# Catastrophe Modeling and Resilience

**OUR MISSION**

The Master of Science and Graduate Certificate programs in Catastrophe Modeling and Resilience (https://catmodeling.lehigh.edu/academics/) at Lehigh University provide comprehensive, interdisciplinary training designed for both full-time students and working professionals in a rapidly expanding global sector. Our mission is to integrate engineering with data science, actuarial science, and social sciences, preparing graduates for high-impact careers in the (re)insurance industry, private consulting, and public service. By equipping students with a broad mastery of systemic risk and specialized expertise in fields such as infrastructure resilience and epidemic forecasting, we empower a new generation of leaders to safeguard global communities and critical systems.

The Master's program offers a rigorous deep dive into risk modeling, featuring a flexible, hybrid format that can be completed in as little as one year or extended based on individual professional needs. The 30-credit curriculum consists of six core courses, covering catastrophe modeling, resilience assessment, and numerical methods, alongside three specialized electives and one free elective from a broad interdisciplinary portfolio. This robust approach ensures students gain the technical excellence and data-driven insights required to lead in the face of systemic threats.

Additionally, the Center offers a four-course Graduate Certificate in Catastrophe Modeling, which can be pursued as a standalone credential, a milestone toward the M.S. degree, or integrated into existing M.S. or Ph.D. programs across the university. This 12-credit certificate also utilizes a hybrid delivery model and can be completed over two or more semesters, requiring two core courses in catastrophe modeling and resilience, one course in data or actuarial science, and an elective covering various applications to natural hazards and public health.

These programs offer unparalleled academic flexibility and professional legitimacy, providing the essential framework for assessing hazards, modeling cascading failures, and designing recovery strategies to protect our increasingly interconnected and volatile world.

**CONTACT US**

Program Director: **Professor Y. C. Ethan Yang**

Program Coordinator: **Ms. Nicole DiRado**

**MASTER OF SCIENCE IN CATASTROPHE MODELING AND RESILIENCE**

This Master's program provides comprehensive training for the expanding catastrophe modeling and resilience sector. Integrating engineering with data science, actuarial science, and social sciences, the curriculum offers a broad understanding of risk and deep expertise in applications like infrastructure resilience or public health. Graduates are prepared for high-impact careers in the (re)insurance industry, private consulting, and government agencies.

The flexible, hybrid format can be completed in one year or longer. The curriculum consists of six core courses, covering catastrophe modeling, resilience assessment, and numerical methods, alongside three specialized electives and one free elective. This interdisciplinary approach equips students to lead in safeguarding communities against systemic threats through technical excellence and data-driven insights.

***Program Requirements***

The program consists of **18** credits of CAT Core Courses, **9** credits of Approved Electives, and **3** credits of Free Electives. The total required credits are **30**.

The six required CAT core courses are:

| | | |
|---|---|---|
| CAT 401 | Catastrophe Modeling and Resilience | 3 |
| CAT 402 | Applications of Catastrophe Modeling and Resilience | 3 |
| CAT 403 | Mathematics of Actuarial Science | 3 |
| DSCI 310 | Introduction to Data Science | 3 |
| ENGR 452 | Mathematical Methods In Engineering I | 3 |
| or BIOE 463 | Numerical Methods for Scientists and Engineers | |
| CAT 411 | Catastrophe Modeling and Resilience Capstone | 3 |
| or CAT 412 | Supervised Research in Catastrophe Modeling and Resilience | |

In addition to the core requirements, students are required to complete a minimum of **9** credits from a list of approved electives on the program website (see below) and **3** credits from a free elective. The course may be chosen among all the 300 or 400 level courses at Lehigh for which the student meets the criteria for enrollment.

***Recommended sequence of courses (11-month accelerated program)***

Summer Session II (July/August)

| | | |
|---|---|---|
| DSCI 310 | Introduction to Data Science | 3 |
| CAT 412 | Supervised Research in Catastrophe Modeling and Resilience | 1-3 |

Fall Semester

| | | |
|---|---|---|
| CAT 401 | Catastrophe Modeling and Resilience | 3 |
| CAT 403 | Mathematics of Actuarial Science | 3 |
| ENGR 452 | Mathematical Methods In Engineering I | 3 |
| Approved Elective | | 3 |

Spring Semester

| | | |
|---|---|---|
| CAT 402 | Applications of Catastrophe Modeling and Resilience | 3 |
| CAT 411 | Catastrophe Modeling and Resilience Capstone (Approved Elective) | 3 |
| Approved Elective | | 3 |
| Free Elective | | 3 |

***Recommended sequence of courses (16-month program)***

Year 1 Fall Semester

| | | |
|---|---|---|
| CAT 401 | Catastrophe Modeling and Resilience | 3 |
| CAT 403 | Mathematics of Actuarial Science | 3 |
| DSCI 310 | Introduction to Data Science | 3 |

Year 1 Spring Semester

| | | |
|---|---|---|
| CAT 402 | Applications of Catastrophe Modeling and Resilience | 3 |
| CAT 411 | Catastrophe Modeling and Resilience Capstone (Approved Elective) | 3 |
| Approved Elective | | 3 |

Year 1 Summer Session

| | | |
|---|---|---|
| CAT 412 | Supervised Research in Catastrophe Modeling and Resilience | 1-3 |

Year 2 Fall Semester

| | | |
|---|---|---|
| BIOE 463 | Numerical Methods for Scientists and Engineers (Approved Elective) | 3 |
| Approved Elective | | 3 |
| Free Elective | | 3 |

**GRADUATE CERTIFICATE IN CATASTROPHE MODELING AND RESILIENCE**

The four-course Graduate Certificate in Catastrophe Modeling can be completed as a standalone credential, a milestone toward the M.S. in Catastrophe Modeling, or integrated into any M.S. or Ph.D. program. Credits count toward both degrees, allowing students to specialize while pursuing other disciplines like Civil Engineering.

This hybrid program offers flexible timing, spanning two or more semesters. The curriculum consists of two core courses in catastrophe modeling and resilience, one course in data or actuarial science,

and one elective from an interdisciplinary portfolio covering various applications to natural hazards and public health.

***Required courses***

Four courses (**12** credits) are required in total for the certificate. The following two courses are required (**3** credits each):

| | | |
|---|---|---|
| CAT 401 | Catastrophe Modeling and Resilience | 3 |
| CAT 402 | Applications of Catastrophe Modeling and Resilience | 3 |

The student will also be required to take at least one of the following core courses:

| | | |
|---|---|---|
| CAT 403 | Mathematics of Actuarial Science | 3 |
| CAT 411 | Catastrophe Modeling and Resilience Capstone | 3 |
| CAT 412 | Supervised Research in Catastrophe Modeling and Resilience | 1-3 |
| DSCI 310 | Introduction to Data Science | 3 |

Students who take only **9** credits of courses listed in the above two tables will need to take three additional credits chosen from the approved electives listed below.

Approved elective courses include:

| | | |
|---|---|---|
| BSTA 308 | Advanced R Programming | 3 |
| BSTA 402 | Biostatistics in Health | 3 |
| CEE 406 | Structural Reliability of Components and Systems | 3 |
| CEE 426 | GIS for Civil and Environmental Engineering | 3 |
| CEE/CSE 430 | Deep Learning | 3 |
| CEE 435 | Coastal and Offshore Infrastructure Engineering | 3 |
| CEE 458 | Random Vibrations | 3 |
| CEE 466 | Advanced Finite Element Methods | 3 |
| EES 343 | Climate and Earth System Modeling | 4 |
| EVST 404 | Socio-cultural Foundations of Environmental Policy | 3 |
| EVST 455 | Environmental Justice: From Theory to Practice | 3 |
| MATH 310/STAT 410 | Random Processes and Applications | 3-4 |
| MATH 338/STAT 438 | Statistical Models in Data Science | 3,4 |
| MATH 339/STAT 439 | Time Series and Forecasting | 3,4 |
| MATH 430 | Numerical Analysis | 3 |
| MATH/STAT 463 | Advanced Probability | 3 |
| MATH 464 | Advanced Stochastic Process | 3 |
| MATH 467 | Stochastic Calculus | 3 |
| MATH 468 | Financial Stochastic Analysis | 3 |
| POLS 319 | Mapping Data for Policymaking | 4 |

Generally, the 400-level courses will have prerequisites such that the 300-level courses are taken first, but there is no prescribed order for the courses.

**Courses**

**CAT 401 Catastrophe Modeling and Resilience 3 Credits**
Introduction to catastrophe modeling and resilience terminology, methods, and tools. General framework of catastrophe modeling and resilience assessment, with simple applications to various fields. Description of hazard, fragility, vulnerability and portfolio analysis. Effect of climate change. Research methods, scientific communication. Use of catastrophe risk and resilience modeling software and databases. Societal impact and ethical concerns raised by catastrophe insurance and resilience enhancement. Guest lectures from experts and term project. Students cannot receive credits for both CEE 331 and CAT 401.

**CAT 402 Applications of Catastrophe Modeling and Resilience 3 Credits**
Advanced analyses of various applications of catastrophe models, such as natural disasters or health-related threats to inform management and policies. Course activities include 1) reading recent publications on catastrophe model development, application and limitations, 2) practical exercises, in-class and as homework, about deterministic and stochastic model construction, and 3) result visualization of disaster impacts via geographic information systems. Theory and context-dependent practical problems on catastrophe model parameterization are covered. Students cannot receive credits for both CEE 332 and CAT 402.
**Prerequisites:** CEE 331 or CAT 401
**Can be taken Concurrently:** CEE 331, CAT 401

**CAT 403 Mathematics of Actuarial Science 3 Credits**
Introduces tools from financial mathematics necessary for insurance applications. It presents the basic mathematics of interest rates and investments, such as present value, annuity calculations, and bond valuation. An introduction to modeling claims with Markov chains and Poisson processes will be presented. In a second part, the course will also introduce some of the standard models used in risk modeling, such as no-arbitrage pricing for derivatives and the Black-Scholes model. Fixed-income markets models are also discussed briefly.
**Prerequisites:** MATH 309 or MATH 310 or STAT 410

**CAT 411 Catastrophe Modeling and Resilience Capstone 3 Credits**
Students work individually or in teams, integrating knowledge and skills acquired in their prior course work, to develop catastrophe models or perform resilience assessment for realistic scenarios and applications. Projects will be inspired by and possibly conducted in collaboration with partners from private sector, public sector, or academia. The students will produce written reports and/or oral presentations, as appropriate for the project.
**Prerequisites:** CEE 331 or CAT 401

**CAT 412 Supervised Research in Catastrophe Modeling and Resilience 1-3 Credits**
A study of selected topics in catastrophe modeling and resilience, applied to any field of interest to the student. The research may include methodological advancements, new findings, or extensions of the scope of application of known techniques. A report and/or presentation is required. Consent of the department required.
**Repeat Status:** Course may be repeated.

**CAT 490 Thesis 1-6 Credits**
Master thesis.
**Repeat Status:** Course may be repeated.