Professional Masters in Industrial Engineering

An inter-disciplinary graduate academic program administered by the George R. Brown School of Engineering.
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Professional Masters in Industrial Engineering

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Modern industrial systems, which arise in fields such as manufacturing, supply chain management, energy, transportation and healthcare, are extremely complex. Analyzing and optimizing their performance is very challenging; for example, the number of ways that Federal Express can route its vehicles vastly exceeds the number of atoms in the universe. These analyses are crucial; their financial impact typically exceeds the profit margins in many industries, such as transportation and retailing.

To meet these challenges, we propose the Professional Masters in Industrial Engineering (MIE), a first-rate educational experience in a 31-credit-hour degree experience. The proposed degree program for a MIE will offer students graduate-level education that emphasizes improving the quality and reliability of complex systems. The proposed degree program provides students with a deep set of analytical and engineering skills, and contextual knowledge of important problem domains, such as healthcare, energy and manufacturing. MIE graduates will help industry, governments and non-profits improve efficiency in changing and uncertain environments.

I. Rationale

Industrial Engineering (IE) uses scientific methods to improve the efficiency of various systems.

IE is at the intersection of Mechanical Engineering (ME) and Operations Research (OR). OR uses mathematical models to make better decisions. At many universities, IE is housed entirely within one of these departments. The first academic department of Industrial Engineering was established at Penn State in 1908. Locally, Texas A&M has a professional masters program in industrial engineering, and the University of Texas-Austin has a professional masters program in operations research and industrial engineering in the department of Mechanical Engineering. The proposed program will differ from these local programs, as 1) the MIE courses are dedicated to only MIE students, and Rice’s reputation and its location in Houston will attract a more selective set of students.

Industrial Engineering is a natural partnership with Mechanical Engineering. Universities with “Mechanical and Industrial Engineering” departments include:

- University of Massachusetts-Amherst
- University of Iowa
- University of Illinois-Chicago
- Northeastern University
- University of Toronto
Universities with “Industrial Engineering and Operations Research” (or similar) departments include:

- UC Berkeley
- Columbia University
- Cornell University (Operations Research & Industrial Engineering)
- Northwestern University (Industrial Engineering & Management Science)
- University of Michigan (Operations and Industrial Engineering)

Programs similar to the MIE exist at Rice’s peer institutions, and these degrees are very popular with students. Stanford’s Management Science and Engineering’s masters program has over 300 students. Georgia Tech’s School of Industrial and Systems Engineering awards 215 professional masters degrees per year. In 2014, Cornell’s School of ORIE enrolled 71 new students into its masters program. Columbia’s Department of Industrial Engineering and Operations Research recently granted over 300 masters degrees in a single year.

Industrial Engineering is the sixth-most popular engineering masters degree in the United States, with 3,538 granted in 2014-15. Nationwide, more than twice as many Masters in Industrial Engineering were granted than Masters in Chemical Engineering. The number of Masters of Industrial Engineering degrees granted has grown by 33% over the last ten years.

Houston “has more manufacturing jobs than any other U.S. city,” according to the Greater Houston Partnership. We anticipate that there are many potential MIE students in greater Houston. Professionals working in the energy, manufacturing, aerospace, infrastructure, finance, healthcare, and petrochemical industries will also be attracted to the MIE program.

Industrial Engineering has many components that are long established at Rice. Operations Research is a key part of Industrial Engineering. Although a stand-alone discipline at many of Rice’s peer institutions, OR at Rice cuts across many departmental boundaries, including faculty from CAAM, STAT, COMP, CEVE, ECE, and ECON, among others. Human factors, which considers how humans interact with complex systems, is traditionally housed in Psychology and Industrial Engineering departments. It is therefore appropriate that the Masters of Industrial Engineering be an inter-disciplinary degree housed in the George R. Brown School of Engineering.

1 [http://msande.stanford.edu/academics/graduate-programs/frequently-asked-questions](http://msande.stanford.edu/academics/graduate-programs/frequently-asked-questions)
2 [http://www.isye.gatech.edu/academics/masters/prospective-students/facts-rankings](http://www.isye.gatech.edu/academics/masters/prospective-students/facts-rankings)
5 ibid page 38
6 [https://www.houston.org/assets/pdf/opportunity/Manufacturing.pdf](https://www.houston.org/assets/pdf/opportunity/Manufacturing.pdf)
II. Faculty and Courses
The MIE will be a two-semester non-thesis masters degree, beginning every Fall semester, and finishing the next spring. As this is a non-thesis masters, students will take 15 hours in the fall and 16 hours in the spring semester.

- **Session 1 (Fall):** 5 courses, 15 credit hours
  - INDE 501 *Fundamentals of Industrial Engineering* (3) -NEW-
  - MECH 503 *Computer Aided Design* (3) -Existing-
  - MECH 545 *Prescriptive Analytics* (3) -NEW-
  - STAT 571 *Probability and Statistical Inference* (3) -NEW-
  - An approved technical elective

- **Session 2 (Spring):** 6 courses, 16 credit hours
  - INDE 509 *Introduction to Human Factors Engineering* (3) -NEW-
  - INDE 590 *Masters Industrial Engineering Capstone Experience* (1) -NEW-
  - MECH 543 *Manufacturing Processes & Systems* (3) -NEW-
  - MECH 546 *Computational Prescriptive Analytics* (3) -NEW-
  - STAT 572 *Stochastic Processes and Simulation* (3) -NEW-
  - An approved technical elective

Technical electives must be relevant to industrial engineering, and will be approved by the Professional Masters of Industrial Engineering Governing Committee.

A unique aspect to the MIE program is that the core courses will be dedicated to masters students. Masters students have educational requirements that are distinct from those of undergraduates and PhD students, and, indeed, most of Rice’s peer institutions offer separate masters courses. We believe that having MIE students in courses designed for masters students will greatly enhance their learning experience.

Seven of the courses will be offered by Rice departments (Mechanical Engineering and Statistics), while the other three will be offered by the Brown School of Engineering.

- MECH 503 *Computer Aided Design* is an existing course. The Department of Mechanical Engineering will offer a dedicated section of MECH 503 for MIE students.
- INDE 501 *Fundamentals of Industrial Engineering*, INDE 509 *Introduction to Human Factors Engineering*, MECH 543 *Manufacturing Processes and Systems*, will be offered by a full-time instructor in the Department of Mechanical Engineering.
- MECH 545 *Prescriptive Analytics*, and MECH 546 *Computational Prescriptive Analytics* will be taught by Andrew Schaefer, CAAM, director of the MIE.
The School of Engineering has provided sufficient funds to cover the initial operating costs.

The Professional Masters of Industrial Engineering Governing Committee, under the direction of the Dean of Engineering, shall oversee every aspect of the curriculum. The curriculum of every course in the MIE will be evaluated by this committee with consultation from the Rice Center for Teaching Excellence.

Admissions  Applicants for the MIE will meet or exceed the standards established in other professional masters programs at Rice and peer institutions. Applicants are expected to have:

- A B.S. or B.A. degree in a quantitative field from an accredited institution expected prior to the start of the program;
- GRE scores;
- TOEFL scores for applicants whose native language is not English;
- Evidence of programming proficiency in C, C++, java, R, matlab, python or an appropriate alternative;
- Official transcripts; and
- At least two letters of recommendation.

The application fee is $85, which is consistent with other professional masters programs in the School of Engineering.

III. Learning Objectives
The MIE program will introduce students to improving the quality and reliability of complex systems arising in industrial and other settings. In particular, they will gain expertise in fundamental industrial engineering tools, including manufacturing, material handling, logistics, decision models, and incorporating uncertainty.
More specifically, the MIE program has the following Program Learning Objectives (PLOs):

- **Program Learning Outcome 1:** *Build physical and mathematical models of complex systems that arise in real-world situations.*

  The building of realistic, yet tractable, models is a key aspect of all of science and engineering. MIE students will learn how to build 1) mathematical models of complex systems, 2) physical models of manufacturing processes, and 3) how humans affect these systems.

  Mathematical models have several variants, such as *statistical models* of complex data, *stochastic models* of uncertain, real-world situations, and *decision models* that choose best choices from a large number of possibilities.

  Physical models of manufacturing processes relate the fundamental physical properties of materials with the economic and physical attributes of various manufacturing processes.

  Human factors in engineering systems are crucial for industrial engineering. Of particular importance is human-machine interaction, as well as understanding the effects of human groups.

  For these models, students will learn the assumptions behind modeling choices, and the trade-offs that they entail.

  Relevant courses include:
  
  i. MECH 503 *Computer Aided Design*;
  ii. INDE 501 *Fundamentals of Industrial Engineering*;
  iii. INDE 509 *Introduction to Human Factors Engineering*;
  iv. INDE 590 *Masters of Industrial Engineering Capstone Experience*;
  v. MECH 543 *Manufacturing Processes & Systems*;
  vi. MECH 545 *Prescriptive Analytics*;
  vii. STAT 571 *Probability and Statistical Inference*;
  viii. STAT 572 *Stochastic Processes and Simulation*.

- **Program Learning Outcome 2:** *Understand the flow of material from manufacturing to warehouses to customers through physical and mathematical models.*

  A key component of industrial engineering is the flow of goods from raw materials to finished goods with end customers.

  The first step in this flow is manufacturing processes (e.g. stamping, forming, casting, 3D printing) and then manufacturing systems, which determine the best way to use these manufacturing processes (e.g. machine scheduling, work flow, personnel scheduling).
Supply chain management considers how goods move from a factory to end customers. Supply chain management is a crucial reason for the success of companies such as Walmart and Amazon. Issues such as inventory management, logistics, and facility location are key issues in successful supply chain management.

MIE students will learn how to build mathematical models of various aspects of manufacturing systems and supply chain management, and how to parameterize these models. They will also learn how to optimize the models to produce superior solutions.

Relevant courses include:

i. INDE 501 Fundamentals of Industrial Engineering;
ii. INDE 509 Introduction to Human Factors Engineering;
iii. INDE 590 Masters of Industrial Engineering Capstone Experience;
iv. MECH 503 Computer Aided Design;
v. MECH 543 Manufacturing Processes & Systems.

- **Program Learning Outcome 3: Produce implementable solutions that improve the efficiency of real-world systems.**

The decision models can be extraordinarily difficult to solve. For example, the number of possible solutions of a classical “traveling salesman problem” over a thousand cities has over 2500 digits! (The number of atoms in the universe has “only” 82 digits). The more general vehicle routing problem, which is routinely solved in practice, is even more difficult. Yet such problems can be solved to optimality in a few hours using industrial engineering techniques.

MIE students will learn how to find exact and approximate solutions to a wide variety of decision models. They will learn commercial/open-source software and how to implement stand-alone algorithms.

The relevant courses include:

i. INDE 590 Masters of Industrial Engineering Capstone Experience;
ii. MECH 545 Prescriptive Analytics;
iii. MECH 546 Computational Prescriptive Analytics;
iv. STAT 571 Probability and Statistical Inference;
v. STAT 572 Stochastic Processes and Simulation.

- **Program Learning Outcome 4: Communicate the solutions and insights generated by the models to a non-technical audience.**

Industrial engineering requires careful trade-offs between model complexity and tractability. These models must be carefully interpreted and their implications
conveyed to nontechnical audiences. As such, effective communication skills are essential for practicing industrial engineers.

The relevant courses are the capstone course INDE 590, as well as INDE 501, MECH 545, MECH 546 and STAT 572. In the capstone course, students will write a field report related to one of the spring core courses (INDE 509, MECH 543, MECH 546, STAT 572), and present it in class. In INDE 501, MECH 545, MECH 546 and STAT 572, students will have a group project that includes a final report and presentation.

**Table 1: Course mapping to program learning objectives (PLOs)**

<table>
<thead>
<tr>
<th>PLO 1: Students will build physical and mathematical models of complex systems that arise in real-world situations</th>
<th>PLO 2: Students will understand the flow of material from manufacturing to warehouses to customers through physical or mathematical models</th>
<th>PLO 3: Students will use these models to produce implementable solutions that improve the efficiency of the real-world system</th>
<th>PLO 4: Students will be able to communicate the solutions and insights generated by the models to a nontechnical audience</th>
</tr>
</thead>
<tbody>
<tr>
<td>FALL Courses</td>
<td></td>
<td></td>
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<tr>
<td>INDE 501 Fundamentals of Industrial Engineering</td>
<td>Practiced</td>
<td>Practiced</td>
<td></td>
</tr>
<tr>
<td>MECH 503 Computer Aided Design</td>
<td>Practiced</td>
<td>Practiced</td>
<td></td>
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<tr>
<td>MECH 545 Prescriptive Analytics</td>
<td>Practiced</td>
<td>Practiced</td>
<td></td>
</tr>
<tr>
<td>STAT 571 Probability and Statistical Inference</td>
<td>Practiced</td>
<td>Practiced</td>
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<tr>
<td>Technical elective</td>
<td></td>
<td></td>
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<tr>
<td>SPRING Courses</td>
<td></td>
<td></td>
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<tr>
<td>INDE 509 Intro to Human Factors Engineering</td>
<td>Practiced</td>
<td>Practiced</td>
<td></td>
</tr>
<tr>
<td>INDE 590 MIE Capstone Experience</td>
<td>Mastered</td>
<td>Mastered</td>
<td>Mastered</td>
</tr>
<tr>
<td>MECH 543 Manufacturing Processes &amp; Systems</td>
<td>Practiced</td>
<td>Practiced</td>
<td></td>
</tr>
<tr>
<td>MECH 546 Computational Prescriptive Analytics</td>
<td>Practiced</td>
<td>Practiced</td>
<td></td>
</tr>
<tr>
<td>STAT 572 Stochastic Processes and Simulation</td>
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<td>Practiced</td>
<td></td>
</tr>
<tr>
<td>Technical elective</td>
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</tbody>
</table>

**Quality Assurance**

**Direct Assessment**

The four Program Learning Objectives will be directly assessed through the report and presentation for the Capstone Experience, INDE 590.

Every course in the program will be evaluated annually, and these evaluations will be used to identify and address any concern that may arise. Classes will be periodically observed by members of the MIE Governing Committee (see Section IV).

To keep the MIE degree current and responsive to industry, the MIE Advisory Committee (see Section IV) will provide feedback on new trends in industry.
Program Assessment Plan
Upon completion of the Professional Masters in Industrial Engineering, students should have expertise in formulating, calibrating, solving and interpreting industrial engineering models. The assessment review will follow best practices established by the Rice Office of Institutional Effectiveness. It will include indirect assessment such as student evaluations of individual courses, performance in the capstone experience, exit interviews and exit surveys so that the effectiveness of the MIE degree can be continually assessed and improved. The MIE Governing Committee will conduct a follow-up survey five years after graduation.

Long-Term Assessment Measures
The program will gather the following data annually: (1) percent of students who finish the degree, (2) additional advanced degrees sought by alumni of the program, (3) elapsed time between completion of the degree requirements and employment, and (4) data from the graduate student exit survey, administered by the Rice Office of Institutional Effectiveness.

The MIE Governing Committee (see Section VI) will work closely with the Rice Office of Institutional Effectiveness\(^8\) to assure that the MIE PLOs are assessed, and that the MIE program undergoes a process of continuous improvement in response to the assessments.

For assessment purposes, the Graduate Council will receive from the Office of the Dean of Engineering an evaluation of the program after three years, to include information regarding staffing, faculty involvement, student admissions, student retention, quality of instruction, and budget overview.

Risk Assessment and Contingency
The biggest risk to the MIE program is that the “break-even” enrollment (see Section V), may not materialize. If the MIE program cannot sustain a steady class of approximately 15 highly qualified students, the Dean of Engineering will terminate the MIE. To reduce this risk, the MIE Governing Committee will work closely with the School of Engineering to market the MIE program. The MIE will not become overly reliant on any single source of students, so as to mitigate economic and political risks.

The Dean of Engineering will have the final say in the MIE’s operations and finances. Professor Andrew Schaefer will teach MECH 545 Prescriptive Analytics and MECH 546 Computational Prescriptive Analytics in the 2018-19 academic year. The Dean of Engineering is committed to having at least three of the core courses will be taught by tenured faculty in the 2019-20 academic year, and at least half of the eight MIE cores will be taught by tenured faculty starting in the Fall of 2020. He has confidence that the MIE Governing Committee will maintain Rice’s high scholarly quality. He plans to appoint a leading external Industrial Engineering faculty member to the MIE Advisory Committee to ensure that the quality of the degree is second-to-none. He says that should this external faculty member raise any concerns, he will make sure that they are immediately addressed.

\(^8\)oie.rice.edu
IV. Resources

The MIE Governing Committee will make all academic decisions regarding the MIE, including admissions decisions. The composition of the MIE Governing Committee will be determined by the Dean of Engineering, who must approve all decisions made by the MIE Governing Committee. The MIE Governing Committee will consist of no fewer than four tenured faculty in engineering. The members of the MIE Governing Committee will be compensated for their efforts through “D funds” provided by the MIE program.

Proposed Initial Masters of Industrial Engineering Governing Committee:

- Leonardo Duenas-Osorio, CEVE. Dr. Duenas-Osorio’s PhD minor was in Industrial Engineering.
- Illya Hicks, CAAM. Dr. Hicks spent 6 ½ years on the Industrial Engineering faculty at Texas A&M.
- Andrew J. Schaefer, CAAM, Director of MIE. Dr. Schaefer’s PhD is in Industrial Engineering, and he spent 15 years on the Industrial Engineering faculty at the University of Pittsburgh.
- Pol Spanos, MECH. Dr. Spanos is an expert in dynamical systems and control, and a member of the National Academy of Engineering.

Rice Center for Operations Research (RCOR) Affiliated Faculty:

- Randy Batsell, Jones School
- Swarat Chaudhuri, COMP
- Dennis Cox, STAT
- Leonardo Duenas-Osorio, CEVE
- Hulya Eraslan, ECON
- Philip Ernst, STAT
- Jeremy Fox, ECON
- Paul Hand, CAAM
- Yinghua He, ECON
- Illya Hicks, CAAM
- Marek Kimmel, STAT
- Mallesh Pai, ECON
- Amit Pazgal, Jones School
- Andrew Schaefer, CAAM, Director of MIE
- Laura Schaefer, MECH
- David Scott, STAT
- Anshumali Shrivastava, COMP
- Robin Sickles, ECON
- Pol Spanos, MECH
- Richard Tapia, CAAM
- Yin Zhang, CAAM
Agustina Fernandez-Moya, the Director of Engineering Professional Masters, and her office will handle all other administrative issues for the MIE students for the first three years of operations. Subsequently, the program will hire an administrator to facilitate the operation of the MIE program.

*MIE Advisory Committee:*
This committee will consist of Industrial Engineering practitioners who can ensure that the program remains relevant to Industrial Engineering in practice. It will also have at least one highly accomplished external academic member from a leading Industrial Engineering department to ensure that the quality of the MIE remains of the highest caliber.

Eventually, we plan to have MIE alumni serve on this committee.

No additional library or information resources are anticipated to launch the program.

V. Financial Model

The following was prepared by Bart Sinclair, Associate Dean of Engineering. The Budget Office and VP of Finance reviewed the budget projections and they have no objections with the budget projections. The Dean of Engineering will determine how tuition revenues are distributed across the participating departments and the Rice Center for Operations Research. The MIE program will use existing Rice staff to process applications, visas, etc., and will compensate the relevant departments appropriately.

### Summary of Budget and Worst-Case Analysis
*Prepared by Bart Sinclair, Associate Dean, George R. Brown School of Engineering*

#### Projected Enrollment and Summary of Budget:

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
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<tbody>
<tr>
<td>Enrollment</td>
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<td>25</td>
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<tr>
<td>Total Tuition</td>
<td>$924,000</td>
<td>$1,189,650</td>
<td>$1,225,340</td>
<td>$1,262,100</td>
<td>$1,299,963</td>
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<td>Central Portion</td>
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<td>$252,420</td>
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<td>Central Portion (20% of total)</td>
<td>$14,784</td>
<td>$19,034</td>
<td>$19,605</td>
<td>$20,194</td>
<td>$20,799</td>
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<tr>
<td>School of Engineering Professional Masters Support (1.6% of total)</td>
<td>$362,208</td>
<td>$466,343</td>
<td>$480,333</td>
<td>$494,743</td>
<td>$509,585</td>
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<tr>
<td>School of Engineering Portion (39.2% of total)</td>
<td>$362,208</td>
<td>$466,343</td>
<td>$480,333</td>
<td>$494,743</td>
<td>$509,585</td>
</tr>
<tr>
<td>Net Tuition Revenue (39.2% of total)</td>
<td>$362,208</td>
<td>$466,343</td>
<td>$480,333</td>
<td>$494,743</td>
<td>$509,585</td>
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<tr>
<td>Instructional Expenses</td>
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<td>$230,841</td>
<td>$236,612</td>
<td>$242,528</td>
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<td>Staff Expenses</td>
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<td>$21,023</td>
<td>$21,549</td>
<td>$22,087</td>
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<td>Operating Expenses</td>
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<td>Total Expenses</td>
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<td>$328,602</td>
<td>$337,203</td>
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<td>Net</td>
<td>$45,055</td>
<td>$137,741</td>
<td>$143,130</td>
<td>$148,712</td>
<td>$154,494</td>
</tr>
</tbody>
</table>

Summary of Break-Even Analysis:

- 8 students in year 1
- 16 in subsequent years

VI. Administration

The target enrollment is 20 MIE students per year in the first year, and a steady-state enrollment of 25 MIE students per year thereafter.

The full-time lecturer will assist the MIE Governing Committee with student advising, including job placement, and degree certification. Students will be informed in writing of their progress towards degree completion after every semester.

Marketing: The MIE program at Rice University will be advertised through multiple channels.

- The MIE program will be advertised on the MECH departmental webpage\(^9\).
- The MIE program will be listed on the Rice School of Engineering Professional Masters webpage\(^10\).
- Links to the MIE webpage will be placed on the RCOR website.
- The MIE program will be advertised in social and print media.
- Professor Leonardo Duenas-Osorio will reach out to leading universities across South and Latin America.
- The MIE program will be advertised to Rice University undergraduates.
- The MIE Governing Committee will work closely with local industry and Alumni relations to reach interested students.

Through these channels, we are confident that the program will attract a strong cohort of students.

We will work closely with the Director of Engineering Professional Masters Programs, Agustina Fernandez-Moya, to prepare a brochure describing the MIE and to benefit from their experience in marketing similar programs at Rice.

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\(^9\) [http://www.mech.rice.edu](http://www.mech.rice.edu)

\(^10\) [http://engrprofmasters.blogs.rice.edu/](http://engrprofmasters.blogs.rice.edu/)
VII. Degree Requirements

(For proposed General Announcements text, please see Attachment A.)

Degree Requirements

<table>
<thead>
<tr>
<th>Core Requirements</th>
<th></th>
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<tbody>
<tr>
<td>INDE 501 (NEW) Fundamentals of Industrial Engineering</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>INDE 509 (NEW) Introduction to Human Factors Engineering</td>
<td>3</td>
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</tr>
<tr>
<td>MECH 503 (Existing) Computer Aided Design</td>
<td>3</td>
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<tr>
<td>MECH 543 (NEW) Manufacturing Processes &amp; Systems</td>
<td>3</td>
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<td>MECH 545 (NEW) Prescriptive Analytics</td>
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<tr>
<td>MECH 546 (NEW) Computational Prescriptive Analytics</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>STAT 571 (NEW) Probability and Statistical Inference</td>
<td>3</td>
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<tr>
<td>STAT 572 (NEW) Stochastic Processes and Simulation</td>
<td>3</td>
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</tr>
</tbody>
</table>

Elective Requirements (from George R. Brown School of Engineering)

Select 2 approved technical electives: 6

Capstone Requirement

<table>
<thead>
<tr>
<th>Capstone Requirement</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>INDE 590 (NEW) Masters of Industrial Engineering Capstone</td>
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</tbody>
</table>

Total Credit Hours 31

Graduates must have a 3.0 GPA in required coursework. At most two courses may be transferred from other institutions. The Masters of Industrial Engineering program is limited to full-time students.

Rice University is accredited by the Southern Association of Colleges and Schools Commission on Colleges (SACSCOC) to award baccalaureate, masters, and doctorate degrees. SACSCOC will be informed of this new degree program once it is approved by the Rice Faculty Senate and the administration. The CIP code is 14.3701.

The eight new courses below are part of the core requirements of the MIE degree program, and will be added to the university's Course Catalog, and the General Announcements.

- **INDE 501: Fundamentals of Industrial Engineering.** Offered every fall. Introduction to fundamental tools in industrial engineering. Topics include productivity analysis, material handling, logistics, design of experiments, quality control, location theory, warehouse design, supply chain management, and scheduling. Prerequisite: Enrollment in the Professional Masters in Industrial Engineering.
• **INDE 509: Introduction to Human Factors Engineering.** Offered every spring. Analysis and design of engineering systems considering human characteristics and limitations. Design of controls, displays, tools, workstations, and groups. Human factors research methods. Prerequisite: INDE 501.

• **INDE 590: Masters of Industrial Engineering Capstone Experience.** Offered every spring. MIE students are required to write a field report related to one of the four spring core courses in the curriculum (INDE 509, MECH 543, MECH 546, STAT 572). With the approval of the course instructor, the student must prepare a report relevant to the course material, and present it in class. Topics must be approved no later than the end of the seventh week of the semester. The final written report is due by the last class meeting.

• **MECH 543: Manufacturing Processes and Systems.** Offered every spring. Fundamentals of manufacturing processes. Topics include machining, casting, 3D printing, material flow, capacities, bottlenecks and just-in-time systems. Simulation and optimization of various manufacturing systems. Trade-offs among various processes. Prerequisite: INDE 501.

• **MECH 545: Prescriptive Analytics.** Offered every fall. A survey of methods for combining mathematical techniques and large data sets to produce optimal decisions. Topics include decision analysis, dynamic programs, mathematical programs, and various heuristics. Prerequisites: undergraduate linear algebra and permission of instructor.

• **MECH 546: Computational Prescriptive Analytics.** Offered every spring. A continuation of MECH 545 that focuses on computational approaches to prescriptive analytics. Topics include decomposition approaches to large-scale optimization, modeling languages, decision analysis and discrete-event simulation software. Emphasis will be placed on using relevant software on practical problems. Prerequisites: MECH 545.

• **STAT 571: Probability and Statistical Inference.** Offered every fall. Probability, random variables, probability distributions, sampling and convergence, hypothesis testing, and ANOVA and regression. Introduction to statistical software. Prerequisite: Enrollment in the Professional Masters in Industrial Engineering.

• **STAT 572: Stochastic Processes and Simulation.** Offered every spring. Markov chains, renewal processes, queueing theory, statistical quality control, and discrete-event simulation. Prerequisite: STAT 571.

### VIII. Launch

The marketing for the MIE degree will begin in the spring of 2018. Applicants will apply in the spring of 2018. The first students will enroll in the fall of 2018.
IX. Support

Attached are:

- A letter from the Dean of Engineering.
- A letter from the Dean for Graduate and Postdoctoral Studies.
- A letter from the Graduate Chair of Mechanical Engineering.
- A letter from the Chair of the Statistics Department.
Attachment A. Proposed General Announcements Text

This proposed new degree program will be referenced in the General Announcements under Industrial Engineering, a new entry in the Programs of Study section;

General Announcements: Industrial Engineering (GA Text: Program Overview)

Industrial Engineering

Modern industrial systems, which arise in fields such as manufacturing, supply chain management, energy, transportation and healthcare, are extremely complex. Analyzing and optimizing their performance is very challenging; for example, the number of ways that Federal Express can route its vehicles vastly exceeds the number of atoms in the universe. These analyses are crucial; their financial impact typically exceeds the profit margins in many industries, such as transportation and retailing.

To meet these challenges, the Professional Masters in Industrial Engineering (MIE) emphasizes improving the quality and reliability of complex systems. It provides students with a deep set of analytical and engineering skills, and contextual knowledge of important problem domains, such as healthcare, energy and manufacturing. MIE graduates will help industry, governments and non-profits improve efficiency in changing and uncertain environments.

Master’s Programs

- Master of Industrial Engineering (MIE) Degree (NEW)

General Announcements: Industrial Engineering (GA Text: Program-Specific Detail)

Master of Industrial Engineering (MIE) Degree

Program Learning Outcomes for the MIE Degree

Upon completing the MIE degree, students will:

1. Build physical and mathematical models of complex systems that arise in real-world situations.
2. Understand the flow of material from manufacturing to warehouses to customers through physical or mathematical models.
3. Produce implementable solutions that improve the efficiency of real-world systems.
4. Communicate the solutions and insights generated by the models to a non-technical audience.
Master of Industrial Engineering (MIE) Degree

Requirements for the MIE Degree

The MIE degree is a non-thesis master's degree. For general university requirements, please see Non-Thesis Master's Degrees. Students pursuing the MIE degree must complete:

- A minimum of 11 courses (31 credit hours) of approved coursework at the 500-level or higher.
- A minimum of 9 courses, including INDE 590, (25 credit hours) must be taken at Rice University.
- A minimum overall GPA of 3.0 in required coursework.
- A maximum of 2 courses (6 credit hours) from transfer credit. For additional departmental guidelines regarding transfer credit, see the Policies tab.
- A capstone course. (MIE students are required to write a field report related to one of the four (4) spring core courses in the curriculum (INDE 509, MECH 543, MECH 546, or STAT 572). With the approval of the course instructor, the student must prepare a report relevant to the course material, and present it in class. Topics must be approved no later than the end of the seventh week of the semester. The final written report is due by the last class meeting.)

The professional master's degree in Industrial Engineering (MIE) is a non-thesis degree program intended for students who have completed a 4-year bachelor's program in engineering and wish to join the workforce as practicing professionals, rather than pursuing a research-oriented or academic career. It offers preparation in advanced engineering topics in order to enhance an engineer's technical qualifications and increases competitiveness in the job market. The MIE program is open to students who have shown academic excellence in their undergraduate studies.

Summary

| Total Credit Hours Required for the MIE degree | 31 |

Degree Requirements

<table>
<thead>
<tr>
<th>Core Requirements</th>
<th></th>
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<tbody>
<tr>
<td>INDE 501 (NEW)  Fundamentals of Industrial Engineering</td>
<td>3</td>
</tr>
<tr>
<td>INDE 509 (NEW)  Introduction to Human Factors Engineering</td>
<td>3</td>
</tr>
<tr>
<td>MECH 503 (Existing)  Computer Aided Design</td>
<td>3</td>
</tr>
<tr>
<td>MECH 543 (NEW)  Manufacturing Processes &amp; Systems</td>
<td>3</td>
</tr>
<tr>
<td>MECH 545 (NEW)  Prescriptive Analytics</td>
<td>3</td>
</tr>
<tr>
<td>MECH 546 (NEW)  Computational Prescriptive Analytics</td>
<td>3</td>
</tr>
<tr>
<td>STAT 571 (NEW)  Probability and Statistical Inference</td>
<td>3</td>
</tr>
<tr>
<td>STAT 572 (NEW)  Stochastic Processes and Simulation</td>
<td>3</td>
</tr>
</tbody>
</table>

| Technical Elective Requirements (from George R. Brown School of Engineering) | 6 |

Capstone Requirement

| INDE 590 (NEW)  Masters of Industrial Engineering Capstone | 1 |

| Total Credit Hours | 31 |
Proposed Plan-of-Study

The following plan-of-study represents the lockstep two-semester sequence in which students pursuing the MIE degree complete the required coursework.

<table>
<thead>
<tr>
<th>First Semester (Fall)</th>
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</thead>
<tbody>
<tr>
<td>INDE 501 (NEW) Fundamentals of Industrial Engineering 3</td>
<td></td>
</tr>
<tr>
<td>MECH 503 (Existing) Computer Aided Design 3</td>
<td></td>
</tr>
<tr>
<td>MECH 545 (NEW) Prescriptive Analytics 3</td>
<td></td>
</tr>
<tr>
<td>STAT 571 (NEW) Probability and Statistical Inference 3</td>
<td></td>
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<tr>
<td>Elective (Existing) Approved Technical Elective 3</td>
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</tr>
<tr>
<td>Total Credit Hours 15</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Second Semester (Spring)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>INDE 509 (NEW) Introduction to Human Factors Engineering 3</td>
<td></td>
</tr>
<tr>
<td>INDE 590 (NEW) Masters of Industrial Engineering Capstone 1</td>
<td></td>
</tr>
<tr>
<td>MECH 543 (NEW) Manufacturing Processes &amp; Systems 3</td>
<td></td>
</tr>
<tr>
<td>MECH 546 (NEW) Computational Prescriptive Analytics 3</td>
<td></td>
</tr>
<tr>
<td>STAT 572 (NEW) Stochastic Processes and Simulation 3</td>
<td></td>
</tr>
<tr>
<td>Elective (Existing) Approved Technical Elective 3</td>
<td></td>
</tr>
<tr>
<td>Total Credit Hours 16</td>
<td></td>
</tr>
</tbody>
</table>

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Master of Industrial Engineering (MIE) Degree

Policies for the MIE Degree

Industrial Engineering Graduate Program Handbook

The General Announcements (GA) is the official Rice curriculum. As an additional resource for students, the Masters in Industrial Engineering publishes a graduate program handbook, which can be found here: [http://gradhandbooks.rice.edu/2017_18/_inserttexthere_.pdf](http://gradhandbooks.rice.edu/2017_18/_inserttexthere_.pdf)

Admission

Admission to graduate study in Industrial Engineering is open to qualified students holding a BS or a BA degree in a quantitative field from an accredited institution. The MIE degree governing committee will evaluate the previous academic record and credentials of each applicant individually, and will make all admissions decisions.
Financial Aid

No financial aid is available from Rice University or the Industrial Engineering program for students in the MIE degree program.

Transfer Credit

For Rice University's policy regarding transfer credit, see Transfer Credit. Some departments and programs have additional restrictions on transfer credit. Students are encouraged to meet with their academic program’s advisor when considering transfer credit possibilities.

Departmental Transfer Credit Guidelines

Students pursuing the MIE degree should be aware of the following departmental transfer credit guidelines:

- No more than 6 credit hours of credit from another U.S. or international universities of similar standing at Rice may apply towards the degree. Transferred courses must be comparable in content and depth to the corresponding course at Rice, and must not have counted toward another degree.

- Request for transfer credit will be considered by the Industrial Engineering Graduate Committee Chair, and the instructor of the equivalent Rice course.

Additional Information

For additional information, please see the Industrial Engineering website: https://insert_text_here.rice.edu/

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Master of Industrial Engineering (MIE) Degree

Opportunities for the MIE Degree

Admittance into the MIE Degree program for Rice Undergraduate Students

Rice undergraduate students have an option to begin pursuing the MIE degree by adding to their four undergraduate years of engineering studies. Advanced Rice undergraduate students in good academic standing may apply to the MIE program during their junior year. Upon acceptance, depending on course load, financial aid status, other variables and special permission, they may then start taking courses for the MIE degree program during their senior year. A plan of study, including special registration for MIE courses will need to be approved by the MIE program director and the relevant MIE course instructors.

As part of this option and opportunity, Rice undergraduate students:

- must complete the requirements for their bachelor's degree and the MIE degree independently of each other (i.e. no course may be counted toward the fulfillment of both degrees).
- should be aware that there could be financial aid implications, if the conversion of undergraduate coursework to that of graduate-level reduces their earned undergraduate credit for any semester below that of full-time status (12 credit hours).

Additional Information

For additional information, please see the Industrial Engineering website: https://insert_text_here.rice.edu/
February 15, 2018

Dear Members of Graduate Council,

I am writing to express my strong support for a Professional Masters in Industrial Engineering in the School of Engineering.

Industrial Engineering is a critical field of study for several key areas including manufacturing, supply chain management, sustainable energy, transportation and mobility, and healthcare. All of these areas are critical for our city, our region, and the nation. The ability to analyze and optimize the performance of engineering systems and processing is a key challenge that is addressed in the study of industrial engineering.

The 31 credit-hour Professional Masters in Industrial Engineering (MIE) will offer a unique graduate-level education that will address some of the most complex programs in society. Industrial Engineering is the largest engineering discipline that is currently not offered in the School of Engineering at Rice. Furthermore, Industrial Engineering brings together several engineering disciplines and is closely linked to the Jones School of Business and the School of Social Sciences. In addition, the program will leverage past and future investments in the Data Science Initiative. I anticipate significant demand for the program among students and employers. In fact, in many top engineering programs, Industrial Engineering is among the top two most popular majors.

Strengthening industrial engineering (and related areas) is one of my highest priorities as Dean of the George R. Brown School of Engineering. To demonstrate my commitment to the MIE, it will be administered through the School of Engineering, rather than through a department. The School of Engineering is the natural home for the MIE, as the field of industrial engineering draws from multiple engineering departments at Rice (faculty with disciplinary experience in IE across the GRB School of Engineering are represented by the MIE Governing Committee. Moreover, note that other schools across Rice, including the Wiess School of Natural Sciences, the Jones School, and the School of Architecture, administer professional master degrees (https://oaa.rice.edu/rice-university-professional-masters-programs)).

I will have final say in the MIE’s operations and finances. I will ensure that a majority of the eight MIE core classes will be taught by full-time Rice faculty. Professor Andrew Schaefer will teach MECH 545 Prescriptive Analytics and MECH 546 Computational Prescriptive Analytics in the 2018-19 academic year. I will ensure that for the 2019-20 academic year, at least three of the 8 core MIE courses will be taught by tenured Rice faculty, and at least half starting in the Fall of 2020. I have great confidence that the MIE Governing Committee will maintain Rice’s high scholarly quality. I will appoint a leading external Industrial Engineering faculty member to the MIE Advisory Committee to ensure that the quality of the degree is second-to-none. Should this external faculty member raise any concerns, I will make sure that they are immediately addressed.

In summary, I enthusiastically support the creation of a Professional MS in Industrial Engineering in the School of Engineering at Rice University. The program can have a significant impact on our students and in the region. Please do not hesitate to contact me if you should have any further questions.

Sincerely,

Reginald DesRoches, Ph.D., F. ASCE, F. SEI
Dean of Engineering
January 9, 2018

Professor April DeConick  
Chair, Graduate Council

Dear April,

I write to endorse the Professional Masters in Industrial Engineering proposal. Industrial engineering is an important topic, and particularly relevant to Rice given the strong manufacturing base in Houston. We clearly have the expertise to do it—a number of our faculty have substantial stature in industrial engineering.

A complication is that we have neither an industrial engineering department, nor bachelor’s or doctoral programs. Master’s programs at Rice generally arise from a department of the same name, and so follow a standard governing structure, with a DGS/graduate committee who are appointed by the department chair, who is in turn appointed by the school dean. The faculty are generally appointed in the same department and are given their teaching assignments by the department chair. Master’s programs generally evolve from a bachelor’s or doctoral program of the same name, and so take advantage of some existing expertise and courses.

The placement of the program directly under the School of Engineering makes sense to me, given that we don’t have a corresponding department. Both the Shepherd School and Architecture have graduate programs directly under the school.

With best regards,

Seiichi P. T. Matsuda  
Dean of Graduate and Postdoctoral Studies
January 12, 2018

To the Graduate Council:

I am writing to enthusiastically endorse the launch of a new professional Masters in Industrial Engineering (MIE) at Rice University, to be administered through the George R. Brown School of Engineering. An educational program in industrial engineering trains students to apply science, mathematics, and engineering methods to complex system integration and operations. A practicing Industrial Engineer strives to improve systematic processes using techniques and methods from statistics, engineering professional communication, design, project management and planning, operations management, and computational simulation.

As Chair of the Graduate Committee in Mechanical Engineering, and on behalf of my department (at the behest of my chair Laura Schaefer, who has recused herself due to the potential appearance of a conflict of interest) I wish to convey the clear and overwhelming support of the Department of Mechanical Engineering for the development and launch of this professional master’s program. At a recent faculty meeting, after extensive discussion of the proposed MIE program, there was a strong and favorable vote of support (9 for, 0 against, 4 abstaining, with 1 abstention coming from the recused chair, and 2 coming from faculty away on sabbatical). We are committed to provide the support necessary to see this program succeed. MECH will serve as the home department for this professional masters program, and as described in the proposal, we acknowledge that an additional section of MECH 503 will be added and taught by a full-time instructor, currently planned to be Dr. Eleazar Marquez.

It has become apparent that – at Rice and elsewhere – the Professional Engineering Masters (PEM) degrees are indeed filling a real need for students, and that business and industry recognize the value of PEM education. Rice already has a successful program of PEM offerings in several fields, thus having established the viability of the concept in Houston and within Rice. The programs are primarily situated within a discipline (e.g. Master of Mechanical Engineering, Master of Electrical Engineering) and allow a student to gain greater depth and breadth in a core area of engineering. What is unique about this proposed PEM program in Industrial Engineering is that, while sitting within a core engineering department (Mechanical Engineering), Industrial Engineering is the largest engineering discipline not present at Rice.

Properly designed and executed, these programs fill a real educational and social need, and can do so in ways that capitalize on existing course offerings without creating a large additional burden on the faculty or the institution. Indeed, the MIE proposal includes dedicated courses that will be taught by a full-time teaching faculty member (already identified, and to be recruited), combined with offerings in mechanical engineering and statistics, and courses offered directly through the School of Engineering (ENGI). The size of the proposed program is expected to be about 20-25 students per year. These students will receive dedicated attention and instruction in their courses.

One critical consideration in the design of – and decision to offer – such programs is the existence of need and opportunity. As the proposal summarizes, students trained in industrial engineering and the related field of operations research are highly sought after, and degree programs that train students in these areas are poised to be attractive to companies in the Houston area both for recruiting new employees, and for retraining of their current workforce. It has also become apparent that such a program can prepare Rice PEM graduates for attractive career opportunities.
As the proposal describes, existing IE programs nationwide are sometimes aligned with mechanical engineering departments, and indeed at Rice, we see this program best fitting within the Department of Mechanical Engineering. Our department has a small but successful PEM degree in our discipline, and we have had discussions regarding the potential to grow this offering. Our Graduate Committee is excited about the opportunity to partner with the Rice Center for Operations Research and its affiliated faculty to offer this novel degree program and to explore how such targeted programs can be leveraged to increase Rice’s impact locally, to grow industrial partnerships in Mechanical Engineering, and to increase the opportunities available to our undergraduate students.

An important aspect of the proposal that our department strongly supports is the implemented plan for review of both the financial viability and academic success of the program in terms of student quality, teaching quality, and assessment of student learning after a three year period. This important evaluative step will ensure that the program is meeting our expectations of a Rice degree, and if falling short, that there is a mechanism to address any deficiencies.

As pointed out in the proposal, similar programs at peer institutions (e.g. Stanford, Cornell, Columbia, and Northwestern) are extremely popular among full-time students. I appreciate that much of the curriculum consists of courses that are especially designed for MIE students. I believe this will be a very successful program that will enhance the reputation and visibility of both IE and MECH at Rice.

A qualified individual has already been identified by the executive committee putting forth the proposal for the degree. Further, we have developed a shared revenue plan that will put funds from tuition in this program both in the Department of Mechanical Engineering to offset the additional load of students in our courses, and in the Center for Operations Research to continuously support activities including recruitment, administration, and teaching.

In summary, I have carefully examined the proposal and fully support the launch of the professional Masters in Industrial Engineering program at Rice University. In my view, the proposed program is carefully thought through and well designed. I have confidence that it will rapidly become a highly respected and valuable program, as viewed on national and international bases. The educational value, the outlook for graduates, and the opportunity for the university to help meet a growing societal need, speak in favor approving this program.

Sincerely,

Marcia O’Malley, PhD
Director of Graduate Studies
Department of Mechanical Engineering
January 11th, 2018

To: Graduate Council

Re: Masters in Industrial Engineering

On behalf of the Department of Statistics, I would like to express enthusiastic support for the proposal for a Professional Masters in Industrial Engineering (MIE) by the George R. Brown School of Engineering, with the assistance of the Department of Mechanical Engineering and the Rice Center for Operations Research.

Statistics and Industrial Engineering have significant overlap nationwide. Many Industrial Engineering departments have significant statistics components, including Cornell and Georgia Tech. Even more Industrial Engineering departments have significant expertise in related areas, such as stochastic processes and queueing theory, which are central to modern statistics and have always been an active component of the Rice Department of Statistics.

The Statistics faculty are very supportive of this proposal, and are confident that it will attract strong interest from students. A particularly attractive aspect of this MIE proposal is that the courses will be designed for and dedicated to professional master students.

The Department of Statistics will create and offer two new courses for the MIE: STAT 571 Probability and Statistical Inference in the fall and STAT 572 Stochastic Processes and Simulation in the spring. These courses will be taught by John Dobelman, a Professor of the Practice in Statistics with many years of experience applying these tools in practice. Professor Dobelman has already put a great deal of thought into the appropriate topics for these classes. Professor Dobelman has a particular strength in balancing a rigorous approach to the fundamentals with the practical aspects of how they are applied in industry. Professor Dobelman has taught professional masters students in Statistics for many years, and we believe that the MIE students will greatly benefit from his courses. It is a sign of our firm commitment to the MIE program that we are willing to commit such an outstanding instructor to teach these courses.

Please do not hesitate to contact me with any questions.

Sincerely,

[Signature]