INDUSTRIAL ENGINEERING
STELLENBOSCH UNIVERSITY

Study Guide
Analytics and Synthesis
(ASY)
10859-874

2016

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Lecturer – Optimisation

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Assessment

- Three major assessments are scheduled for this module (*i.e.* two for optimisation and one for statistics).
- The first optimisation assessment opportunity (O_1) (on linear programming and integer programming) is scheduled for 09:00–12:00 on Thursday 11 February 2016, the second optimisation assessment opportunity (O_2) (on metaheuristics and multi-objective optimisation) is scheduled for 14:00–17:00 on Thursday 11 February 2016 and the statistics assessment opportunity (S) is scheduled for 09:00–12:00 on Friday 12 February 2016.
- Students who arrive late will ***not*** receive any additional time for any assessment opportunity.
- All three of the assessments are closed-book tests. Students are, however, allowed to take one A4 page (both sides) with handwritten notes into the assessment venue for each assessment opportunity.
- Students who have completed an undergraduate degree in Industrial Engineering at Stellenbosch University have the option to use their OR345 marks for syllabus themes 1 and 2, which are assessed in assessment opportunity O_1 – therefore assessment opportunity O_1 is not compulsory for these students.
- The final mark for the optimisation block is calculated as $FO = 0.5O_1+0.5O_2$.
- The final mark for the statistics block FS consists of only assessment opportunity S.

The final mark for this module will be made up of two components as follows:

- Optimisation block final mark FO 65%
- Statistics block final mark FS 35%

Pass requirements	• A minimum of P = 50% is required to pass the module. • A subminimum of 40% is required for both blocks (FO and FS) to pass the module. • There are no second assessment opportunities. Students are required to partake in the assessment opportunities on 11 and 12 February 2016. • Students who fail the module will be required to repeat it in 2017.

Course Schedule

Contact period:	25 January 2016	08:00–17:00	(Syllabus Themes 1 and 2)
	26 January 2016	08:00–17:00	(Syllabus Theme 3)
	27 January 2016	08:00–17:00	(Syllabus Themes 4 and 5)
	28 January 2016	08:00–17:00	(Syllabus Themes 4 and 5)
	29 January 2016	08:00–17:00	(Syllabus Theme 6)

Optimisation assessment O_1:	11 February 2016	09:00–12:00
Optimisation assessment O_2:	11 February 2016	14:00–17:00
Statistics assessment S:	12 February 2016	09:00–12:00

References

Prescribed Material

1. Deb, K; Mutli-objective optimisation using evolutionary algorithms, John Wiley & Sons, 2001. ISBN: 0-471-87339-X

2. El-Ghazali, T; Metaheuristics: From Design to Implementation, John Wiley & Sons, 2009 ISBN: 978-0-470-27858-1

3. Hamburg, M; Basic Statistics — A Modern Approach, Third Edition, Harcourt Brace Jovanovich, 1974. ISBN: 0-15-505113-X

4. Hillier, FS and Liebermand, GS; Introduction to operations research, Ninth Edition, McGraw-Hill, 2010. ISBN: 978-007-126767-0

5. Winston, WL; Operations Research — Applications and Algorithms, Fourth Edition, Brooks/Cole, 2004. ISBN: 0-534-42362-0

6. Rardin, RL; Optimisation in Operations Research, Prentice Hall, Upper Saddle River, 1998. ISBN: 0-02-398415-5

Additional Notes

Lecture slides will be posted on Sunlearn.

Syllabus Structure

SYLLABUS THEME	STUDY UNIT
1. Linear programming (LP)	1.1 What is an LP problem?
	1.2 Graphical solution of two-variable LP problems
	1.3 The Simplex algorithm
	1.4 Special cases of LP problem structures
	1.5 Formulating LP problems
2. Integer programming (IP)	2.1 Introduction to IP problems
	2.2 Formulating IP problems
	2.3 The branch-and-bound method
	2.4 Solving knapsack problems
	2.5 Scheduling and assignment problems
	2.6 The travelling salesman problem
3. Nonlinear programming (NLP)	3.1 Review of basic notions from differential calculus
	3.2 Introductory concepts of NLP
	3.3 Convex and concave functions
	3.4 Solving NLP problems in one variable
	3.5 The golden section search
	3.6 Unconstrained NLP: Several variables
	3.7 The method of steepest ascent
	3.8 Lagrange multipliers
	3.9 The Kuhn-Tucker conditions
4. Heuristics and metaheuristics	4.1 Improving search heuristics
	4.2 Single solution-based metaheuristics
	4.3 Population-based metaheuristics
5. Multi-objective optimisation	5.1 Introduction to multi-objective optimisation
	5.2 The notions of solution dominance and Pareto-optimality
	5.3 Classical multi-objective optimisation methods
6. Statistics	6.1 Introduction to statistics
	6.2 Statistical investigations and data
	6.3 Frequency distributions and summary measures
	6.4 Introduction to probability
	6.5 Probability distributions
	6.6 Sampling distributions
	6.7 Estimation
	6.8 Hypothesis testing
	6.9 Chi-square tests and analysis of variance
	6.10 Regression and correlation analysis
	6.11 Comparing results of optimisation algorithms statistically

Module Content

Syllabus theme 1: Linear Programming

Learning objectives	The aim in this syllabus theme is to introduce the student to the notion of LP. Emphasis is placed on both how LP models of real-life decision problems are formulated and how these models may be solved by using the celebrated Simplex algorithm. The interpretation of model solutions is also elucidated in the context of the real-life situations in which the models arise within application areas such as workforce scheduling, capital budgeting and inventory control.
References	Winston, WL; Operations Research — Applications and Algorithms, Fourth Edition, Chapter 3, Brooks/Cole, 2004. ISBN: 0-534-42362-0

Syllabus theme 2: Integer Programming

Learning objectives	The aim in this syllabus theme is to introduce the student to the notion of IP. Emphasis is again placed on both how IP models of real-life decision problems are formulated and how these models may be solved by using the well-known branch-and-bound method. The interpretation of model solutions is elucidated in the context of the real-life situations in which the models arise within application areas such as machine scheduling, assignment decisions and the travelling salesman problem.
References	Winston, WL; Operations Research — Applications and Algorithms, Fourth Edition, Chapter 9, Brooks/Cole, 2004. ISBN: 0-534-42362-0

Syllabus theme 3: Nonlinear Programming

Learning objectives	The aim in this syllabus theme is to extend the notion of LP to the case where the objective function (but not the constraints) of an LP problem are nonlinear. Emphasis is placed on how NLP models of hypothetical decision problems are formulated and how these models may be solved by using a variety of well-known methods, such as the golden section search algorithm, the method of steepest ascent, the method of Lagrange multipliers and the Kuhn-Tucker conditions for optimality.
References	Winston, WL; Operations Research — Applications and Algorithms, Fourth Edition, Chapter 11, Brooks/Cole, 2004. ISBN: 0-534-42362-0

Syllabus theme 4: Heuristics and Metaheuristics

Learning objectives	The aim in this syllabus theme is to introduce the student to a number of well-known approximate optimisation techniques which are applicable in cases where the complexity of an optimisation problem is such that exact solution methods are too slow to implement, and where near-optimal solutions are instead sought within a fraction of the time required to find solutions which are exactly optimal. Emphasis is placed on rule-based local search heuristics as well as on both single solution-based and population-based metaheuristics.
References	Hillier, FS and Lieberman, GS; Introduction to operations research, Ninth Edition, Chapter 13, McGraw-Hill, 2010. ISBN: 978-007-126767-0 Rardin, RL; Optimisation in Operations Research, Prentice Hall, Chapter 12, Upper Saddle River, 1998. ISBN: 0-02-398415-5 El-Ghazali, T; Metaheuristics: From Design to Implementation, Chapter 1-3, John Wiley & Sons, 2009. ISBN: 978-0-470-27858-1

Syllabus theme 5: Multi-objective Optimisation

Learning objectives	The aim in this syllabus theme is to extend the traditional paradigm of single-objective optimisation, where solutions to optimisation problems are sought which are superior in terms of a single criterion, into the realm of multi-objective optimisation, where high-quality trade-offs are instead sought between optimising a number of simultaneous, conflicting objectives. Emphasis is placed on the notions of solution dominance and Pareto-optimality, and a number of classical multi-objective optimisation techniques are considered.
References	Deb, K; Multi-objective optimisation using evolutionary algorithms, Chapters 2 & 3, John Wiley & Sons Ltd., 2001. ISBN: 0-471-87339-X

Syllabus theme 6: Statistics and Inference

Learning objectives	The aim in this syllabus theme is to review a number of basic concepts and methods from the realm of statistics in a clear, systematic and straight-forward manner so as to equip students with the practical skills required to perform critical judgment and inference within a stochastic context.
References	Hamburg, M; Basic Statistics — A Modern Approach, Third Edition, Chapters 1-10, Harcourt Brace Jovanovich, 1974. ISBN: 0-15-505113-X