to large data sets. Some alternative business analytics strategies are introduced. Descriptive, predictive, and prescriptive models are included. Topics covered in this course include data visualization and exploration, cluster analysis, and developing and calibrating predictive models for big data. Applications of multivariate, logistic, and probit regression to business analytics are discussed. Software packages such as SAS/JMP/SPSS may be used.

BNAL 721 Simulation Modeling for Business Systems (3 credits)
This course covers both the theory and application of simulation modeling and analysis to business systems. Both discrete-event and continuous simulation modeling approaches are covered, using a major commercial simulation package. Emphasis will be on the use of simulation as a tool to support business decision making.

IT 650 Database Management Systems (3 credits)
Introduction to database management systems. The topics addressed include system architecture, data models, database analysis, design and implementation, query processing, business transaction processing, and database security. Prerequisites: IT 620 or equivalent; or permission of the department.

IT 651 Business Intelligence (3 credits)
Introduction to business intelligence and its three components: data warehouse, data mining, and OLAP. Examines traditional techniques as well as emerging technologies. Prerequisite: IT 650 or permission of the instructor or department.

IT 652 Information and Communications Technology for Big Data (3 credits)
Introduction to emerging ICT techniques for big data analytics and big data science. Topics cover WSN, cloud computing and IoT. Prerequisite: IT 650 or permission of the instructor or department.

APPENDIX C
ABBREVIATED CVs

N. Rao Chaganty PhD, 1982, Statistics, Florida State University. Professor of Statistics. Specialization areas: biostatistics, copula models, linear and nonlinear statistical methods, categorical, longitudinal and multivariate data analysis.

Dean Chatfield, Ph.D. 2001, Management Science and Information Systems, Pennsylvania State University. Associate Professor of Information Technology and Decision Sciences. Specialization areas: management science, modeling and simulation, big data analytics, supply chain management.

Sampath Jayarathna, PhD, 2016, Computer Science, Texas A&M University. Assistant Professor of Computer Science. Specialization areas: data science, human trafficking, neuro information retrieval, human-information interaction, machine learning and data mining, eye tracking, biometrics.

Yet Nguyen, PhD, 2018, Statistics and Data Science, Iowa State University, Assistant Professor of Statistics. Specialization areas: Statistical methods for high-dimensional data, large-scale inference, biostatistics, statistical learning, data science.

Michele Weigle, PhD, 2003, Computer Science, University of North Carolina at Chapel Hill. Associate Professor of Computer Science. Specialization areas: information visualization, web science, visual analytics, wireless networks.

Mohammad Zubair, PhD, 1987, Electrical Engineering, Indian Institute of Technology, Delhi, India. Professor of Computer Science. Specialization areas: application of high performance computing to scientific applications; big data analytics.

APPENDIX D
EMPLOYMENT DEMAND
LETTERS OF SUPPORT

APPENDIX E
EMPLOYMENT DEMAND
EMPLOYER SURVEY

APPENDIX F
EMPLOYMENT DEMAND
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APPENDIX G
STUDENT DEMAND
SURVEY