THE UNIVERSITY OF MEMPHIS

THE ECONOMIC IMPACTS & BENEFITS OF

THE UNIVERSITY OF MEMPHIS

AND ITS INVESTMENTS IN RESEARCH ACTIVITIES

2020

APPLIED ANALYSIS

Prepared By: APPLIED ANALYSIS | appliedanalysis.com

PREFACE

Applied Analysis is pleased to present this economic impact analysis prepared on behalf of the University of Memphis (the "University"). The primary objective of this analysis is to quantify the economic contributions of the University to the Memphis community and the State of Tennessee as a whole. More specifically, the impact analysis considers the University's recurring operations, capital investment program and the benefits of the University's research efforts relative to its goal of achieving the nation's highest research university classification (R1: Doctoral Universities - Very High Research Activity) as defined by the Carnegie Classification of Institutions of Higher Education® ("Carnegie"). The salient findings of our research and analysis are contained within this report.

The economic impacts of the University of Memphis are substantial and far-reaching. While economic impacts are typically characterized by the number of jobs created, wages paid and economic activity generated by an organization, they alone do not tell the full story. This analysis is designed to quantify the data but also demonstrate the direction the University is heading and the investments it is making to increase its contributions to the future.

With approximately 6,600 employees, the University is one of Tennessee's largest employment centers, directly and indirectly impacting the lives of tens of thousands of residents, including 22,000 enrolled students, every day. Perhaps equally important to the traditional impacts is the ripple effect throughout the community, with suppliers to the University benefiting from $190 million in purchases and employees spending $300 million in wages and salaries earned at countless businesses in their respective neighborhoods every year.

Apart from the University's status as a large employer is its importance for the community as a center for research and learning. With more than 22,000 students attending the University annually, substantial economic and societal contributions are produced as a result of their education and experiences. Roughly 80 percent of the University's graduates stay in Tennessee to live and work after graduation, clearly suggesting that the lion's share of the human capital benefits produced by the University inure to the benefit of the state, adding both depth and breadth to Tennessee's workforce. The social impacts of a more highly educated workforce are not ethereal; they too are explored further in this analysis.

The impact of the University's ongoing research initiatives and planned investments to achieve R1 status are also worthy of consideration. In addition to the quantifiable economic contributions of the University's research and innovation are community outcomes and benefits. A number of research programs and partnerships are highlighted throughout this report that demonstrate the wide-ranging impact of the University's research programs, improving the lives of people in this state and throughout the United States. Achieving the University's goal – R1 status – not only requires significant research-related funding but also the ability to attract and retain high-quality staff, critical thinkers and innovators.

Notably, the University is also the largest R2-designated university in the state, as the University of Tennessee, Knoxville is the only other public university to reach the coveted R1 designation. Given continued growth in higher education and an increased emphasis on research prowess and innovation within the state's educational ecosystem, the University of Memphis is well positioned to be the second public Tennessee university to reach this important designation, improving its own reputation and perception around the globe and elevating Tennessee's status as a progressive hub of innovation, education and economic development.

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EXECUTIVE SUMMARY

Over the course of its 108-year history, the University of Memphis has evolved along with the needs of the community and the interests of its students. Today, the University spans over 1,600 acres, boasts an enrollment of roughly 22,000 students and directly supports approximately 6,600 employees. In addition to its position as a center of excellence for research and learning, the University's contributions to the Memphis area economy have been invaluable.

The investments the University makes in its students, faculty and facilities are reflected in graduates' interest to stay in the local area. Nearly two-thirds of graduates take up residence in Memphis for more than 10 years after entering the workforce. Additionally, over 80 percent of graduates remain within the State of Tennessee during the same timeframe. High retention rates translate into a strong labor pool of highly educated prospects for local businesses. This also means the state retains the value of its investments in human capital.

A single University of Memphis graduating class increases incomes within the State of Tennessee by nearly $110 million annually. During the past decade, graduating classes earned a combined $2.1 billion statewide. As the University continues to grow, these graduate-based earnings impacts will naturally follow suit. Importantly, the University recorded its largest graduating class in school history in 2020.

Beyond the University's ability to diversify and improve the quality of the state and local workforce, the broader economic contributions are notable. From an operational perspective, the University contributes nearly $1.1 billion in economic activity annually, supports nearly $500 million in wage and salary payments for local workers and is directly or indirectly responsible for approximately 9,900 Memphis-area jobs. During the past five years, the University accounted for $4.8 billion in economic output and $2 billion in wages. It is important to note that every $1 in economic activity translates into $1.87 in total impact in the local economy.

In addition to the stable and recurring economic activity of the University's operations, the capital investments being made to modernize and expand its infrastructure are also critical

OPERATIONAL IMPACTS

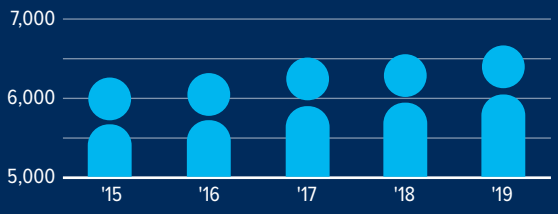
	2020e	Five-Year Total/Avg.
ECONOMIC OUTPUT	$1.07 B	$4.76 B
LABOR INCOME	$0.48 B	$2.03 B
EMPLOYMENT	9,900	9,300

ABOUT THE UNIVERSITY

1,607
ACREAGE

239
BUILDINGS

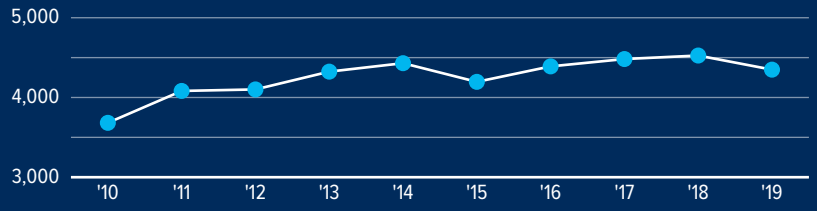
TOTAL EMPLOYEES



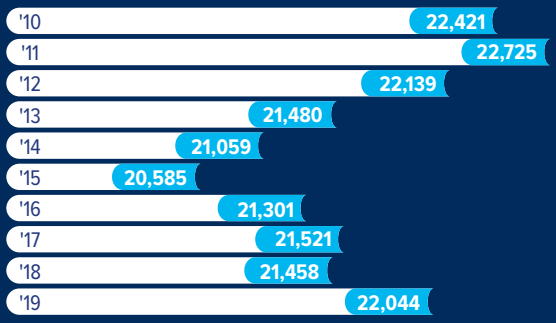
TOP 10 UNDERGRADUATE MAJORS

1,495	975	961	819	769	667	597	560	498	406
HEALTH STUDIES	HEALTH PROFESSIONS, UNDECIDED	PROFESSIONAL STUDIES	PSYCHOLOGY	NURSING	BIOLOGY	ACCOUNTING	CRIMINOLOGY & CRIMINAL JUSTICE	MANAGEMENT	COMPUTER SCIENCE

TOTAL DEGREES AWARDED



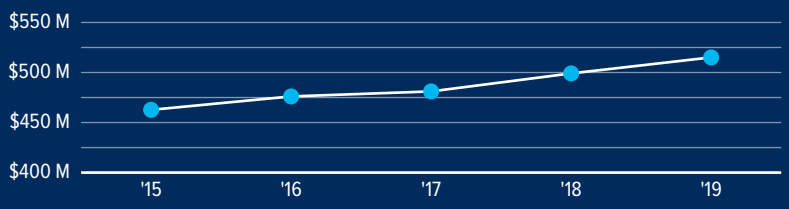
FALL ENROLLMENT

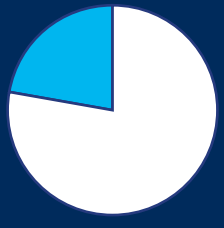


DEGREE TYPES

BACHELORS	250
MASTERS	54
DOCTORATE	26
EDUCATION SPECIALIST	2
JURIS DOCTORATE (LAW)	1
GRADUATE CERTIFICATE	44

TOTAL BUDGET





2019 BUDGET

RESTRICTED	22.2%
UNRESTRICTED	77.8%

economic impact considerations. These investments provide a $500 million boost to the Memphis area economy while supporting more than $250 million in wages and 4,200 jobs (i.e., person-years of employment). The ripple effect associated with construction related activities at the University equates to 2.1 times – simply stated, every dollar of University-related capital investment translates into $2.10 in total economic activity.

While the economic impacts sourced to the University of Memphis are significant, important to the community and a stabilizing factor in the workforce, it is the academic and research-related activities taking place at the University that provide the greatest value. The University is making capital, operational and strategic investments in its Division of Research and Innovation and other community assets centered around research.

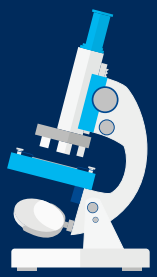
The University is focused on developing a diverse community of researchers engaged in pioneering work to develop creative ways to enhance the human experience. Its research efforts are designed to push the boundaries of every discipline – from exploring how markets and economies function, to improving the health and wellness of society, and diving into the inner workings of the material world. In addition to exclusively in-house activities, the University is also partnering with outside organizations to more closely align innovation and action and increase the relevance of the University's research efforts relative to the state's economic development and diversification goals. These include partnerships like the FedEx Institute of Technology, the Office of Technology Transfer and the UMRF Research Park – just to name a few. The University is also making major capital investments in research infrastructure, including a new $41 million STEM facility designed to expand its Herff College of Engineering and College of Arts & Sciences capacity.

These types of innovations, along with valuable and appreciated financial commitments, solidify the trajectory of the University's

CONSTRUCTION IMPACTS

$519.0 M	$257.6 M	4,250
ECONOMIC OUTPUT	LABOR INCOME	EMPLOYMENT

Note: Impacts reflect the five-year total ending in 2022. Construction-related employment impacts are stated on a person-years of employment basis (i.e., one person employed full-time for one year).



RESEARCH IMPACTS

	2020e	Five-Year Total/Avg.
ECONOMIC OUTPUT	$168.0 M	$551.45 M
LABOR INCOME	$75.2 M	$218.5 M
EMPLOYMENT	1,190	880

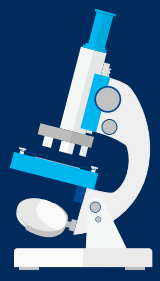
research functions. Total economic output sourced to the University's scientific research and development services during the past five years totals approximately $551 million, supporting a total of $218 million in salaries and wages for local employees – a total of 1,200 positions in 2020. Research funding has increased by nearly 70 percent during the past 12 months and research-related payroll tripled in the past five years. It is worth noting, for every $1 spent on research funding, a total of $2.18 is supported in the Memphis economy.

Past investments in research and innovation have proven successful and provide a strong foundation from which future growth will be measured. Demonstrated by its recent increases in research-oriented funding, the University is committed to expanding its research efforts and, in turn, its standing among other universities. The University of Memphis believes it is well positioned to elevate its Carnegie ranking from an R2 classification to the top-tier R1 standard. The benefits of this advancement for the University and the community it serves are significant.

Currently, the University of Memphis receives nearly $124,000 per faculty member in grant or contract funding from local, state and federal sources each year. This level of grant funding, while not all directly supporting research, is already 34 percent more than the average R2 institution in the region. To achieve the regional R1 average funding of $223,000 per faculty member would require an additional $90 million in total grant funding from all sources annually, without any change in the current faculty count. Evaluating potential growth in faculty rather than grant awards, the University would need to double its faculty count of just over 900 to reach the regional R1 average of 1,800 faculty, but maintaining per-faculty grant funding levels while increasing faculty on this scale would require an additional $112 million annually in grant awards for the University from private, local, state, and federal sources.

Increased grant funding on the order of $100 million, which would generally place the University on par with the regional R1 average, would have significant and far-reaching economic impacts. The University's ability to secure recurring and stable sources of incremental funding are important to achieving its objectives, and support from a wide range of sources will be required, including the private and public sectors. The total economic impact of the incremental spending would reach $218 million, support approximately $98 million in wages and salaries and employ another 1,550 workers in the local community. Beyond the economic contributions of achieving R1 status, increased research capacity, higher level learning and increased innovation taking place at the University of Memphis is expected to pay dividends into the future.

It is also worth noting, the University of Tennessee (main campus) is the state's only other public R1 institution. For a state of its size, Tennessee underperforms its peers in this respect. With 14 total doctoral-level universities, the state's share of R1 universities among all doctoral-level universities (14.3 percent) is the second-lowest among states with at least one R1 university. By contrast, the University of Memphis is uniquely positioned among the state's R2 institutions. The University's overall enrollment, faculty base and sizable grant and research funding clearly put it in near-R1 status. With a further emphasis on STEM programs, graduate enrollment and improving the University's grant award capture, the University of Memphis is well positioned to be the next R1 institution in the state of Tennessee.



INCREMENTAL ECONOMIC IMPACTS OF ACHIEVING R1 STATUS

$218.0 M	$98.0 M	1,550
ECONOMIC OUTPUT	LABOR INCOME	EMPLOYEES

RESEARCH HIGHLIGHT — NEW STEM BUILDING

The proposed STEM Research and Classroom Building (SRCB) would support 22 STEM areas of study and multiple interdisciplinary research centers from the Herff College of Engineering (HCOE) and the College of Arts & Sciences (CAS). The facility would add 65,000 square feet of new classroom, lab and office space while renovating an additional 17,000 square feet.

The push for such a new facility is driven by enrollment growth in the STEM fields at the University of Memphis in recent years. Between 2013 and 2018, enrollment in the HCOE increased by 37 percent, while the number of bachelor's degrees awarded by the college increased 50 percent. Similarly, computer science enrollment within the CAS increased 47 percent. With this growth in enrollment, the University of Memphis has exceeded guidelines for academic space per student and the capacity of their current facilities, based on recommendations from THEC.

The University of Memphis expects enrollment in areas supported by the proposed new STEM center to increase by 12 percent annually over the next four years, pushing STEM enrollment from 1,700 to over 2,500. By graduate count, the proposed facility would support growth in annual graduates of 64 percent, from roughly 320 annually to nearly 530. With STEM-related occupations in high-demand not only in the Memphis area but throughout the country, greater STEM capacity at the University of Memphis would allow it to better contribute to the region's workforce needs as well as materially grow its overall economic impact. Increased STEM research capacity would also increase the University's ability to compete for STEM-related grants, which account for the vast majority of available federal research funds.

THE ECONOMIC VALUE OF EDUCATION

The value of a college degree is significant, particularly when it comes to the earning potential of the degree holder – both for a single year and over a lifetime. The University of Memphis awards nearly 4,500 degrees each year, including bachelor's, master's and doctoral degrees. Of these graduating students, over 70 percent tend to stay in the Memphis area and roughly 80 percent remain in Tennessee to live and work following graduation. Simple translation – the University helps to add more than 3,500 degree-holding individuals to the state's workforce every year.

On average, workers with a bachelor's degree in the Memphis area earn roughly $21,000 more per year than workers with just a high school diploma or GED. For workers with a graduate or professional degree, the difference is $36,500. Assuming these average earnings for University of Memphis graduates, one year of graduates can be expected to add an average of $110 million to total labor income in Tennessee.[1]

University of Memphis graduates, however, tend to earn slightly more than the average worker with an equivalent degree. Five years after graduating, University of Memphis grads with bachelor's degrees earn nearly nine percent more than the average college graduate in the Memphis area. For graduates with more advanced degrees, the difference is even more dramatic, as University of Memphis graduates out-earn their peers by over 22 percent. This is in part due to the specific graduate degree-mix offered by the University, where the law school can award upwards of 10 percent of the University's total graduate degrees. These graduates can also be expected to earn higher salaries post-graduation, increasing the average earning of University graduates.

Among undergraduates, the most common areas of studies are in the science and health fields. Five of the six most common choices of major are health studies, health professions, psychology, nursing and biology. This heavy concentration in

[1] *Based on five-year average of graduates and earnings.*

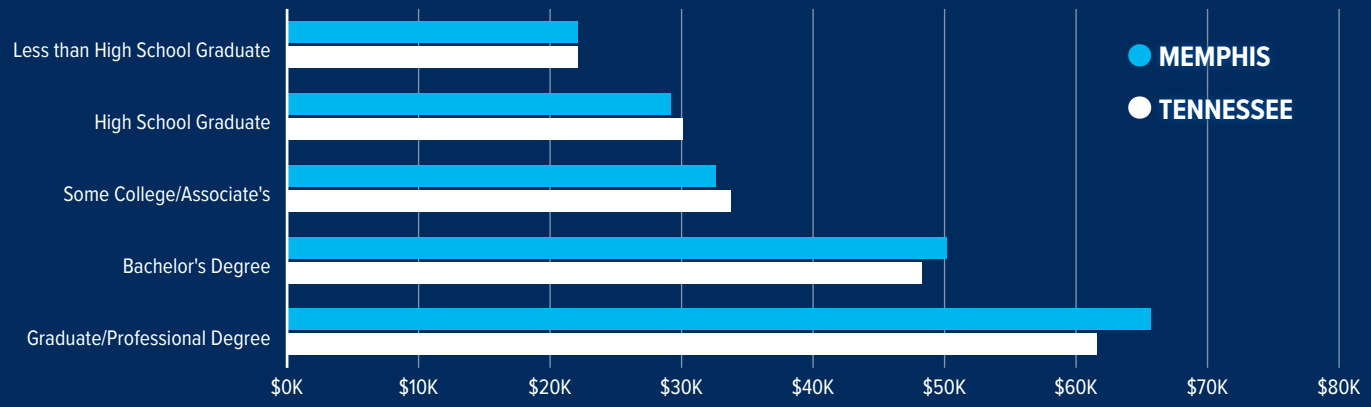
RESEARCH HIGHLIGHT — INSTITUTE FOR INTELLIGENT SYSTEMS

The Institute for Intelligent Systems (IIS) at the University of Memphis is dedicated to advancing the state of knowledge and capabilities of intelligent systems, including psychological, biological and artificial systems. By conducting cutting-edge research and publishing findings in peer-reviewed venues, the Institute contributes to the discipline and, ultimately, to the public. In doing so, IIS is also training the next generation of scientists. IIS takes an interdisciplinary approach to research and development that brings together researchers from many different areas of study in the cognitive sciences, including biology, communication sciences and disorders, computer science, education, engineering, linguistics, philosophy, physics and psychology.

Intelligent systems developed by IIS differ from conventional technologies in that they are fast, dynamic, flexible and adaptive. Researchers in IIS have developed technologies in the cutting-edge areas of cognitive science, artificial intelligence, complex dynamic systems, neural networks, evolutionary modeling, massively parallel systems and biological systems.

THE ECONOMIC VALUE OF EDUCATION

MEDIAN EARNINGS BY EDUCATION



Five-Year Average $110 M

ANNUAL ADDITIONAL LABOR INCOME FOR THE STATE

BECAUSE STUDENTS EARNING DEGREES AT THE UNIVERSITY OF MEMPHIS REMAINED IN THE STATE OF TENNESSEE

GRADUATE EXPECTED EARNINGS

3,770
Graduates Remaining in Tennessee

$91.6 M
High School Diploma only

$204.7 M
University Graduates

TOTAL TENNESSEE LABOR INCOME GAINS

$113.1 M

Note: The latest earnings data by educational attainment is for 2018.

the sciences and health studies puts the University of Memphis in an excellent position to help fill Tennessee's workforce needs in the coming years, where the health sciences are expected to produce the second-highest number of annual job openings in the state at more than 11,500. This trails only business management with an anticipated 14,500 annual openings among the sectors where a bachelor's degree is required, according to the Tennessee Higher Education Commission (THEC) and Tennessee Department of Labor & Workforce Development (TDLWD).[2] Chief among the in-demand health occupations is nursing, where 4,300 annual openings are expected, but only 2,000 new registered nurses are trained annually in Tennessee. This leads to nurses being among the most employable graduates in the state, as more than 72 percent gain employment within the State of Tennessee after graduation, which is the highest rate among occupations along with middle and secondary education teachers. With demand for healthcare workers rising not only in Tennessee but across the country, the University of Memphis' Loewenberg College of Nursing, School of Health Studies and School of Public Health could become an integral source of talent for developing the state's healthcare workforce.

A greater investment in the STEM fields, in particular health, would not only yield results in terms of research for the University, but also further increase the economic impact of University graduates. With fields of study better aligned with the expected economic and workforce needs of the community, both the University and the regional economy operate more efficiently.

[2] *2020 Academic Supply and Occupational Report.*

RESEARCH HIGHLIGHT — FEDEX INSTITUTE OF TECHNOLOGY

The FedEx Institute of Technology is an advanced technology and research organization that functions as a catalyst for interdisciplinary research and innovation in emerging technologies by supporting cross-campus research innovation clusters. These clusters focus on areas such as intelligent systems, drones, cyber security testing, biologistics, autonomous vehicles, robotics, smart biomaterials, additive manufacturing, precision medicine, data science and SMART cities.

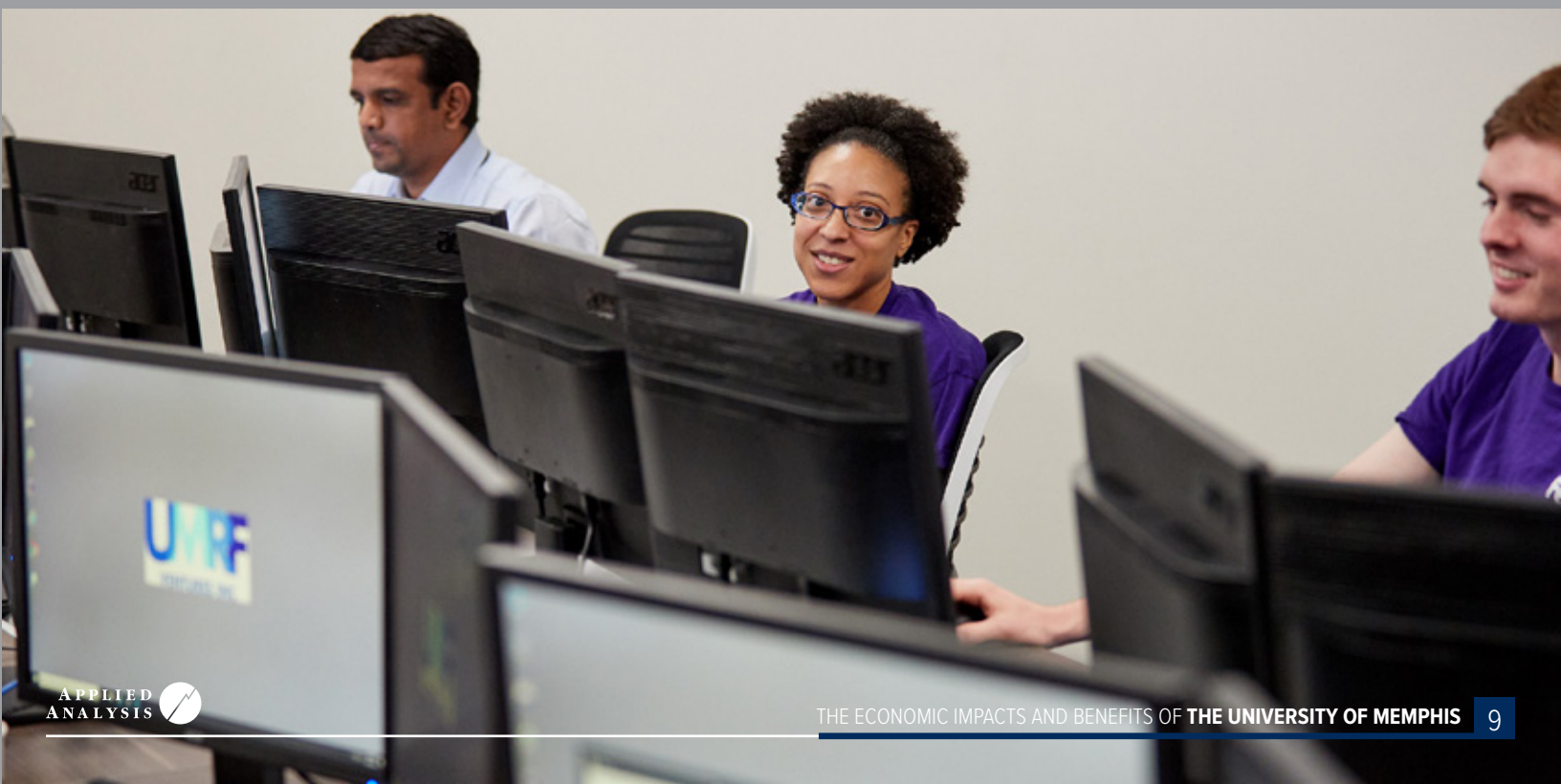
The Institute is also home to the University's intellectual property and patent repository, which is the focal point of technology transfer and licensing operations. The Institute supports regional community efforts to increase both the size and technical sophistication of the regional technology workforce. Additionally, the University's Graduate School that serves approximately 1,000 doctoral and 3,000 master students in 118 graduate and research programs across campus is also located at the FedEx Institute of Technology.

The Institute enjoys a unique innovation partnership with FedEx, which sponsors the Institute for advanced research purposes. The Institute is the central hub for efforts to maintain a cutting-edge innovative environment in the Mid-South. It also offers training and collaboration opportunities in emerging technologies and related breakthrough concepts.

The Office of Technology Transfer within the FedEx Institute promotes investment in new technologies and innovations related to commercial products. The office licenses intellectual property to companies in the Memphis area, allowing those companies to benefit from the cutting-edge research performed at the Institute.

New Research Technologies

The Office of Technology Transfer, through the FedEx Institute of Technology, signed agreements to license five new technologies in 2019. These technologies include Engage, Green Living and Caregivers Support, developed by Dr. Susan Elswick, assistant professor in the School of Social Work; Ultrasonic Dispersion of Cohesive Powders, invented and developed by Dr. Ranga Gopalakrishnan, assistant professor in Mechanical Engineering; and Adaptive Multi-factor Authentication System (A-MFA), invented and developed by a team led by Dr. Dipankar Dasgupta, professor in Computer Science and director of the Center for Information Assurance (CfIA).



1. **ENGAGE TECHNOLOGY** is a cloud-based data collection system that offers real-time data collection capabilities and dynamic reporting opportunities for the user. The Engage system is a data collection tool that allows pedagogical practitioners to gather live data on any student in the classroom for up to three behaviors per student. Numbers can increase based on student needs.

2. **GREEN LIVING TECHNOLOGY** is an app that allows individuals to plot their green living activities and community concerns on a map so they will be geo-located. This allows for better planning and support of green living along with demonstrating to UofM students, faculty and the surrounding areas how to have sustainable green living practices. The technology is game-based, letting students and faculty receive points for practicing green living and reporting green living issues and activities.

3. **CAREGIVERS SUPPORT TECHNOLOGY** is a parenting app that answers the many questions parents have about common behaviors such as sleeping, eating and emotional regulation, all provided from a developmental and function-based lens. This app is designed to assist caregivers in improving child behavior, developing healthy social/emotional literacy and enhancing the parent-child bond. Engage, Green Living and Caregivers Support were licensed to Engage Data System LLC based in Cordova, Tenn. Engage Data Systems is a cutting-edge data collection and reporting company.

4. **ULTRASONIC DISPERSION OF COHESIVE POWDERS** was licensed to the University of Minnesota. The technology is related to aerosol science and technology, powder technology and spray-based additive manufacturing. It was developed to aid in generating aerosol particles (less than 10 microns in size) of sticky powders such as titanium dioxide and calcium phosphate at high concentration for long periods of time for spray-coating processes. The ultrasonic disperser mechanism was designed at low cost and is able to achieve superior concentration compared to commercially available products and designs.

5. **ADAPTIVE MULTI-FACTOR AUTHENTICATION SYSTEM**, developed by Dr. Dasgupta and his team at the C*f*IA, was licensed in 2019 by i2Chain, a Silicon Valley cybersecurity startup. The technology uses multiple markers to authenticate users of a program and make programs more secure, including passwords, biometrics and hardware/software sensors, among others.

This partnership with FedEx has allowed the Institute to facilitate many of the research programs and advances made at the University, advances which have also aided many companies throughout the region. Moving forward, this partnership with FedEx will be a catalyst for future research growth and is a major asset to the University of Memphis in this regard.

RESEARCH 1 CLASSIFICATION

Carnegie Classification of Institutions of Higher Education®, along with its predecessors, has been evaluating institutional diversity during the past four and a half decades. In 1970, the Carnegie Commission on Higher Education developed a classification of colleges and universities to support its program on research and policy analysis. The resulting rankings of the United States' colleges and universities include the classification of "Doctoral Universities: Very High Research Activity," also known as Research 1 or R1, which is the highest designation for institutions of higher learning.

The next classification tier is the "Doctoral Universities: High Research Activity," known as Research 2 or R2 universities. This is where the University of Memphis currently ranks in the Carnegie classifications. These universities averaged $46.6 million in research expenditures in 2018 (latest rankings), with median research spending of $28.7 million. The University of Memphis is comfortably in the upper portion of this group, ranking 39th out of 135 R2 universities with $49.7 million in research expenditures for the year. It is also worth noting the budgeted research expenditures for the University in 2020 reach $77 million.

The most basic of the doctoral classifications is the "Doctoral/Professional University" designation, which simply means that the institution includes doctoral-level programs, but performs minimal to moderate research activity outside of the educational obligations of the institution.

It is worth pointing out that the Research 1 tier includes 131 universities as of the latest rankings. These institutions see research activity of nearly 10 times that of Research 2 institutions on average. Research 1 institutions averaged $449.9 million in research expenditures during 2018, with the median school spending just over $316 million.

Research dollars are not the sole evaluation criteria when it comes to these classifications, however, as the index used to rank universities includes a broad array of metrics. For example, the City University of New York is a Research 1 institution but only had $11.3 million in research spending during 2018, while Rockefeller University reported over $319 million but remains a Research 2 institution.

Research quality as well as the number and type of both faculty and degrees awarded at the institution also play a significant role in the Carnegie classifications. Among all Research 2 institutions nationwide, roughly 35 percent of doctorate degrees awarded are in the STEM fields, while the share at Research 1 institutions rises to nearly 56 percent. At the time of the 2018 Carnegie classification rankings, the University of Memphis only awarded roughly 22 percent of its doctoral degrees in the STEM fields. The demand clearly exists, given the University of Memphis' undergraduate field of study trends, but the capacity for graduate STEM research lags. A greater focus on STEM fields at all levels will be key for the University to move into the ranks of Research 1 institutions.

Among all Research 1 and 2 institutions, science, health and engineering research accounts for 94 percent of all research expenditures. The University of Memphis varied from this average, spending a more modest 83 percent of its research resources in those areas during 2018. These research sectors account for the vast majority of research grant awards, particularly at the federal level, and increasing the University's capacity for STEM research will be an important step in competing for many of these grants and evolving to Research 1 status.

UNIVERSITY COMPARISON

R1 VS. UNIVERSITY OF MEMPHIS VS. R2

ENROLLMENT	GRADUATE ENROLLMENT	FACULTY	POST-DOCTORAL RESEARCHERS
30,283	7,783	1,525	437
24,809	4,125	727	28
18,047	3,144	571	28

RESEARCH $	RESEARCH $ PER STUDENT	RESEARCH $ PER GRAD STUDENT	RESEARCH $ PER FACULTY + POST-DOCTORAL
$462.7 M	$59,460	$15,281	$235,911
$49.7 M	$12,047	$2,003	$65,821
$25.7 M	$1,983	$11,381	$59,748

● AVERAGE REGIONAL R1[3] ● UNIVERSITY OF MEMPHIS ● AVERAGE REGIONAL R2[4]

	Memphis Growth to Average R1	Average R2 Growth to Average R1
Enrollment	0.22x	0.68x
Graduate Enrollment	0.89x	1.48x
Faculty	1.10x	1.67x
Post-Doc Researchers	14.61x	14.61x
Research $	8.31x	11.93x
Research $ per Student	6.63x	6.71x
Research $ per Grad Student	3.94x	4.22x
Research $ per Faculty + Post-Doctoral	2.58x	2.95x

[3] *Regional R1 universities include all R1 universities within Tennessee and its bordering states.*

[4] *See regional R2 institutions on page 14.*

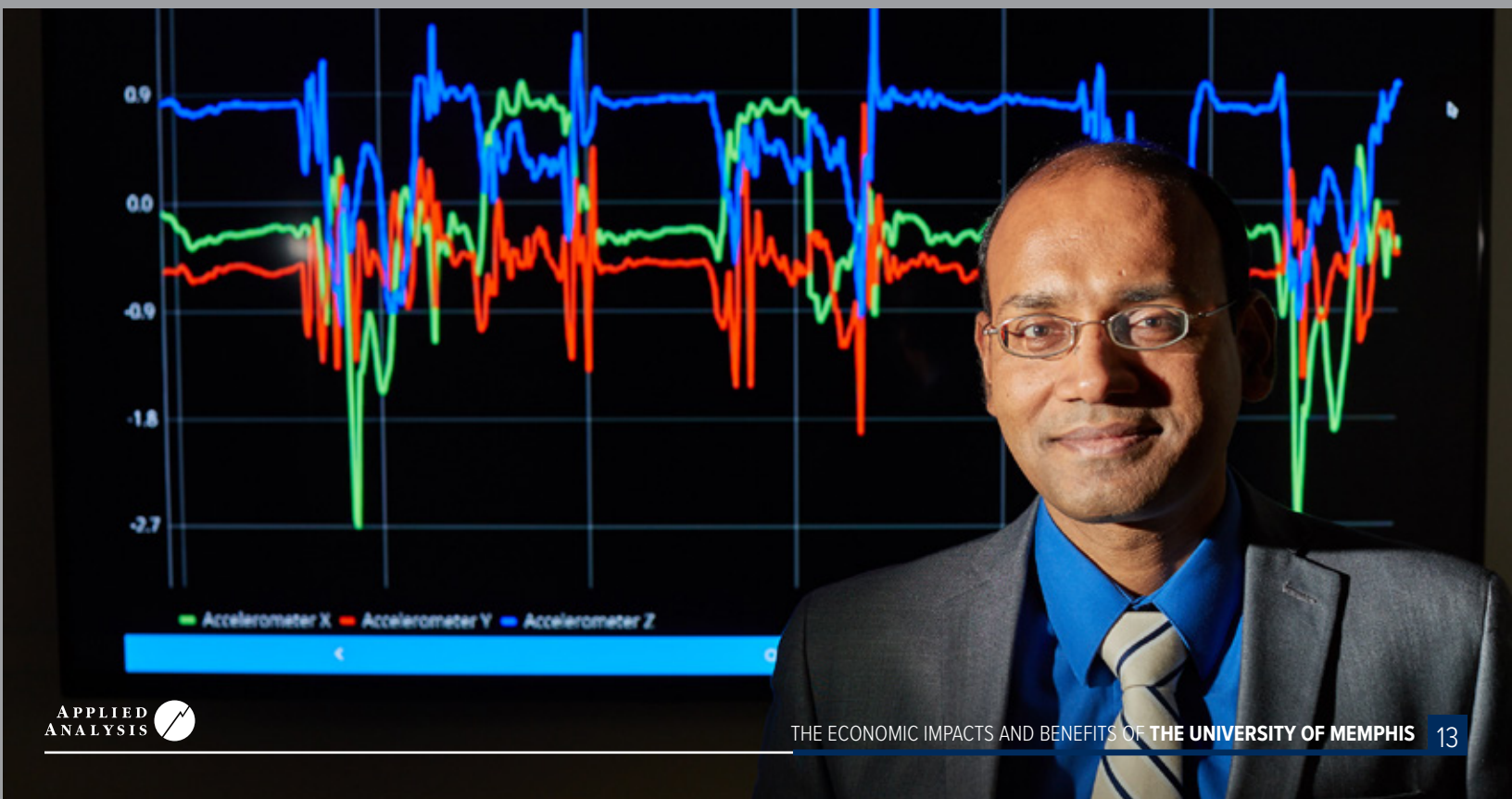
RESEARCH HIGHLIGHT — MD2K CENTER OF EXCELLENCE

The Center of Excellence for Mobile Sensor Data-to-Knowledge (MD2K) is the nation's leading research center for developing the next generation of wearable sensing technologies for improving health and wellness. Headquartered at the University of Memphis (in the FedEx Institute of Technology building), MD2K brings together world-renowned research experts in artificial intelligence, computer science, electrical engineering, medicine, behavioral psychology and statistical learning from 13 R1 research universities.

The MD2K Center of Excellence was established in 2014 via a $10.8 million research grant from the National Institutes of Health (NIH). Since then, MD2K has brought in a total of $34 million in competitive federal research grants and contracts and expanded collaborations to 20 R1 research universities.

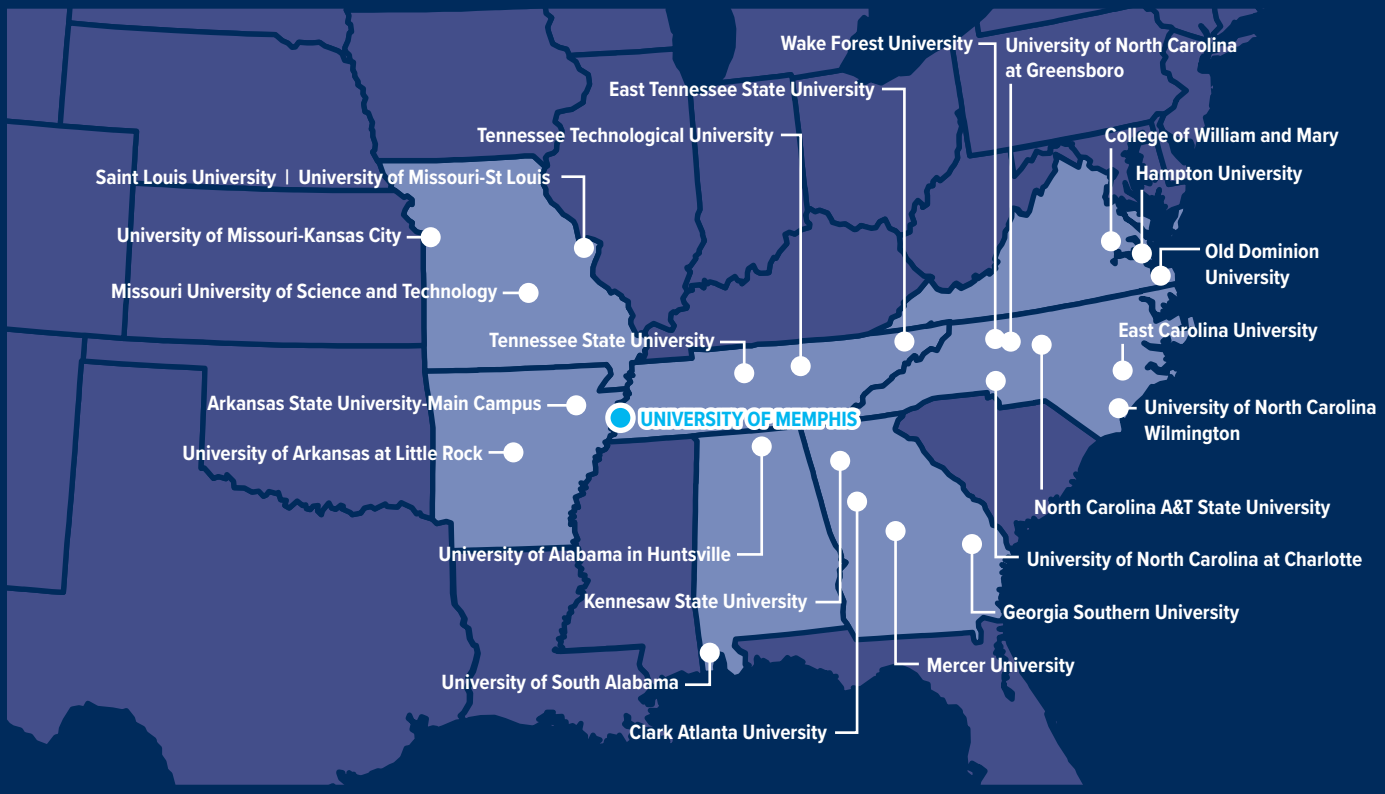
A nationwide visibility for research excellence in the area of mobile health (mHealth) has helped MD2K attract a highly-educated workforce to Memphis. MD2K employs 10 full-time staff who include four software experts, each with a doctoral degree in computer science. MD2K's software team has developed large-scale, open-source software for smartphones and cloud analytics that are used at 11 medical schools and universities for collecting and analyzing mobile sensor data in scientific studies. This data is being used to develop and test new treatments and interventions for stress management, pain management, cardiovascular health, smoking cessation, cocaine and opioid usage, overeating, oral health and work performance.

To develop a high-quality workforce in Memphis, MD2K supports and trains 10 doctoral students in Computer Science who get an opportunity to collaborate with world-renowned faculty and their doctoral students from 20 R1 research universities in the MD2K consortium. These students have developed new machine learning algorithms to provide new intelligence in the next generation of smartwatches and activity trackers. When widely adopted, these innovative smartwatch capabilities can be used to cope with stress, resist craving, abstain from smoking and other addictive behaviors, improve brushing and flossing habits and reduce marital conflicts, among several others.



R2 RESEARCH COMPARISON

REGIONAL R2 INSTITUTIONS



TOP 10 RANKINGS BY ENROLLMENT

Among Regional R2 Institutions

ANNUAL ENROLLMENT

1	Kennesaw State University	40,676
2	University of North Carolina at Charlotte	33,351
3	East Carolina University	32,388
4	Georgia Southern University	31,984
5	Old Dominion University	28,758
6	University of Memphis	24,809
7	University of North Carolina at Greensboro	22,138
8	University of Missouri-St Louis	20,987
9	University of Missouri-Kansas City	19,796
10	Saint Louis University	19,729

GRADUATE ENROLLMENT

1	East Carolina University	5,866
2	University of North Carolina at Charlotte	5,403
3	University of Missouri-Kansas City	5,000
4	Old Dominion University	4,835
5	Saint Louis University	4,671
6	University of South Alabama	4,581
7	Arkansas State University-Main Campus	4,326
8	University of Memphis	4,125
9	Mercer University	3,906
10	University of North Carolina at Greensboro	3,483

TOP 10 RANKINGS

Among Regional R2 Institutions

DEGREES CONFERRED

1	University of North Carolina at Charlotte	6,966
2	East Carolina University	6,462
3	Kennesaw State University	5,796
4	Georgia Southern University	5,594
5	Old Dominion University	5,314
6	University of Memphis	4,439
7	University of North Carolina at Greensboro	4,247
8	University of North Carolina Wilmington	4,187
9	Arkansas State University-Main Campus	4,026
10	University of South Alabama	3,609

FACULTY + POST-DOCTORAL RESEARCHERS

1	Wake Forest University	1,636
2	Saint Louis University	1,187
3	East Carolina University	976
4	Kennesaw State University	831
5	University of North Carolina at Charlotte	782
6	University of Memphis	755
7	University of South Alabama	687
8	East Tennessee State University	659
9	University of Missouri-Kansas City	657
10	College of William and Mary	650

RESEARCH $

1	Wake Forest University	$182,227,000
2	University of Alabama in Huntsville	$94,376,000
3	Old Dominion University	$67,990,000
4	College of William and Mary	$64,127,000
5	Saint Louis University	$56,402,000
6	University of Memphis	$49,695,000
7	University of South Alabama	$41,431,000
8	Missouri University of Science & Technology	$38,243,000
9	North Carolina A&T State University	$37,379,000
10	Mercer University	$29,447,000

R&D $ PER GRAD STUDENT

1	Wake Forest University	$60,460
2	University of Alabama in Huntsville	$46,930
3	College of William and Mary	$26,121
4	North Carolina A&T State University	$24,335
5	Hampton University	$19,954
6	Missouri University of Science & Technology	$19,472
7	Old Dominion University	$14,062
8	Saint Louis University	$12,075
9	University of Memphis	$12,047
10	Clark Atlanta University	$11,604

R&D $ PER FACULTY/POST-DOCTORAL RESEARCHER

1	University of Alabama in Huntsville	$258,564
2	Wake Forest University	$111,386
3	Old Dominion University	$105,575
4	College of William and Mary	$98,657
5	North Carolina A&T State University	$95,598
6	Missouri University of Science & Technology	$90,409
7	Hampton University	$83,242
8	Mercer University	$71,473
9	University of Memphis	$65,821
10	University of South Alabama	$60,307

RESEARCH HIGHLIGHT — CYBER SECURITY AND BLOCKCHAIN

The Center for Information Assurance (CfIA) stands as a nationally-designated Center of Academic Excellence in Cyber Defense Education and Research (CAE-CDE, CAE-R) by the NSA/DHS (National Security Agency/ Department of Homeland Security). Among multiple different research areas, current focuses include negative authentication, adaptive multi-factor authentication, smart-grid security and game theory and cyber security.

Negative Authentication

Password authentication is critical for secure access to company servers as it verifies the identity of computer users and processes. Most authentication systems use some form of Positive Identification (PI) to identify legitimate users, while the Anti-Password (Anti-P) space includes all non-legitimate password strings. While the Anti-P space is very large, the CfIA technique utilizes a form of implicit clustering to generate a small set of Anti-P detectors to cover this password guessing and hacking space. Thus, the system can filter out all illegitimate users (hackers, crackers, etc.) before allowing them to access the positive password verification system, providing an additional layer of protection that is invisible to the user. The prototype system called Password Immunizer was developed by Dr. Dipankar Dasgupta and his research group at the University of Memphis.

Adaptive Multi-Factor Authentication

Multi-factor Authentication (MFA) is the current trend to genuinely identify authorized users, in multiple ways, through an authentication process via passwords, security token, biometrics, cognitive behavior metric, software/ hardware sensors, etc. The goal of this project is to develop a multi-factor authentication system with an adaptive selection of authentication modalities (with their features) in different operating environments making the selection strategy unpredictable to compromise.

Game Theory and Cyber Security

The Game Theory and Cyber Security (GTCS) group conducts cutting-edge research to explore how game theoretic approaches can be applied to address network security issues. Current projects that students are working on include Game Theory Inspired Defense Architecture (GIDA), and AVOIDIT: A Cyber Attack Taxonomy. The center provides a student-centered research environment where both undergraduates and postgraduates can work on federally-funded projects. Previous students have participated in cyber defense competitions such as CANsec, as well as the NSA Codebreaking Challenge and security challenges like CyberSEED, giving them the chance to put their theory knowledge into practice.

THE UNIVERSITY OF MEMPHIS AND PEER INSTITUTIONS

In general, Tennessee underperforms the nation in terms of Research 1 institutions on a per capita basis. Nationwide, 16 states and the District of Columbia have exactly two Research 1 institutions. Of this group, only two states (Washington and Arizona) have a larger population than Tennessee. Tennessee has a relatively high number of doctoral-level universities overall at 14, sixth-most in the country on a per-capita basis. However, with just the two R1 universities (one public, one private) out of that group of 14, Tennessee has the second-lowest proportion of R1 universities in the country among states with at least one R1 university.

Within Tennessee and its eight surrounding border states, there are 21 R1 institutions and 25 R2 institutions, including the University of Memphis. Comparing the University of Memphis to these peer R2 institutions, the University is well positioned to become the next R1 institution in the region.

Among the 25 R2 institutions in the region, the University of Memphis ranked sixth in terms of both total enrollment and total research and development (R&D) spending according to the 2018 Carnegie rankings, and the University ranked ninth in R&D dollars per faculty member. Since these rankings were released, the University's research spending has increased from a total of $49.7 million to $65.6 million, which would have ranked fourth among this group of institutions. This level of research funding would also have pushed the University of Memphis past the University of Alabama - Tuscaloosa, which has the lowest level of overall research funding of the R1 institutions in the region. For 2020, the University has budgeted more than $77 million in research spending.

While the size of a university, whether measured by enrollment or faculty count, is not a prerequisite for R1 status, R1 institutions tend to be larger by both measures and therefore have a greater

capacity for research. While the University of Memphis is a sizable school, it lags many R1 institutions in overall enrollment, graduate enrollment and faculty count. Comparing the University of Memphis to a smaller group of peers, universities which have made the jump from Research 2 to Research 1 over the past 10 years, this difference is clearer.

The closest comparison in terms of overall size among this group is the University of Louisville, with a nearly identical annual enrollment to the University of Memphis. However, Louisville's enrollment is skewed more heavily to graduate students with roughly 2,300 more than the University of Memphis. Additionally, the University of Louisville has nearly twice the faculty of the University of Memphis, another product of a greater focus on graduate-level education.

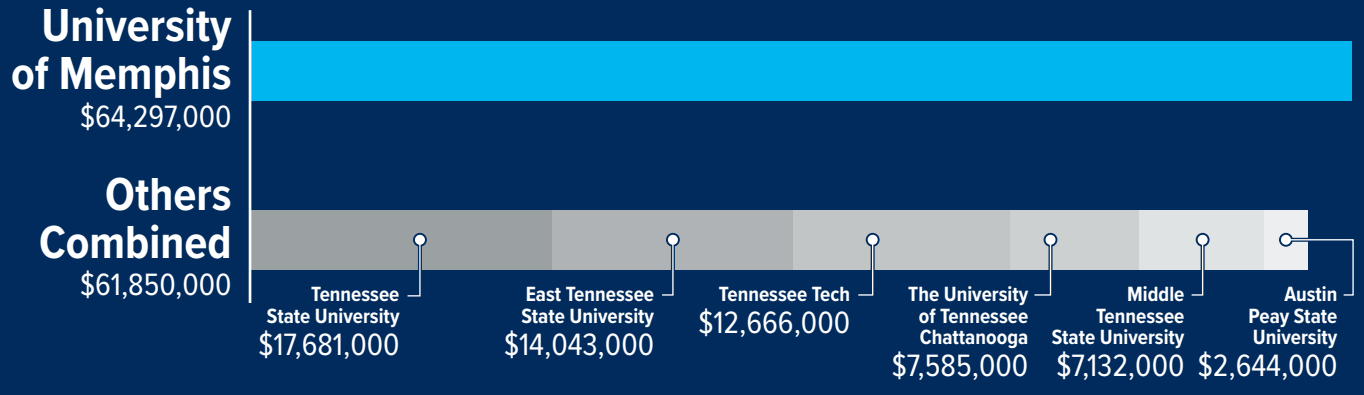
Simply put, growth can have a significant impact when attaining Research 1 status. Overall enrollment is not necessarily an important factor, but higher levels of graduate enrollment and doctorates conferred weighs significantly and is an area where the University of Memphis currently lags many Research 1 institutions. While the University performs well with its current level of faculty, leveraging research dollars and grant funding well above average for R2 institutions in the region, a larger faculty base would increase the University's capacity for research and grant awards, not to mention the inherent ability to educate more students and expand the quality of the educational experience.

PEER UNIVERSITY COMPARISON[5]

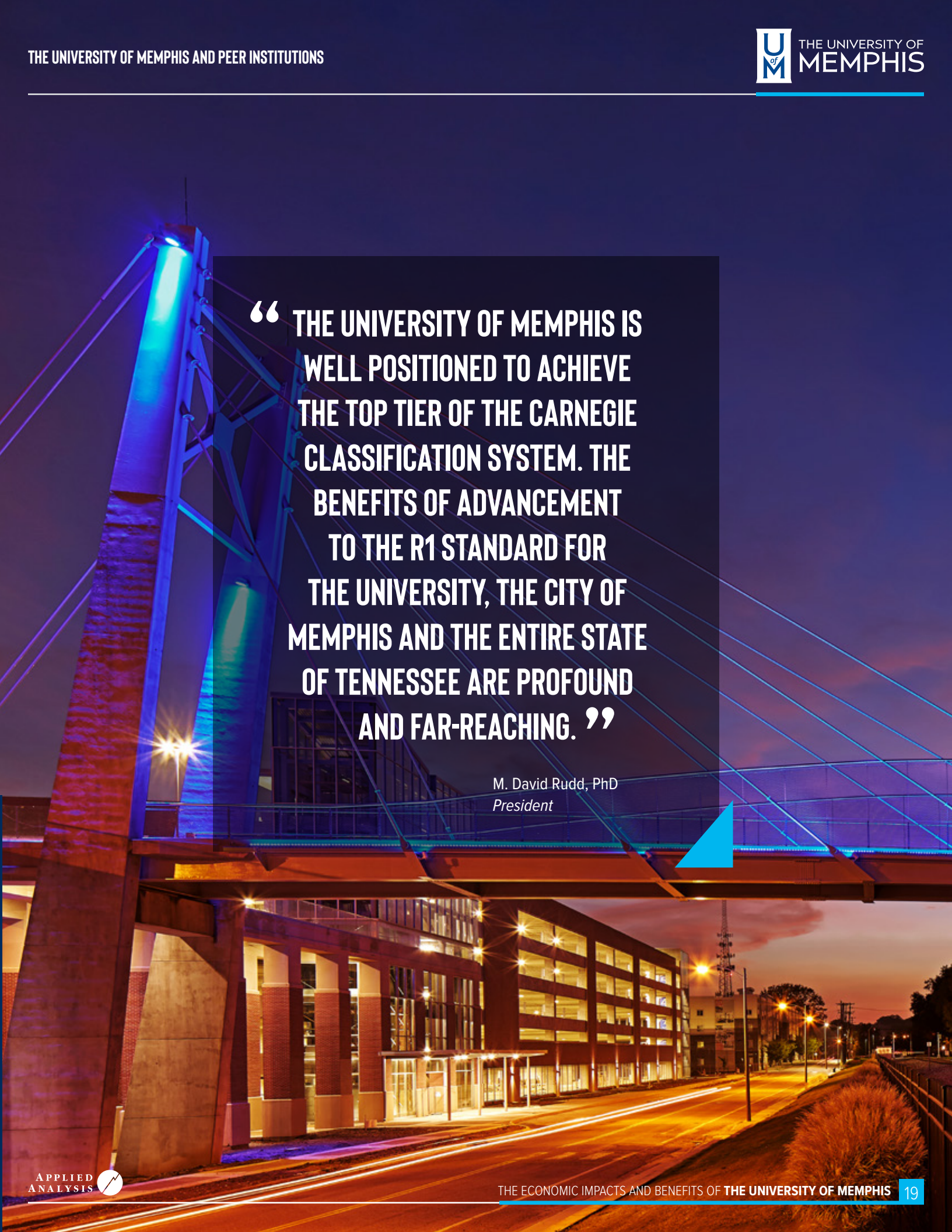
	2018 Faculty	2018 Annual Enrollment	2018 Graduate Enrollment
Texas Tech University	1,569	39,987	7,346
University of Arkansas	1,227	30,378	5,481
University of Houston	1,316	51,371	9,475
University of Louisville	1,776	24,828	7,165
University of Memphis	907	24,847	4,889

[5] *Integrated Postsecondary Education Data System.*

DATA RESEARCH EXPENDITURES[6]



[6] *2018 National Science Foundations' Higher Education Research & Development (HERD) survey.*



> "THE UNIVERSITY OF MEMPHIS IS WELL POSITIONED TO ACHIEVE THE TOP TIER OF THE CARNEGIE CLASSIFICATION SYSTEM. THE BENEFITS OF ADVANCEMENT TO THE R1 STANDARD FOR THE UNIVERSITY, THE CITY OF MEMPHIS AND THE ENTIRE STATE OF TENNESSEE ARE PROFOUND AND FAR-REACHING."

M. David Rudd, PhD
President

RESEARCH HIGHLIGHT — AGTECH

Memphis and the surrounding area has long been the center of Tennessee's agricultural sector, as well as a hub for agricultural activity throughout the Mississippi Delta. The natural benefits enjoyed by the University of Memphis by virtue of geography put it in an excellent position to grow into a regional hub for agricultural research. Increased research and the potential development of an agricultural research institute are the types of investments that remain on the horizon.

Global population growth in recent years and for the foreseeable future raises critical supply/demand issues as well as environmental concerns in the agricultural sphere, and points to the need to engage in fundamental and applied research that will improve innovation and efficiency in food production while protecting our environment.

In addition, agriculture is increasingly going high-tech and now using big data and rapidly adopting AI, drones, blockchain technologies and more to increase productivity, profitability and sustainability. The food industry (food manufacturing and processing) is a fast-growing staple of the U.S. economy and the food supply chain has become global, thus creating challenges for food safety, quality, fraud management and logistics.

Targeted Areas of Research

The Agriculture and Food Technologies Research Cluster at the University of Memphis brings together a core group of scientists from biology, chemistry, computer science, engineering and health to work on theoretical, experimental and applied approaches to contemporary food and agriculture challenges. Additional areas of inquiry and application in law and business are also being explored.

Due to this diverse group of scientists and projects, the potential impacts of the AgTech research performed at the University of Memphis are significant. Within biology, scientists are researching crops, animals, microbes and their interactions with one another with a focus on bioproducts, biodiversity and sustainability. Microbiological research into pathogens at the University also have implications in the realm of food safety and food supply chains, while the work of chemists on other food contaminants has the potential to improve food processing, manufacturing and packaging processes.

Other research within the University's AgTech activities focuses on improved technology and efficiencies throughout the food supply chain. This includes everything from developing high-tech tools to improve yields and efficiency in agricultural production to blockchain and cyber security research to address potential vulnerabilities in both the national and global food supply chain. Simply put, the University of Memphis is attempting to revolutionize what the very term "agricultural technology" means by venturing into numerous modern areas of study to improve one of the world's oldest industries.

PEER COMPARISON

	Status	Annual Enrollment	Graduate Enrollment	Faculty	Total Research Spending	Local/ Private Grant Awards	State Grant Awards	Federal Grant Awards	Total Grant Awards
Texas Tech University	R1	39,987	7,346	1,569	$191,482,000	$14,611,807	$19,149,325	$79,758,158	$113,519,290
University of Arkansas	R1	30,378	5,481	1,227	$157,791,000	$38,178,531	$62,146,422	$88,828,732	$189,153,685
University of Houston	R1	51,371	9,475	1,316	$169,431,000	$22,453,305	$41,690,723	$137,471,808	$201,615,836
University of Louisville	R1	24,828	7,165	1,776	$177,588,000	$16,966,000	$29,022,000	$93,945,000	$139,933,000
University of Memphis	**R2**	**24,847**	**4,889**	**907**	**$49,695,000**	**$8,087,204**	**$35,564,535**	**$68,433,862**	**$112,085,601**

	GRANT MONEY RECEIVED PER INSTITUTION			GRANT MONEY RECEIVED PER FACULTY MEMBER			GRANT MONEY RECEIVED PER STUDENT			GRANT MONEY RECEIVED PER GRAD STUDENT		
TEXAS TECH UNIVERSITY	$113.5 M			$72,351			$2,839			$15,453		
	LOCAL/ PRIVATE	STATE	FEDERAL	LOCAL/ PRIVATE	STATE	FEDERAL	LOCAL/ PRIVATE	STATE	FEDERAL	LOCAL/ PRIVATE	STATE	FEDERAL
	$14.6 M	$19.1 M	$79.7 M	$9,313	$12,205	$50,834	$365	$479	$1,995	$1,989	$2,607	$10,857
UNIVERSITY OF ARKANSAS	$189.1 M			$154,159			$6,227			$34,511		
	LOCAL/ PRIVATE	STATE	FEDERAL	LOCAL/ PRIVATE	STATE	FEDERAL	LOCAL/ PRIVATE	STATE	FEDERAL	LOCAL/ PRIVATE	STATE	FEDERAL
	$38.1 M	$62.1 M	$88.8 M	$31,115	$50,649	$50,649	$1,257	$2,046	$2,924	$6,966	$11,339	$16,207
UNIVERSITY OF HOUSTON	$201.6 M			$153,204			$3,925			$21,279		
	LOCAL/ PRIVATE	STATE	FEDERAL	LOCAL/ PRIVATE	STATE	FEDERAL	LOCAL/ PRIVATE	STATE	FEDERAL	LOCAL/ PRIVATE	STATE	FEDERAL
	$14.6 M	$41.6 M	$41.6 M	$17,062	$31,680	$104,462	$437	$812	$2,676	$2,370	$4,400	$14,509
UNIVERSITY OF LOUISVILLE	$139.9 M			$78,791			$5,636			$19,530		
	LOCAL/ PRIVATE	STATE	FEDERAL	LOCAL/ PRIVATE	STATE	FEDERAL	LOCAL/ PRIVATE	STATE	FEDERAL	LOCAL/ PRIVATE	STATE	FEDERAL
	$16.9 M	$29.0 M	$93.9 M	$9,553	$16,341	$52,897	$683	$1,169	$3,784	$2,370	$4,051	$13,112
UNIVERSITY OF MEMPHIS	$112.0 M			$123,578			$4,511			$22,926		
	LOCAL/ PRIVATE	STATE	FEDERAL	LOCAL/ PRIVATE	STATE	FEDERAL	LOCAL/ PRIVATE	STATE	FEDERAL	LOCAL/ PRIVATE	STATE	FEDERAL
	$8.0 M	$35.5 M	$68.4 M	$8,916	$39,211	$75,451	$325	$1,431	$2,754	$1,654	$7,274	$13,998

GRANT COMPARISON

GRANT MONEY RECEIVED PER INSTITUTION

	Local/Private	State	Federal	Total
Average Regional R2	$7,180,898	$11,131,755	$49,188,017	$67,500,670
University of Memphis	$8,087,204	$35,564,535	$68,433,862	$112,085,601
Average Regional R1	$83,119,509	$35,734,248	$285,372,519	$404,226,277
Percentage Increase R2 to R1	1,057.5%	221.0%	480.2%	498.8%
Percentage Increase University of Memphis to R1	927.8%	0.5%	317.0%	260.6%

GRANT MONEY RECEIVED PER FACULTY MEMBER

	Local/Private	State	Federal	Total
Average Regional R2	$9,812	$15,211	$67,211	$92,234
University of Memphis	$8,916	$39,211	$75,451	$123,578
Average Regional R1	$45,821	$19,699	$157,317	$222,837
Percentage Increase R2 to R1	367.0%	29.5%	134.1%	141.6%
Percentage Increase University of Memphis to R1	413.9%	-49.8%	108.5%	80.3%

GRANT MONEY RECEIVED PER STUDENT

	Local/Private	State	Federal	Total
Average Regional R2	$397	$616	$2,722	$3,736
University of Memphis	$325	$1,431	$2,754	$4,511
Average Regional R1	$2,702	$1,162	$9,278	$13,142
Percentage Increase R2 to R1	579.9%	88.6%	240.8%	251.8%
Percentage Increase University of Memphis to R1	730.3%	-18.8%	236.9%	191.3%

GRANT MONEY RECEIVED PER GRADUATE STUDENT

	Local/Private	State	Federal	Total
Average Regional R2	$1,839	$2,851	$12,597	$17,287
University of Memphis	$1,654	$7,274	$13,998	$22,926
Average Regional R1	$9,113	$3,918	$31,287	$44,318
Percentage Increase R2 to R1	395.5%	37.4%	148.4%	156.4%
Percentage Increase University of Memphis to R1	450.9%	-46.1%	123.5%	93.3%

RESEARCH HIGHLIGHT — WATER RESEARCH

The University of Memphis' Center for Applied Earth Science and Engineering Research, or CAESER, is an interdisciplinary research center that emphasizes data-driven decision making. CAESER's applied research in water and geographic information systems (GIS) works with public, private and government partners in both natural and populated environments.

Water Research and Analysis

Sustainability is a common buzzword today, but it has been CAESER's focus for more than 25 years. Understanding the challenges water managers face in meeting the demands of their diverse customer base (municipalities, industry, agriculture) without damaging the natural water system or the ecological dependencies of that system, CAESER seeks solutions to a variety of problems experienced within those systems. CAESER's water research encompasses groundwater, surface water and atmospheric contributions to surface processes. This includes research into water mass balance, environmental assessments, groundwater assessment and modeling, contaminant fate and transport, groundwater/surface water interaction, subsurface mapping of geologic features and strata, hydrological studies, sustainable river engineering, as well as restoration and public awareness.

Urban Analytics

Cities are hubs of knowledge and information. Accessing and interpreting this information is essential for discovering hidden patterns. These patterns are used to understand how cities evolve and how they can operate more efficiently – a hugely important task for cities with limited resources. CAESER works with several organizations to open access to urban data and utilize it in a way that helps public and private sector entities make better decisions to improve quality of life, public health and safety. CAESER uses various modeling and visualization techniques to simplify complicated, abstract concepts and make them solvable. A few of these projects include tax delinquency solutions, employment and residential density research and land productivity analysis.

Geographic Information Systems (GIS)

A geographic information system allows one to visualize, question, analyze and interpret data to understand relationships, patterns and trends on a spatial or geographic level. GIS benefits organizations of all sizes in almost every industry.

CAESER provides a wide array of GIS services to provide a wide variety of organizations with comprehensive solutions. Services particularly valuable to public sector organizations are utility and municipal infrastructure mapping and planning, as well as neighborhood planning and analysis. CAESER also provides web and mobile app development services, providing platforms for mobile data collection or the dissemination of data to the public. Other GIS services offered by CAESER include asset management, geodatabase design and storage, data visualization and manipulation services. Ultimately, CAESER serves as a full-service center for state-of-the-art GIS systems and services.

ECONOMIC IMPACTS

The Ripple Effect

Consistent with traditional economic impact modeling, this analysis considers both the non-recurring construction related activities of the University, along with the recurring impacts sourced to its operations and daily activities. Included with the annual, operational impacts are the research-related activities taking place at the University; those results have been identified separately to demonstrate the level of investment being made with a research focus.

Economic impact analyses tend to focus on three key components: (1) direct impacts; (2) indirect impacts; and (3) induced impacts. These impacts combine to quantify the total impact of the University.

To estimate the impacts, direct impact data is largely sourced to the University, and with the use of the nationally recognized input-output model IMPLAN, the overall impacts are referred to as the "ripple effect."

The ripple effect includes secondary and tertiary economic impacts, which are referred to in this analysis as indirect and induced effects, respectively. The direct operational impacts of the University are the most obvious and include those employed by the University, their wages and all direct expenditures made by the University. One-time construction projects also provide a source of economic activity and are also reflected.

Indirect economic impacts measure the impact of vendor purchases or the University's spending with other businesses. For example, when the University purchases supplies, such as research equipment or classroom furniture, that money becomes revenue for the supplier or distributor from which those items are purchased. This revenue in turn supports jobs and wages at other businesses in the area, broadening the University's economic impacts.

Finally, induced impacts measure the impact of employees' spending on the economy. More than 6,500 people are employed by the University (full- and part-time) and spend their wages on various items ranging from food to footwear. This spending ripples through the economy. By combining these various effects, a more complete assessment of the University of Memphis' economic contributions on the region is presented.

DIRECT IMPACT → **INDIRECT IMPACT** → **INDUCED IMPACT** → **TOTAL IMPACT**

The direct expenditures of the University on its operations, research and construction-related activities.

The vendor purchases of goods and services that support the University's operations, research and construction activities.

Consumer spending in the local economy sourced to employee wages.

The combined impact of the direct spending of the University, vendor purchases and overall employee spending throughout the local community.

Recurring Operations Impacts

Universities are complex, multifaceted operations that help create the future community leaders and serve as incubators for innovation in research. To accomplish this, universities like the University of Memphis invest in their talent, their facilities and their overall operations. As a result, the University of Memphis is a major driver of the local economy.

To support the objective of reaching R1 status, the University is demonstrating increased investments and economic output of approximately $572 million in 2020 (estimated), which is up 9.5 percent from the prior year.

The University's annual operations had a substantial overall economic impact (including indirect and induced spending), contributing between $915.6 million and $1.07 billion to the local economy during the past five years. Over the course of those five years, the University's expenditures have directly contributed between $507.6 million and $572.2 million to the local economy on an annual basis. Additionally, over the same time period, its supplier purchases have contributed between $163.5 million and $191.5 million annually, and the inducing spending contributed between $244.5 million and $304.8 million annually. During the past five years, the University was responsible for nearly $4.8 billion in economic activity.

Simply stated, for every $1 in direct economic activity sourced the University, a total of $1.87 is spent throughout the local economy.

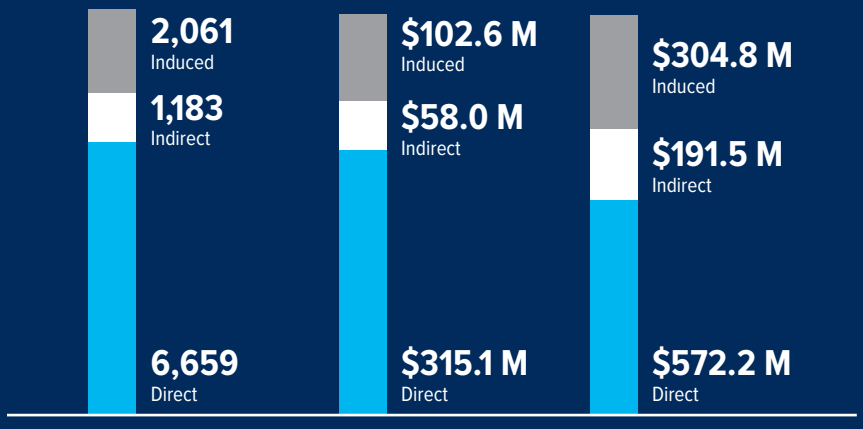
Similar trends in the amount of sales, wage and benefits were reported by the University. During 2020, the University directly invested approximately $315.1 million in labor-related costs, which represented a 26 percent increase from 2016, or a compound annual growth rate of 5.9 percent.

Beyond what it paid its own employees, the University's supplier purchases supported between $49.1 million and $58 million of indirect labor income between 2016 and 2020, and the spending of employees supported annual induced labor income from 2016 to 2020 of between $82.3 million and $102.6 million. In total, the University of Memphis supported between $381.5 million and $475.7 million of local salaries and wages between the years 2016 and 2020 for a five-year total of over $2 billion.

From an employment perspective, the number of direct employees expanded from 6,245 in 2016 to 6,659 in 2020 (estimated). The range of professionals have a meaningful impact on the local community. Additionally, indirect employment sourced to the University ranged from 1,007

ANNUAL OPERATIONS IMPACTS

Total Five-Year Impact | 2016-2020



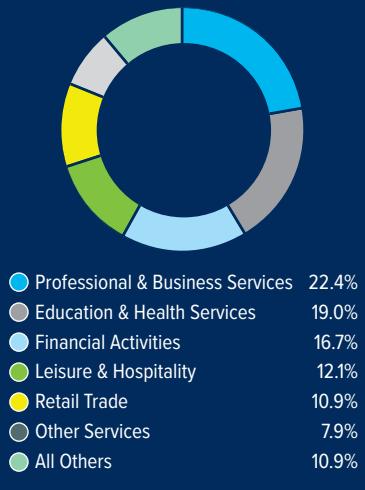
9,904 EMPLOYMENT IMPACT

$475.7 M LABOR IMPACT

$1,068.5 M ECONOMIC OUTPUT

ANNUAL OPERATIONS

Indirect and Induced
Jobs Supported by Industry



in 2016 to 1,183 in 2020. Furthermore, induced job counts ranged from 1,653 to 2,061 each of the past five years. In total, University operations was responsible for between 8,906 and 9,904 local jobs over each of the past five years. Note, for every direct job at the University, a total of 1.5 jobs are supported throughout the community.

Research Impacts

While the operational pace of expansion of the University during the past five years has been relatively impressive, research-related activities have been especially robust.

Research institutions such as the University of Memphis spend substantial sums on research, which produces advancements in fields such as sciences, technology and humanities. These initiatives are a core part of the University's operations and their economic impacts are worth highlighting individually.

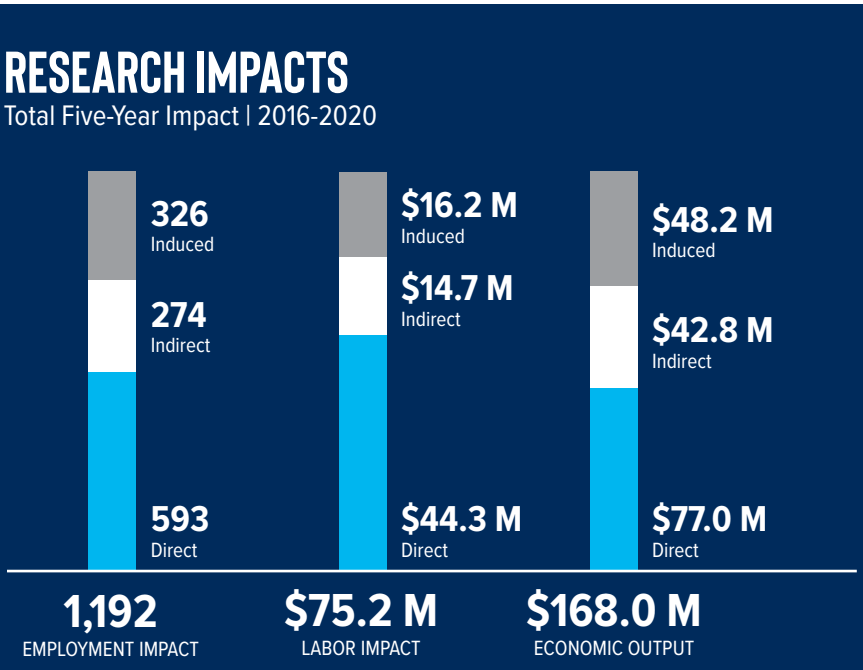
The University's annual research expenditures are notable, and over the course of the past five years, the University's research expenditures have directly contributed between $45.3 million and $77 million each year to the local economy. Since 2016, overall University spending on research has increased by 50 percent, or a compound annual growth rate of 10.6 percent.

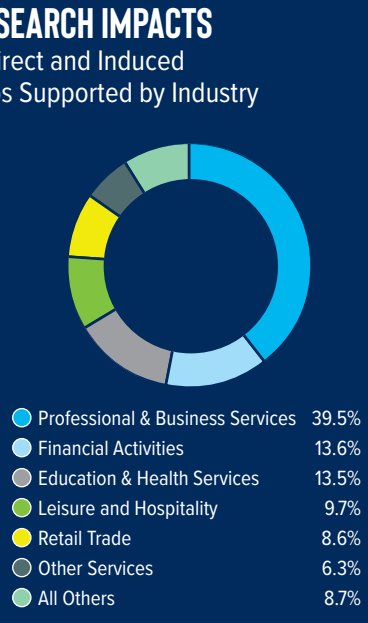
While annual expenditures tend to ebb and flow, the 2020 estimated spend reflects a 69.9 percent increase from 2019.

Over the same five-year time period, research-related supplier purchases (indirect) have contributed between $25.1 million and $42.8 million annually, and the induced impacts contributed between $20.3 million and $48.2 million annually. The University's research efforts have contributed a total of between $92.3 million and $168 million to the local economy each year over the past five years, for a grand total of $551.5 million in economic impact.

The University's research efforts also support wages for local workers. From 2016 to 2020, the University of Memphis paid its research personnel between $15 million and $44.3 million in wages and salaries, which reflects a tripling of funding for research workers Importantly, investments in direct wages increased by 31 percent from 2019 to 2020.

Beyond what it paid its own researchers, the University's supplier purchases supported between $8.6 million and $14.7 million of indirect labor income between 2016 and 2020, and induced wages ranged from $6.8 million to $16.2 million during the past five years. In total, the University of Memphis' research initiatives alone will have supported between





$31.6 million and $75.2 million of local salaries and wages between the years of 2016 and 2020. The ripple effect of the direct wages equates to 1.7 times during 2020. In aggregate, the University's research efforts alone accounted for $218.5 million in wages during the past five years.

On an annual basis between the years 2016 and 2020, the University of Memphis has directly employed between 375 and 593 research professionals. Additionally, purchases from suppliers needed for research have created between 161 and 274 additional indirect jobs annually over the past five years. Furthermore, spending by researchers has created an additional 148 to 326 induced jobs over each of the past five years. In total, University's research efforts have supported between 695 and 1,192 jobs annually over the past five years. To put this into perspective, every research position at the University translates into two total positions in the Memphis area.

Construction Impacts

The operational impacts provide insight into the recurring operations of the University, but they do not necessarily capture the capital investments that are being made to ensure the necessary infrastructure exists to support future demand. This analysis captures the one-time construction-related impacts of the University for the period from 2018 to 2022.

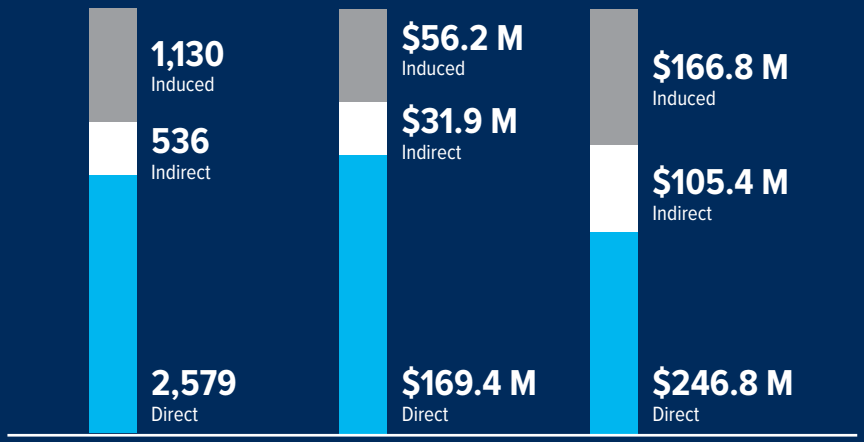
The University of Memphis has taken on a number of construction projects in recent years, including the development of a pedestrian bridge, parking garage and wellness and fitness center. However, perhaps most important is the new STEM facility that is expected to expand the University's engineering capacity and research capabilities going forward. These types of projects are important to the economy, the students and the University's objective to expand its research capabilities.

The construction process itself will strengthen the local workforce. Beginning in 2018 and through 2022, the construction, repairs, renovations and specialty equipment purchases will create jobs and provide working families with incomes. Total capital projects completed and programmed for the campus total approximately $247.5 million.

In addition to the direct impacts of development related activity, the indirect impacts are expected to add another $105.4 million during construction and another $166.8 million in induced

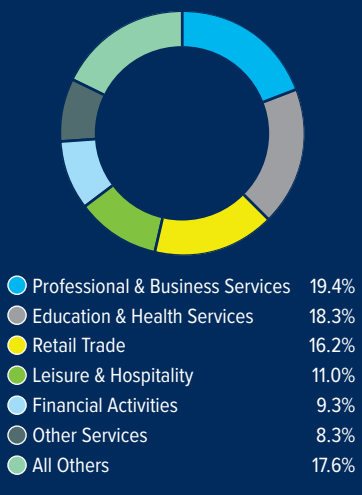
CONSTRUCTION IMPACTS[7]

Total Five-Year Impact | 2018-2022



CONSTRUCTION

Indirect and Induced Jobs Supported by Industry



[7] *Construction-related employment impacts are stated in person-years of employment (i.e., one person employed full-time for one year).*

activity. In total, the capital program at the University is estimated to reach $519 million through 2022. Note, for every $1 directly invested in construction-related activities at the University, a total of $2.10 in economic output is generate.

These construction projects will also provide salaries and wages for local families. Between 2018 and 2022, the construction projects at the University of Memphis will support an estimated $169.4 million in direct salaries, $31.9 million in indirect wages and $56.2 million in induced payroll. In total, construction at the University of Memphis will have contributed $257.6 million to local salaries and wages between the years 2018 and 2022.

Increased wages and investments will contribute to incremental jobs in the Memphis area, including approximately 2,579 person-years of employment. Note, non-recurring positions are often stated in "person-years" to account for the temporary nature of the positions and the timing of the projects. A person-year is the equivalent of one person employed full-time for one year.

Additionally, supplier purchases will contribute an additional 536 person-years of indirect employment and induced impacts created by employee spending are estimated to reach 1,130 person-years between 2018 and 2022. In total, construction projects at the University of Memphis are estimated to support a total of 4,245 person-years of employment between 2018 and 2022.

RESEARCH HIGHLIGHT — METAL ADDITIVE MANUFACTURING

The University of Memphis Metal Additive Manufacturing Lab creates next-generation, precision-engineered products that have previously eluded traditional manufacturing methods. The lab's work will help position the University of Memphis as a national leader advancing the important new technology of metal additive manufacturing. The possibilities are limitless, with exciting opportunities to enhance the future of industries like aviation, automotive, biomedical and more.

The Metal Additive Manufacturing Lab operates as a University core research facility located in the Herff College of Engineering. In addition to serving the needs of the College, it provides opportunities for researchers campus-wide to engage in research involving 3D metal printing, and it provides opportunities for involvement with external constituents as well.

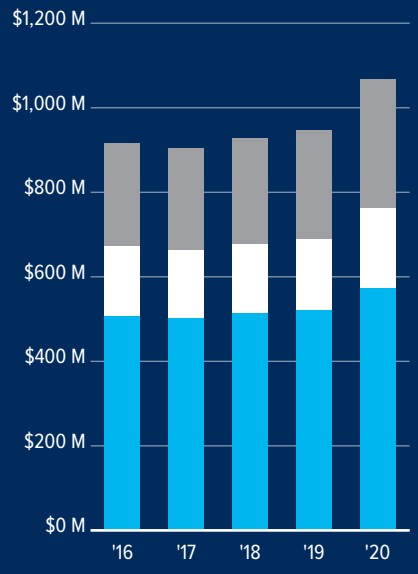
The Metal Additive Manufacturing Lab has been the site of research into various products and processes. Some of this research has been focused on 3D printing of metal implants that will grow with young patients or disappear after healing in adult patients. Other research includes improving the metal 3D printing process for US Navy applications, spinal implants and highly porous and lightweight structures.

Detail of Economic Impacts Sourced to the University of Memphis

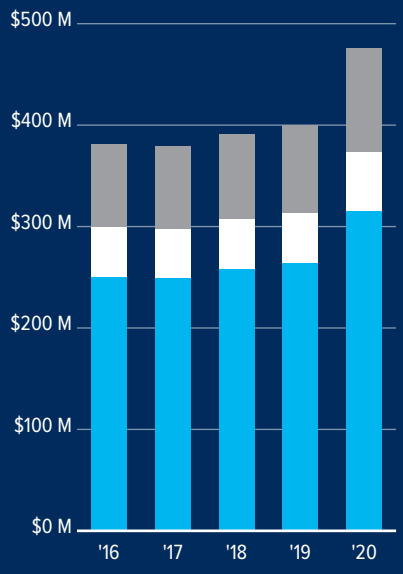
RECURRING OPERATIONS IMPACTS

	2016	2017	2018	2019	2020	Five-Year Total/Avg.
Economic Output						
Direct	$507.6 M	$501.6 M	$513.2 M	$522.3 M	$572.2 M	**$2,616.9 M**
Indirect	$163.5 M	$160.6 M	$164.1 M	$166.9 M	$191.5 M	**$846.7 M**
Induced	$244.5 M	$243.0 M	$250.9 M	$256.3 M	$304.8 M	**$1,299.5 M**
TOTAL	**$915.6 M**	**$905.3 M**	**$928.3 M**	**$945.5 M**	**$1,068.5 M**	**$4,763.1 M**
Labor Income						
Direct	$250.1 M	$249.2 M	$257.8 M	$263.6 M	$315.1 M	**$1,335.7 M**
Indirect	$49.1 M	$48.2 M	$49.3 M	$50.0 M	$58.0 M	**$254.6 M**
Induced	$82.3 M	$81.8 M	$84.5 M	$86.3 M	$102.6 M	**$437.4 M**
TOTAL	**$381.5 M**	**$379.2 M**	**$391.5 M**	**$399.9 M**	**$475.7 M**	**$2,027.7 M**
Employment						
Direct	6,245	6,302	6,504	6,550	6,659	**6,452**
Indirect	1,007	990	1,013	1,029	1,183	**1,045**
Induced	1,653	1,644	1,697	1,733	2,061	**1,758**
TOTAL	**8,906**	**8,936**	**9,214**	**9,312**	**9,904**	**9,254**

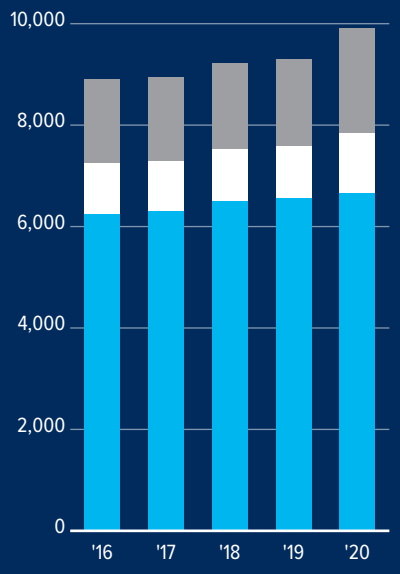
ECONOMIC OUTPUT



LABOR INCOME



EMPLOYMENT

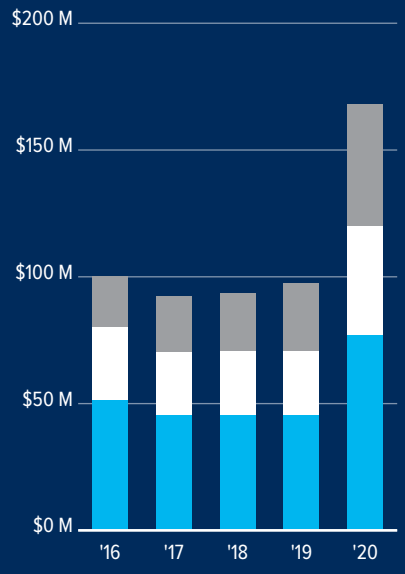


DIRECT INDIRECT INDUCED

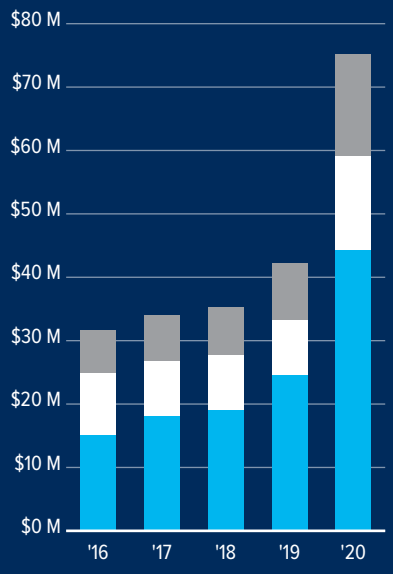
RESEARCH ACTIVITY IMPACTS

	2016	2017	2018	2019	2020	Five-Year Total/Avg.
Economic Output						
Direct	$51.4 M	$45.3 M	$45.5 M	$45.4 M	$77.0 M	**$264.6 M**
Indirect	$28.5 M	$25.1 M	$25.2 M	$25.2 M	$42.8 M	**$146.9 M**
Induced	$20.3 M	$21.8 M	$22.6 M	$27.1 M	$48.2 M	**$140.0 M**
TOTAL	**$100.2 M**	**$92.3 M**	**$93.3 M**	**$97.7 M**	**$168.0 M**	**$551.5 M**
Labor Income						
Direct	$15.0 M	$18.1 M	$19.0 M	$24.6 M	$44.3 M	**$121.0 M**
Indirect	$9.8 M	$8.6 M	$8.7 M	$8.6 M	$14.7 M	**$50.3 M**
Induced	$6.8 M	$7.3 M	$7.6 M	$9.1 M	$16.2 M	**$47.1 M**
TOTAL	**$31.6 M**	**$34.0 M**	**$35.3 M**	**$42.4 M**	**$75.2 M**	**$218.5 M**
Employment						
Direct	375	457	480	611	593	**503**
Indirect	183	161	162	161	274	**188**
Induced	137	148	153	184	326	**189**
TOTAL	**695**	**765**	**795**	**956**	**1,192**	**881**

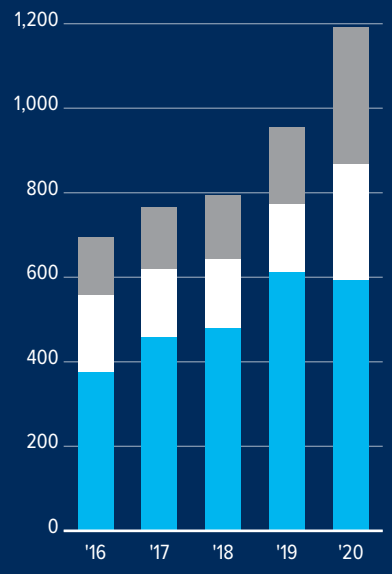
ECONOMIC OUTPUT



LABOR INCOME



EMPLOYMENT



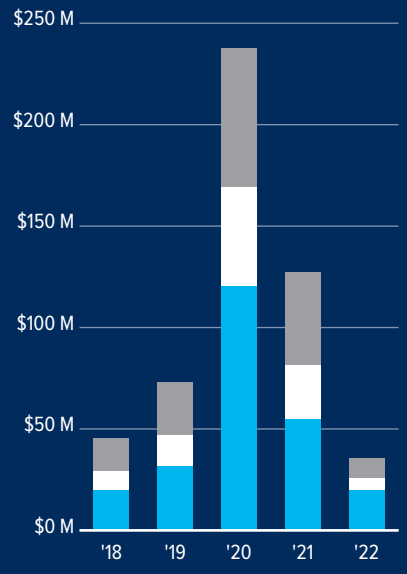
● DIRECT ● INDIRECT ● INDUCED

CONSTRUCTION IMPACTS[8]

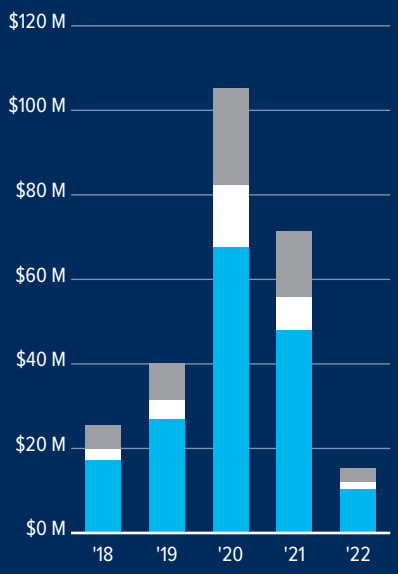
	2018	2019	2020	2021	2022	Five-Year Total
Economic Output						
Direct	$19.7 M	$31.9 M	$120.5 M	$55.0 M	$19.7 M	**$246.8 M**
Indirect	$9.4 M	$15.1 M	$48.8 M	$26.2 M	$5.9 M	**$105.4 M**
Induced	$16.5 M	$26.0 M	$68.1 M	$46.2 M	$9.9 M	**$166.8 M**
TOTAL	**$45.5 M**	**$73.0 M**	**$237.4 M**	**$127.5 M**	**$35.5 M**	**$519.0 M**
Labor Income						
Direct	$17.1 M	$26.8 M	$67.6 M	$47.8 M	$10.2 M	**$169.4 M**
Indirect	$2.8 M	$4.6 M	$14.7 M	$8.0 M	$1.8 M	**$31.9 M**
Induced	$5.6 M	$8.8 M	$23.0 M	$15.6 M	$3.3 M	**$56.2 M**
TOTAL	**$25.5 M**	**$40.1 M**	**$105.2 M**	**$71.4 M**	**$15.3 M**	**$257.6 M**
Employment						
Direct	260	408	1,027	727	157	**2,579**
Indirect	48	77	250	133	29	**536**
Induced	112	176	461	313	67	**1,130**
TOTAL	**419**	**661**	**1,739**	**1,174**	**253**	**4,245**

[8] *Construction-related employment impacts are stated in person-years of employment (i.e., one person employed full-time for one year).*

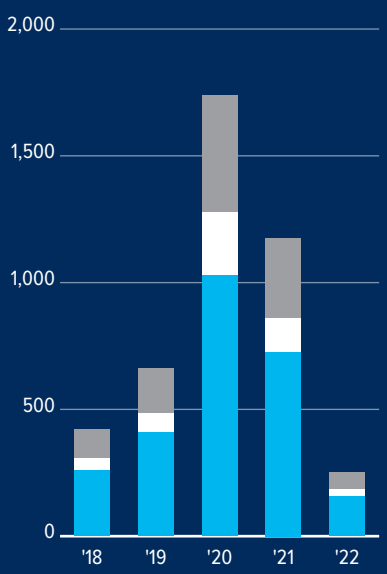
ECONOMIC OUTPUT



LABOR INCOME



EMPLOYMENT



DIRECT INDIRECT INDUCED

RESEARCH HIGHLIGHT — CENTER FOR EARTHQUAKE RESEARCH AND INFORMATION

CERI is a Tennessee Center of Excellence created to perform state-of-art scientific research into the nature of earthquakes in continental interiors, monitor earthquakes within the central and southeastern United States and to serve the public and educational institutions of the State of Tennessee in providing accurate information on earthquake effects and hazards. CERI technical staff operate and maintain more than 144 seismic stations in 10 states in the region from Arkansas to Virginia, part of the Advanced National Seismic System (ANSS). CERI became a Core Institution of the Southern California Earthquake Center (SCEC) in 2019. SCEC is an international earthquake consortium funded by the National Science Foundation addressing problems of earthquake physics, hazards and early warning.

As the central data analysis center for the ANSS, CERI responds to significant regional earthquake events by fielding aftershock studies using temporary seismic stations and provides the public, media and other scientific organizations data and earthquake information.

In addition to its national responsibilities, CERI is involved with seismic monitoring research with the states of Arkansas and Louisiana concerning earthquakes induced by industrial activity. In Arkansas, wastewater injection associated with gas field development caused thousands of earthquakes to occur near Conway, Ark. In Louisiana, a salt dome gas storage facility failed and caused a sinkhole to form with associated earthquakes. CERI provided important information to the State of Arkansas in 2011 that led to an emergency stop order for wells injecting large amounts of waste water into the subsurface. Induced seismicity is becoming a national issue with the large amount of shale gas drilling that is occurring throughout the country. CERI is looking to expand its monitoring efforts of induced earthquakes.

CERI staff members also perform a significant amount of work connecting with the public. CERI education and outreach programs directly reach more than 2,000 K-12 students from Shelby County each year through site visits and in-school presentations. Many more students are influenced through CERI workshops for teachers who use provided materials in their classrooms. In addition, several public service announcements for earthquake awareness have been co-produced with the Tennessee Emergency Management Agency each year since 2006 and shown throughout the central U.S.

CERI's research mission into the causes and effects of earthquakes is greatly enhanced by participation in graduate programs in Earth Sciences and Civil Engineering. In fall 2015, the CERI faculty was given full responsibility for administering the Geophysics Concentration for the MS and PhD in Earth Sciences. At the same time, CERI and the Civil Engineering Department started an interdisciplinary program in Engineering Seismology that has resulted in cross-listing many CERI and Civil Engineering graduate courses.

UNIVERSITY OF MEMPHIS

THE UNIVERSITY OF MEMPHIS

2019

ENROLLMENT	DEGREES AWARDED	EMPLOYEES
22,044	4,349	6,659

GRANT AWARDS PER FACULTY MEMBER	INCREMENTAL LABOR INCOME PER GRADUATING CLASS
$123,578	$110 M

ECONOMIC IMPACTS

OPERATIONS

9,904	$475.7 M	$1,068.5 M
ANNUAL EMPLOYMENT SUPPORTED	ANNUAL LABOR INCOME SUPPORTED	ANNUAL ECONOMIC IMPACT

RESEARCH

1,192	$75.2 M	$168.0 M
ANNUAL EMPLOYMENT SUPPORTED	ANNUAL LABOR INCOME SUPPORTED	ANNUAL ECONOMIC IMPACT

CONSTRUCTION

4,245	$257.6 M	$519.0 M
FIVE-YEAR EMPLOYMENT IMPACT	FIVE-YEAR LABOR INCOME SUPPORTED	FIVE-YEAR ECONOMIC IMPACT

LIMITATIONS

Our research was conducted using both quantitative and qualitative data provided by the University and third-party sources. This summary report was assembled by Applied Analysis using that data. While we have no reason to doubt the accuracy of the data reported herein or utilized in the formation of our findings, the information collected was not subjected to any auditing or review procedures by Applied Analysis; therefore, we make no representations or assurances as to its completeness. Our findings and estimates are as of the last day of our fieldwork (May 31, 2020).

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APPLIED ANALYSIS