

UNIVERSITY OF TORONTO

Department of Mechanical & Industrial Engineering

MIE 1723F ENGINEERING ASSET MANAGEMENT

(September 2021)

Instructors: Professor Andrew K. S. Jardine

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And

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Course Outline: This course is concerned with the determination of optimal maintenance and replacement practices for components and capital equipment. The lectures will be supplemented by case study assignments including short-term deterministic replacement; short-term probabilistic replacement; use of OREST, PERDEC, AGE/CON, EXAKT and SMS software for the optimization of physical asset management decisions.

Professor Taghipour will cover the topic: Role of Emerging Technologies in Physical Asset Management along with a brief introduction to inspection optimization of assets with hidden failures or soft failures, sustainable asset management along with the application of sustainable asset management for utilization, purchase, and disposal of a fleet of assets.

Required Text: 1) Jardine, A. K. S. and Tsang, A. H. C., *Maintenance, Replacement, and* 1

Reliability: Theory and Applications, 3rd Edition, CRC Press, Taylor and Francis Group, 2022. Available at U of T bookstore or at “www.amazon.ca”. (Note: Publication date for book is September 16, 2021). Link for eBook:
<https://uoftbookstore.vitalsource.com/textbooks?term=9780429664465>

Additionally: Jardine, A. K. S., Lecture power point slides on *Maintenance, Replacement and Reliability: Theory & Applications*. Can be downloaded from the course website approximately one week before each class.

Supplementary Texts: 1) Campbell, J. D. and Jardine, A. K. S. and McGlynn, J., *Asset Management Excellence: Optimizing Equipment Life Cycle Decisions*, 2nd Edition, CRC Press, Taylor and Francis Group, 2011.

2) Campbell, J. D., and Reyes-Picknell, J. V., *Uptime: Strategies for Excellence in Maintenance Management*, 3rd Edition, Productivity Press, 2016.

Software: Download from q.utoronto.ca

Lecture Room: TBA. Wednesdays from 5:00-8:00 pm

Total Class Hours: $12 \times 2 = 24$. NOTE: Since most of the material is contained in the textbook or course power-points, very little notetaking is required. However, students should spend significant time to read the materials and to solve example problems to assimilate the material outside of lectures. There is a significant body of knowledge covered in the 24 hours of formal classes.

Lecture Times:

Date	Time (hours)	Activities
September 15	5:00 PM-8:00 PM	Class 1
September 22	5:00 PM-8:00 PM	Class 2
September 29	5:00 PM-8:00 PM	Class 3
October 6	5:00 PM-8:00 PM	Class 4
October 13	5:00 PM- 8:00 PM	Tutorial by TA to review problem sets of Classes 1 - 4
October 20	6.00 PM-7.30 PM	Exam (1.5 hours starting 6.00 pm) based on Classes 1-4 material
October 27	5:00 PM-8:00 PM	Class 5
November 3	5:00 PM-8:00 PM	Class 6
November 10	5:00 PM-8:00 PM	Class 7 (by Prof. Taghipour)
November 17	5:00 PM-8:00 PM	Class 8 (by Prof. Taghipour)
November 24	5:00 PM- 8:00 PM	Tutorial by TA & Prof Jardine
December 1	5:00 PM-8:00 PM	Final Exam

Course Schedule (Indicative):

<p>Class 1</p> <p>NOTE: Each class 5:10-8:00 pm</p>	<p>Achieving Maintenance Excellence: The Pyramid; Role of RCM and TPM in establishing maintenance practices within an organization.</p> <p>Statistical Preliminaries: Normal, exponential, hyper-exponential and Weibull distribution; probability distribution function; reliability function; hazard function; bathtub curve.</p>
<p>Class 2</p>	<p>Analysis of Component Failure Data: Weibull analysis: Use of Weibull probability paper; using median rank tables; dealing with censored data; the 3-parameter Weibull; Kolmogorov-Smirnov test.</p> <p>Reliability Improvement through Preventive Maintenance: Age and block strategies for preventive replacement; component replacement procedures using Glasser's graph; setting policies based on safety constraints; cost minimization and availability maximization.</p>
<p>Class 3</p>	<p>Case Studies in Reliability Improvement through Preventive Replacement: Bearing, pumps, sugar feeders, etc.; the role of OREST software package.</p> <p>Stockholding of Slow-Moving Capital Spares. Role of the SMS software including case studies for repairable and non-repairable spares.</p> <p>Cost Optimization through Component Replacement: The short-term deterministic replacement problem-case study: air pre-heater in boiler plant.</p>
<p>Class 4</p>	<p>Reliability Improvement through Inspection: Inspection frequency and depth; Inspection intervals to maximize profit; maximizing equipment availability; inspection intervals for equipment used in emergency situations.</p>
<p>Class 5</p>	<p>Reliability Improvement through Inspection: Health Monitoring Procedures: Proportional hazards modelling; spectroscopic oil analysis; optimization of condition-based maintenance (CBM) procedures; the role of the EXAKT software package.</p>

<p>Class 6</p>	<p>Reliability Improvement through Asset Replacement: Aspects of discounted cash flow used in capital equipment replacement; estimating the interest rate appropriate for discounting; present value calculations; the effect of inflation in the analysis; equivalent annual cost (EAC).</p> <p>The Economic Life of Capital Equipment: The classical economic life model; before-and-after tax calculations; the repair vs. replacement decisions; life cycle costing; technological improvement.</p> <p>Case Studies in Capital Equipment Replacement: Fixed and mobile equipment including food processing, material handling, heavy mobile equipment, vehicle fleets; the role of AGE/CON and PERDEC software packages.</p>
<p>Classes 7 & 8</p> <p>If time permits during Class 8 (by Prof Jardine)</p>	<p>Role of Emerging Technologies in PAM: An in-depth examination of current developments regarding new technologies already being applied by organizations seeking excellence in physical asset management, or those that are at the research stage that are expected to provide valuable benefits to PAM decision-making. The following will be covered:</p> <p>Emerging technologies such as artificial intelligence (AI), big data analytics, augmented reality/virtual reality (AR/VR), digital twin, IoT enabled devices, blockchain, and edge computing, and their impact on the management of physical assets.</p> <p>Maintenance 4.0 and Cyber-Physical Systems in Industry 4.0</p> <p>Machine learning algorithms and a step-by-step guide to build a machine learning model for predicting the remaining useful life of a machine.</p> <p>Deep learning algorithms and predictive maintenance</p> <p>Applications of various emerging technologies in sectors such as transportation, manufacturing and mining.</p> <p>Some extensions of Classes 5 & 6: A brief introduction to inspection optimization of assets with hidden failures or soft failures; sustainable asset management along with the application of sustainable asset management for utilization, purchase, and disposal of a fleet of assets.</p> <p>Effective Use of Maintenance Resources: Organizational structure, crew sizes, workshop resource requirements; balancing maintenance costs against plant reliability; resource requirements using queuing theory and simulation; utilization of outside resources. Maintenance management information systems; 7-step methodology for designing a CMM/EAM System; selecting a CMM/EAM System.</p>

Marking Scheme:

<p>Alternative 1 <i>Final mark = 0.25 × mid-term exam + 0.75 × final exam</i></p>	<p>Alternative 2 <i>Final mark = 0.45 × max (mid-term exam mark, course project mark) + 0.55 × final exam mark</i></p>
<p>Mid-Term Exam: 1.5-hour exam</p> <p>Date: October 20 Time: 6:00 - 7.30pm Formula sheet provided</p>	<p>Mid-Term Exam: 1.5-hour exam</p> <p>Date: October 20 Time: 6:00 - 7.30 pm Formula sheet provided</p>
<p>Final Examination: 3-hour final examination</p> <p>Date: December 1ST Time: 5:10 pm-8:10 pm Formula sheet provided</p>	<p>Final Examination: 2-hour final examination</p> <p>Date: December 1ST Time: 5:10 pm-7:10 pm Formula sheet provided</p>
	<p>Course Project: (Individual and Independent) Select one of the options listed below for the course project:</p> <ol style="list-style-type: none"> 1) A project on reliability improvement through preventive replacement (perhaps using OREST). 2) A project on establishing the economic life of a piece of capital equipment (perhaps using AGE/CON or PERDEC). 3) A project identified by the student based on course material and agreed to by the instructor <p>Note: Students selecting alternative 2 must submit a summary of proposed project—not more than 1 page, double-spaced to the instructor (Prof. Jardine) on or before Friday, October 15 th, 5:00 pm.</p> <p>Style: The written report should be word-processed, double-spaced, and contain at least the following sections: executive summary; introduction; body; conclusion; references. In addition to its technical content, the written report will be evaluated as to its worth as a written communication. For example: presentation and clarity.</p> <p>Material: The subject material must relate to material covered in the course. The project may include a literature survey if appropriate; in-depth study of a particular model; or application of knowledge to a particular problem. Since the length of the written report will depend on the subject material, it is impossible to give an assessment of how long the report should be. Remember, however, that the project counts for a significant portion of the marks (see above) for a <u>graduate</u> student.</p> <p>Due Date for Course Project: Monday, December 20th, 5:00 pm (please email to jardine@mie.utoronto.ca Subject line: MIE1723 Project-NAME). Late Penalty: 3 marks, then 0.5 mark per day late.</p>