Business Analytics MSc

VU University Amsterdam - Faculteit der Exacte Wetenschappen - M Business Analytics - 2013-2014

The Master's programme in Business Analytics (BA) is a multidisciplinary programme, geared to improving business processes by applying a combination of methods based on mathematics, computer science and business management. The Master's programme BA will deepen your knowledge of these methods and give you the opportunity to specialize in areas like business process optimization, computational intelligence and financial risk management. Their synthesis is often called Business Analytics.

Business problems will be the center of attention and the motivation for the methods to be learned from the three subdisciplines. The Master's programme is concluded by a Master Project conducted during an internship or a research project at the VU of half a year.

There are three variants of the programme: The Professional Variant, the Research Variant and the Dual Master’s Programme.

In the Professional and Research Variant, the students choose courses for 45 EC, including 24 EC of compulsory optional courses, and complete their studies with an internship (Professional Variant) or an internal Master Project (Research Variant) for 36 EC. The students can only start their internship or Master Project after having finished the compulsory Research Paper BA (6 EC) and having completed all but possibly one programme components.

In the Dual Master’s Programme, the students choose courses for 33 EC, including 18 EC of compulsory optional courses. The final internship, as well as the compulsory Research Paper BA (6 EC), typically is incorporated in the work. If you are interested in the Dual Master’s Programme, please note that admission also depends on obtaining suitable employment. Please contact the internship office well in advance.

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BA Dual variant

The dual Master's programme combines work and study. During this programme the student is employed part time, and studies part time. The work has to be relevant for the study. The external master's project is incorporated in the work, although supervision of the external master's project has to involve at least one university staffmember. In addition the student gets 18 EC for the Dual work period. Moreover, it is possible to do the Research Paper BA (6 EC) on a case-study that is work related, provided the case-study is combined with a sound theoretical basis. This makes the total of work related credit points, including the external master's project, 60 EC, being the equivalent of one year of study. Typically, a student participating in the dual master's programme should expect to obtain the Master's diploma after two and a half years.

Admission to the dual Master's programme is granted to those who have a Business Analytics Bachelor's degree. For those with another university Bachelor's degree, such as Mathematics, Econometrics, Computer Science, or a Bachelor's degree from an institute of higher education, admission may be granted on an individual basis. Those seeking admission to the dual Master's programme should realize that admission also depends on obtaining suitable employment. The VU has contacts with a number of companies that are interested in participating in this programme.

For more information concerning the dual master's programme, contact the coordinator for the external master's project or the master coordinator.

The programme consists of 120 European creditpoints (EC)
- compulsory courses 87 EC (including a Master Project of 36 EC)
- compulsory choice 18 EC
- optional courses 15 EC

Note: Every programme, including the choice of optional courses, has to be discussed and agreed upon with the master coordinator and approved by the Examination Board.

Programme components:

- Compulsory Selection Mathematics and BA (18 EC)
- Compulsory Courses

Compulsory Selection Mathematics and BA (18 EC)

There is a compulsory choice of at least three courses (18 EC) from this list below.

Note: Every programme, including the choice of optional courses, has to be discussed and agreed upon with the master coordinator and approved by the Examination Board.

Courses:

Name	Period	Credits	Code
Advanced Selforganisation	Period 2	6.0	X_400434

Business Intelligence	Period 1	6.0	E_BK3_BI
Corporate Financial Management	Period 4	6.0	E_BK3_CFM
Discrete Mathematics	Period 1+2	6.0	X_400582
Evolutionary Computing	Period 1	6.0	X_400111
Investments	Period 4	6.0	E_EBE3_INV
Mathematical Systems and Control Theory	Period 1+2	6.0	X_400180
Neural Networks	Period 1	6.0	X_400132
Numerical Methods	Period 4+5	6.0	X_401039
Optimization of Business Processes	Period 4+5	6.0	X_400422
Ordinary Differential Equations	Period 1+2	6.0	X_400026
Performance of Networked Systems	Period 4	6.0	X_405105
Project Optimization of Business Processes	Period 3	6.0	X_400213
Stochastic Optimization	Period 1+2	6.0	X_400336
Stochastic Processes for Finance	Period 1+2	6.0	X_400352

Compulsory Courses

Both the Research Paper BA (6 EC) and the Master Project (36 EC) may be work-related. The work period consists of 18 EC. The total work related credit points has therefore a maximum of 60 EC.

Compulsory alongside the mentioned courses, are a compulsory choice (18 EC) and optional courses (15 EC) to complete 120 EC.

Note: Every programme, including the choice of optional courses, has to be discussed and agreed upon with the master coordinator and approved by the Examination Board.

Courses:

Name	**Period**	**Credits**	**Code**
Applied Analysis: Financial Mathematics	Period 1+2	6.0	X_400076
Applied Stochastic Modeling	Period 1+2	6.0	X_400392
Data Mining Techniques	Period 5	6.0	X_400108
Dual Workperiod Master	Ac. Year (September)	18.0	X_400460
Master Project Business Analytics	Ac. Year (September)	36.0	X_400459
Research Paper Business Analytics	Ac. Year (September)	6.0	X_400206
Scientific Writing in English	Period 4	3.0	X_400512
Statistical Models	Period 1+2	6.0	X_400418

Professional and Research variant

These are the standard Master's programmes. The goal of the programme is to prepare students for a career in business, industry, or within governmental or research facilities, with (possibly only initially) a major quantitative aspect.

The emphasis will be on a broad and multidisciplinary education, preparing the student for a role as an academically trained quantitative professional in a multidisciplinary organisation. Even so, the possibility to continue after the Master in a PhD programme exists also for these variants.

There are three specializations possible:

Business Process Optimization

This subject underscores the multidisciplinary nature of Business Analytics: you will tackle quantitative business problems with the aid of mathematical algorithms which are then implemented in decision-support systems. All aspects of this subject are addressed from the perspective of interrelationships.

Computational Intelligence

Computational Intelligence (CI) is a collective name for various fields of application and problem-solving techniques. Typical CI applications are optimization and data mining. CI offers a successful pragmatic approach to actual problems.

Financial Risk Management

This specialization prepares you for a quantitative position in the financial world. The subjects covered include the pricing of derivatives, such as share options, and risk management. You will deal with both practical and theoretical aspects of the discipline.

The progamme consists of 120 European creditpoints (EC)
- compulsory courses 75 EC (including a Master Project of 36 EC)
- compulsory choice 24 EC
- optional courses 21 EC

Note: Every programme, including the choice of optional courses, has to be discussed and agreed upon with the master coordinator and approved by the Examination Board.

Programme components:

- Compulsory Selection
- Compulsory Courses

Compulsory Selection

There is a compulsory choice of at least four courses (24 EC) from this list below.

Note: Every programme, including the choice of optional courses, has to be discussed and agreed upon with the master coordinator and approved by the Examination Board.

Courses:

Name	Period	Credits	Code
Advanced Selforganisation	Period 2	6.0	X_400434
Business Intelligence	Period 1	6.0	E_BK3_BI
Corporate Financial Management	Period 4	6.0	E_BK3_CFM
Discrete Mathematics	Period 1+2	6.0	X_400582
Evolutionary Computing	Period 1	6.0	X_400111
Investments	Period 4	6.0	E_EBE3_INV
Mathematical Systems and Control Theory	Period 1+2	6.0	X_400180
Neural Networks	Period 1	6.0	X_400132
Numerical Methods	Period 4+5	6.0	X_401039
Optimization of Business Processes	Period 4+5	6.0	X_400422
Ordinary Differential Equations	Period 1+2	6.0	X_400026
Performance of Networked Systems	Period 4	6.0	X_405105
Stochastic Optimization	Period 1+2	6.0	X_400336
Stochastic Processes for Finance	Period 1+2	6.0	X_400352

Compulsory Courses

Compulsory alongside the mentioned courses, are a compulsory choice (24 EC) and optional courses (21 EC) to complete 120 EC.

Note: Every programme, including the choice of optional courses, has to be discussed and agreed upon with the master coordinator and approved by the Examination Board.

Courses:

Name	Period	Credits	Code
Applied Analysis: Financial Mathematics	Period 1+2	6.0	X_400076
Applied Stochastic Modeling	Period 1+2	6.0	X_400392
Data Mining Techniques	Period 5	6.0	X_400108
Master Project Business Analytics	Ac. Year (September)	36.0	X_400459
Project Optimization of Business Processes	Period 3	6.0	X_400213

Research Paper Business Analytics	Ac. Year (September)	6.0	X_400206
Scientific Writing in English	Period 4	3.0	X_400512
Statistical Models	Period 1+2	6.0	X_400418

Advanced Selforganisation

Course code	X_400434 (400434)
Period	Period 2
Credits	6.0
Language of tuition	English
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	dr. M.C. Schut
Teaching staff	dr. M.C. Schut
Teaching method(s)	Lecture
Level	400

Course objective
To understand, simulate and analyse the behaviour and self-organization of complex systems. The student is able to explain, implement and recognize basic principles and properties of such systems.

Course content
This course is about the understanding of the behavior and self-organization of complex systems: systems in which the interaction of the components is not simply reducible to the properties of the components. The general question the we address is: how should systems of very many independent computational (e.g. robotic or software) agents cooperate in order to process information and achieve their goals, in a way that is efficient, self- optimizing, adaptive, and robust in the face of damage or attack? We will look at natural systems that solve some of the same problems that we want to solve, e.g. adaptive path minimization by ants, wasp and termite nest building, army ant raiding, fish schooling and bird flocking, coordinated cooperation in slime molds, synchronized firefly flashing, evolution by natural selection, game theory and the evolution of cooperation. The course includes a practical part in which students implement a simulation of a self-organizing complex system and conduct structured experimental analysis with this simulation.

Form of tuition
Theory in lectures and practice in labs.

Type of assessment
Report including description of simulation and experimental analysis.

Course reading
Schut M.C., Scientific Handbook for Simulation of Collective Intelligence, 2007. Will be distributed in class.

Target group
mAI, mBA, mCS, mPDCS

Remarks

More information available on BlackBoard. This is a project- oriented course and therefore students will be expected to have basic programming skills.

Applied Analysis: Financial Mathematics

Course code	X_400076 (400076)
Period	Period 1+2
Credits	6.0
Language of tuition	English
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	prof. dr. A.C.M. Ran
Teaching staff	prof. dr. A.C.M. Ran
Teaching method(s)	Lecture
Level	400

Course objective
The course aims to introduce the student to several aspects of the mathematical theory of option pricing.

Course content
This course gives an introduction to financial mathematics.
The following subjects will be treated:
- introduction in the theory of options;
- the binomial method;
- introduction to partial differential equations;
- the heat equation;
- the Black-Scholes formula and applications;
- introduction to numerical methods, approximating the price of an (American) option.

Form of tuition
Lectures, exercises, discussion of exercises.

Type of assessment
Homework exercises and oral examination

Course reading
The Mathematics of Financial Derivatives, A Student Introduction, by Paul Wilmott, Sam Howison, Jeff Dewynne. Cambridge University Press.

In addition, lecture notes will be made available for several topics which are not treated in the book.

Recommended background knowledge
Calculus and Linear Algebra

Target group
3W, mMath, mBA, 3Ect

Remarks
It is possible to do some additional work by elaborating on a specific subject from the theory of partial differential equations or financial mathematics.

Applied Stochastic Modeling

Course code	X_400392 (400392)
Period	Period 1+2
Credits	6.0
Language of tuition	English
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	prof. dr. G.M. Koole
Teaching staff	prof. dr. G.M. Koole
Teaching method(s)	Lecture, Seminar
Level	400

Course objective
To learn the most often used stochastic models and how they are applied in practice.

Course content
This course deals with a number of stochastic modeling techniques that are often used in practice. They are motivated by showing the business context in which they are used. Topics we deal with are: birth-death-processes, basic queueing models, inventory models, renewal theory and simulation. We also repeat and extend certain parts of probability theory. We end with an overview of mathematical modeling, including aspects such as the economic context, the choice of solution method, decision support systems, etc.

Form of tuition
Hoor- en werkcollege.

Type of assessment
Written examination.

Course reading
Lecture notes.

Target group
mBA, mMath

Business Intelligence

Course code	E_BK3_BI (61312020)
Period	Period 1
Credits	6.0
Language of tuition	English
Faculty	Fac. der Economische Wet. en Bedrijfsk.
Coordinator	dr. J.F.M. Feldberg
Teaching staff	dr. J.F.M. Feldberg
Teaching method(s)	Lecture, Practical, Computer lab
Level	300

Course objective
Students that have successfully accomplished this course will:

- Have an academic attitude towards business intelligence (BI) and decision support systems theories and business issues.
- Have the appropriate knowledge to sensibly think about decision support systems and BI solutions in an organizational context (design, development, implementation and evaluation).
- Have the skills to work with a popular decision support tool (Cognos Powerplay). By means of 'learning by doing' elementary skills in the usage of decision support systems are acquired.
- Be able to identify the (break through) opportunities of BI solutions in realizing sustainable competitive advantage.
- Be able to participate in project teams that decide on the design, development, implementation, and use of BI solutions.
- Be able to apply scientific theories on decision support systems in an organizational context.
- Have the appropriate knowledge and skills to self- reliantly deepen their knowledge on BI solutions and decision support systems.

Course content
Modern organizations, in particular the management of these organizations, tend to suffer more from an overload of data than from a lack of data. To a great extent this overload is caused by the overwhelming growth of information systems in organizations. Enterprise Systems (ERP), Customer Relationship Systems (CRM) as well as the growing number of Internet- based applications (e. g. e- commerce) are all important sources for the explosion of financial, production, marketing and other business data. The challenge for most organizations is to develop and build systems that support the transformation of the collected data into knowledge. To be successful in this transformation processes organizations have to develop the capability to aggregate, analyze and use data to make informed decisions. This course deals with the theory concerning business intelligence as well as with the application of business intelligence solutions. To be able to successfully implement business intelligence solutions, one has to have knowledge about their functioning and proficiency in using them, as well as knowledge about their field of application, e. g., how to select, transform, integrate, condense, store and analyze relevant data. This course uses the term 'business intelligence' in a broad sense. A narrow interpretation would only deal with software solutions ('data warehousing' and 'online analytical processing'). The broad interpretation - to be used in this course - also includes: theories concerning decision making, related decision support systems and their application for management, i. e., data warehousing, online analytical processing and data mining.

Form of tuition
lecture
tutorial

Type of assessment
written interim examination
(weekly) Business intelligence tutorial tests.
All tests and exams will be administered through a digital test system.

Course reading
- To be announced.
- Various papers.

Recommended background knowledge
- Basic course in Information Systems, f. e. on the level of Laudon & Laudon, Management Information Systems, Managing the Digital Firm. 9th edition. Prentice Hall, 2004.
- O'Brien, James A., Introduction to Information Systems. 12th edition. Mc Graw Hill, 2005.

Remarks
Language: "Dutch & English"

Corporate Financial Management

Course code	E_BK3_CFM (61342390)
Period	Period 4
Credits	6.0
Language of tuition	English
Faculty	Fac. der Economische Wet. en Bedrijfsk.
Coordinator	prof. dr. A.B. Dorsman
Teaching staff	prof. dr. A.B. Dorsman
Teaching method(s)	Lecture, Study Group
Level	300

Course objective
This course expands on financial topics covered in the first and second year. The emphasis in this course is on the Optimal Capital Structure of a corporation. The aim is to prepare students for a (possible) career as (assistant) Financial Manager in Industry or in the FBI sector: Finance, Banking (commercial and investment) and Insurance, incl. pension funds, investments funds, stock markets, Euronext, DNB, ECB, AFM, Ministry of Finance etc.

Course content
The following topics, issues and concepts will be dealt with:
- Capital structure in perfect Markets
- Leverage and Debt
- Optimal Capital Structure with Taxes and Financial Distress
- Payout Policy, Dividends and Share Repurchases
- Capital budgeting and Valuation
- Financial Modeling
- Corporate Governance

Form of tuition
Lecture. Students have to complete before each lecture quizzes (tests) on MyFinancLab.

Type of assessment
written interim examination (80% 5, 0 min.) cases / tutorials (20% of final grade based on average of scores of tests and quizzes on MyFinanceLab.

Entry requirements
This course is for Business Administration students and/or Pre- Master BK students specializing in Financial Management. Students must be familiar with Corporate Finance / Financial Management as covered in the 1st and 2nd year.

Data Mining Techniques

Course code	X_400108 (400108)
Period	Period 5
Credits	6.0
Language of tuition	English
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	dr. M. Hoogendoorn
Teaching staff	dr. M. Hoogendoorn
Teaching method(s)	Lecture
Level	500

Course objective
The aim of the course is that students acquire data mining knowledge and skills that they can apply in a business environment. How the aims are to be achieved: Students will acquire knowledge and skills mainly through the following: an overview of the most common data mining algorithms and techniques (in lectures), a survey of typical and interesting data mining applications, and practical assignments to gain "hands on" experience. The application of skills in a business environment will be simulated through various assignments of the course.

Course content
The course will provide a survey of basic data mining techniques and their applications for solving real life problems. After a general introduction to Data Mining we will discuss some "classical" algorithms like Naive Bayes, Decision Trees, Association Rules, etc., and some recently discovered methods such as boosting, Support Vector Machines, and co-learning. A number of successful applications of data mining will also be discussed: marketing, fraud detection, text and Web mining, possibly bioinformatics. In addition to lectures, there will be an extensive practical part, where students will experiment with various data mining algorithms and data sets. The grade for the course will be based on these practical assignments (i.e., there will be no final examination).

Form of tuition
Lectures and compulsory practical work. Lectures are planned to be interactive: there will be small questions, one-minute discussions, etc.

Type of assessment
Practical assignments (i.e. there is no exam). There will be three assignments mostly done in groups of three. There is a possibility to get a grade without doing
these assignments: to do a real research project instead (which will most likely to involve more work, but it can also be more rewarding).

Course reading
Ian H. Witten, Eibe Frank, Mark A. Hall, Data Mining: Practical Machine Learning Tools and Techniques (Third Edition). Morgan Kaufmann, January 2011
ISBN 978-0-12-374856-0

Recommended background knowledge
Kansrekening en Statistiek of Algemene Statistiek (knowledge of statistics and probabilities) or equivalent. Recommended: Machine Learning.

Target group
mBA, mCS, mAI, mBio

Discrete Mathematics

Course code	X_400582 (400582)
Period	Period 1+2
Credits	6.0
Language of tuition	Dutch
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	prof. dr. R.M.H. de Jeu
Teaching staff	prof. dr. R.M.H. de Jeu
Teaching method(s)	Lecture, Seminar
Level	300

Course objective
Het geven van een goede basiskennis in de discrete wiskunde.

Course content
Grafentheorie en toepassingen (Euler- en Hamiltongrafen, bomen, stromen in netwerken, algoritmen voor optimalisatie zoals het vinden van een kortste pad). Recurrente betrekkingen. Teltheorie met genererende functies en inclusie/exclusie.

Form of tuition
Hoorcollege met practicum.

Type of assessment
Twee schriftelijke deeltentamens

Course reading
Fred Roberts and Barry Tesman
Applied Combinatorics
2nd edition, 2009
Chapman and Hall/CRC
ISBN: 9781420099829

Recommended background knowledge
Veronderstelde voorkennis: Calculus en Lineaire Algebra.

Target group
3W, 3BA, mBA

Dual Workperiod Master

Course code	X_400460 (400460)
Period	Ac. Year (September)
Credits	18.0
Language of tuition	English
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	drs. H.J.M. van Goor-Balk
Level	500

Course objective
During the dual work period the student gains experience and skills. The dual period allows the student to bring the learning into practice. So the student can apply his theoretical knowledge into practice. The student also brings practical work experience back to the university. In addition, the student will receive relevant work experience while studying. As a result the student is easier to deploy in the labor market after graduation.

Course content
During two years, students are required to divide their time equally between work and study. So study and work are fully integrated. The student is an employee and a student at the same time. The student is on the payroll of the host organization. The student will conduct work which is of direct relevance to the BA master study programme.

Form of tuition
The student is an employee of the host organization.

Type of assessment
Direct supervision of the students day-to-day activities is provided by the host organization. There will be frequent contact and consultation between the student, the university (by the coordinator of the BA master's dual variant programme) and the host organization throughout the programme. The student writes a report on his/her activities in the organization. The performance of the student will be evaluated by the organization, the coordinator of the BA master's dual variant programme, and a member of the BA Internship Committee. The organization completes an assessment form.

Recommended background knowledge
The formal approval of the BA Internship Committee is required before the student can actually take up employment.

Target group
mBA-D

Remarks
For more information on the dual program:
- http://www.few.vu.nl/nl/studenten/project-en-stage/stagebureau-wiskunde-informatica/duaal-ba-studer/index.asp (NL)
- http://www.few.vu.nl/en/current-students/internship-office-for-mathematics-and-computer-science/dualprogramme-ba/index.asp (EN)

Evolutionary Computing

Course code	X_400111 (400111)

Period	Period 1
Credits	6.0
Language of tuition	English
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	prof. dr. A.E. Eiben
Teaching staff	prof. dr. A.E. Eiben
Teaching method(s)	Lecture
Level	400

Course objective
To learn about computational methods based on Darwinian principles of evolution. To illustrate the usage of such methods as problem solvers and as simulation, respectively modelling tools.To gain hands-on experience in performing experiments.

Course content
The course is treating various algorithms based on the Darwinian evolution theory. Driven by natural selection (survival of the fittest), an evolution process is being emulated and solutions for a given problem are being "bred". During this course all "dialects" within evolutionary computing are treated (genetic algorithms, evolutiestrategieën, evolutionary programming, genetic programming, and classifier systems). Applications in optimisation, constraint handling and machine learning are discussed. Specific subjects handled include: various genetic structures (representations), selection techniques, sexual and asexual genetic operators, (self-)adaptivity. If time permits, subjects in Artificial Life and Evolutionary Robotics will be handled. Hands-on-experience is gained by a compulsory programming assignment.

Form of tuition
Oral lectures and compulsory pogramming assignment.

Type of assessment
Written exam and pogramming assignment (weighted average).

Course reading
Eiben, A.E., Smith, J.E., Introduction to Evolutionary Computing. Springer, 2003 ISBN 3-540-40184-9.
Slides available from http://www.cs.vu.nl/~gusz/ecbook/ecbook.html .

Target group
mBA, mAI, mCS, mPDCS

Investments

Course code	E_EBE3_INV (60332090)
Period	Period 4
Credits	6.0
Language of tuition	English
Faculty	Fac. der Economische Wet. en Bedrijfsk.
Coordinator	dr. D.G. Stefanova
Teaching staff	T.C. Dyakov MSc BA

Teaching method(s)	Lecture
Level	300

Course objective
This course aims to make students familiar with the insights from investments and portfolio management theory. Students also have to be able to apply these insights in practical situations involving portfolio decisions and investment management for both individuals and institutions.

Course content
Investment decisions take a prominent role in everyday life. We can think of investment decisions taken by institutional investors (banks, insurance companies, pension funds, mutual funds), but also financial decisions taken by individual households (additional pension savings, saving for ones children's education (and how), buying a house, etc.) Investment theory is also strongly linked with risk management. The importance of sound decision making in this field has been underlined by recent experiences on financial markets, law suits involving complex financial products for retail clients, the debate about the (in)solidity of pensions, etc. The Investments course aims to provide an overview of the principles of investment analysis. A framework is developed that allows one to address a variety of (at first sight) completely different investment problems in a unified way. The theoretical underpinnings are developed from modern portfolio theory, with mean-variance optimization and the CAPM as key ingredients. The second component of the course deals with the empirical research for financial markets and the actual mechanisms driving these markets. Factor models for returns on financial products are very important here. The third component consists of valuation and risk attribution (including performance attribution) for individual financial products as well as portfolios of these products.

Form of tuition
Lectures and tutorial sessions.

Type of assessment
Written exam and Case work. Exam questions are meant to test the candidate's theoretical insight as well as analytical and computational skills. Case work is used to test students implementation skills in Excel of the material treated in the course. Correctly completing a minimum of case work is compulsory for obtaining a pass for this course. Guidelines are communicated via Blackboard at the start of the course.

Course reading
The course literature consists of detailed lecture slides to be found under Course documents on Blackboard. These will be posted weekly before each set of lectures. In addition to them, the textbook below is a compulsory reading material:
- Zvi Bodie, Alex Kane and Alan J. Marcus: Investments, McGraw Hill (8th edition)
As optional supporting material for the applied Excel work, I suggest the following books:
- Adair, Excel Applications for Investments (introductory book to Excel and its applications for investment problems).
- Mary Jackson and Mike Staunton, Advanced Modeling in Finance using Excel and VBA, Wiley Finance (advanced VBA applications and programming).

Entry requirements
The course builds upon prior knowledge in the 1st and 2nd year Finance courses (Finance 1.4, 2.2 and 2.4 for Economics students and Finance and Financial modeling 1.5 and Financial Management 2.4 for Financial Management students). For students coming from different programs or having a different background, this should correspond to mastering the concepts in the book of Braeley and Myers, Principles of corporate finance, chapters 1-15, 20-23, 27-30.

Remarks
The course is taught in English

Master Project Business Analytics

Course code	X_400459 (400459)
Period	Ac. Year (September)
Credits	36.0
Language of tuition	English
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	drs. H.J.M. van Goor-Balk
Teaching staff	drs. H.J.M. van Goor-Balk
Teaching method(s)	Lecture
Level	600

Course objective
The objectives of the internship are:
- To research and analyse a specific issue or problem affecting the host organization, and to suggest (potential) solutions.
- To gain an understanding of the way in which the organization functions. The student will gain a general impression of the how the organization as a whole works, including its primary business processes and its support processes. The work placement project should be positioned within these processes.
- To practise and develop social and communication skills. The student is introduced to the standards and values in place within the host organization. He will develop communication skills through personal interaction with the staff of the organization, and through the written and verbal reports.
- To explore potential career options.

Course content
Each Master's programme is concluded by an external master project. This is in principle a project to be carried out within a business, industry or research facility other than the departments of Mathematics and Computer Science.

Form of tuition
The student is an intern of the host organization. The student will be supervised by a staff member of the Faculty of Science.

Type of assessment
A written report and a verbal presentation.

Course reading
assigned individually

Recommended background knowledge
At least 78 credits, and the Research Paper Business Analytics.

Target group
mBA, mBA-D

Remarks
If you are planning to start your Master Project within four months,
please make an appointment with Annemieke van Goor
(H.J.M.van.Goor-Balk@vu.nl)

More information (NL):
- http://tinyurl.com/masterproject
- http://tinyurl.com/bedrijfscontacten
handleiding:
- http://tinyurl.com/plmq8nd

More information (EN):
- http://tinyurl.com/phvzzbz
- http://tinyurl.com/guide-internship
- http://tinyurl.com/internship-vacancies

Mathematical Systems and Control Theory

Course code	X_400180 (400180)
Period	Period 1+2
Credits	6.0
Language of tuition	English
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	prof. dr. A.C.M. Ran
Teaching staff	prof. dr. A.C.M. Ran
Teaching method(s)	Lecture, Seminar
Level	400

Course objective
The course aims to introduce the student to the mathematical theory of control systems.

Course content
Many phenomena are characterized by dynamic behaviour where we are interested in a certain input/output behaviour. Examples are to be found in the exact and natural sciences (mechanics, biology, ecology), in engineering (air- and spacecraft design, mechanical engineering) as well as in economics and econometrics (macro- economical models, conjucture, trend and seasonal influences in demand and supply, production systems). Systems theory is concerned with modeling, estimation and control of dynamical phenomena. During the course the following subjects will be treated: models and representations (linear systems, input-output, state space, transfer function, stochastic systems, spectrum), control (stabilisation, feedback, pole placement, dynamic programming, the LQ problem), and identification and prediction (parameter estimation, spectral analysis, Kalman- filter, model reduction). Applications are in

the area of optimal control and prediction.

Form of tuition
There is a lecture of two hours each week. In addition, there is another session which will be half lecture and half practicum, in which there is the possibility to ask questions about the compulsary computerpracticum. The practicum makes use of the Matlab package.

Type of assessment
The computerpracticum counts for 70 %, the oral examination concerns the theory and counts for 30 %.

Course reading
Chr. Heij, A.C.M. Ran and F. van Schagen, Introduction to Mathematical Systems Theory, Birkhauser Verlag.

Recommended background knowledge
Analysis, probability theory, statistics.
Complex analysis and Fourier theory would be useful, but are not absolutely necessary.

Target group
3W, mBA, mMath

Neural Networks

Course code	X_400132 (400132)
Period	Period 1
Credits	6.0
Language of tuition	English
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	dr. M. Hoogendoorn
Examinator	dr. M. Hoogendoorn
Teaching staff	dr. M. Hoogendoorn
Teaching method(s)	Lecture, Practical
Level	500

Course objective
The course provides an introduction to key concepts and algorithms for pattern recognition and neural networks. It strives towards providing insight both from a theoretical perspective as well as more practical settings. In the end, the student should be able to confidently apply the aforementioned techniques in real-life settings and understand their theoretical basis.

Course content
The course provides an introduction to key concepts and algorithms for pattern recognition and neural networks. It covers the following topics:

- classification, regression, and clustering problems,
- elements of statistical pattern recognition,
- methods for estimation of probability distributions,
- linear classifiers, including Support Vector Machines,
- single-layer and multi-layer networks,
- RBF-networks and kernel methods

- methods for dimensionality reduction
- methods for feature extraction and selection

Moreover, several real-life applications of pattern recognition, including recognition of speech, handwritten characters, images, etc., will be discussed in depth.

Form of tuition
Lectures and compulsory programming assignments.

Type of assessment
Programming assignments and written examination (weighted average).

Course reading
Simon Haykin, Neural Networks and Learning Machines, Pearson Education, 3rd international edition, 2008

Target group
mAI mBio, mBA, mCS

Remarks
More information will be available via Blackboard.

Numerical Methods

Course code	X_401039 (401039)
Period	Period 4+5
Credits	6.0
Language of tuition	English
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	dr. R. Planque
Teaching staff	dr. R. Planque
Teaching method(s)	Lecture, Seminar
Level	300

Course objective
- Gain experience in numerically solving a variety of problems.
- Getting acquainted with methods from numerical analysis.
- Develop intuition for the reliability of numerical methods.
- Learn how to use matlab.

Course content
Numerical methods are used frequently in all areas of science, such as fluid dynamics, meteorology and financial risk management. Moreover, techniques from numerical analysis play an important role in mathematical research on differential equations, stochastics, optimization, etcetera.
We focus on the main numerical methods from modern-day analysis and scientific computing. The theory is implemented in hands-on practical assignments. Active participation is expected. The list of subjects includes: error analysis, systems of nonlinear equations, eigenvalue problems, least square methods, fast Fourier transform, ordinary and partial differential equations. Applications include phone number recognition, ranking algorithms, curve following and planet motions.

Form of tuition
Lectures alternated with practical work in the computer rooms.
A number of matlab assignments form an integral part of the course.

Type of assessment
Active participation is expected. The grade is determined on the basis of the assignment (matlab code and short reports).

Course reading
Alfio Quarteroni, Fausto Saleri and Paola Gervasio, Scientific Computing with Matlab and Octave.
Springer-Verlag, 2010, 3rd edition, ISBN 9783642124297

Entry requirements
A basic course in linear algebra (e.g. X_400041 or X_400042)

Recommended background knowledge
A basic course in linear algebra.

Target group
2W, 2W-B, 2-WN, mBA, mBA-D

Optimization of Business Processes

Course code	X_400422 (400422)
Period	Period 4+5
Credits	6.0
Language of tuition	English
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	prof. dr. G.M. Koole
Teaching staff	prof. dr. G.M. Koole
Teaching method(s)	Lecture
Level	400

Course objective
To learn about applications of stochastic operations research in the context of a few application areas, especially in services.

Course content
We deal with a number of application areas of stochastic modeling: production logistics, call centers, health care and revenue management. For each area we present quantitative problems and discuss how they can be solved using mathematical models. We also discuss a number of new models. Several guest lectures are given by people from industry.

Form of tuition
Lectures and practical work.

Type of assessment
Written examination, individual assignments, and a book presentation.

Course reading
Lecture notes.

Target group
mBA, mBA-D, mMath

Remarks
Attendance mandatory.

Ordinary Differential Equations

Course code	X_400026 (400026)
Period	Period 1+2
Credits	6.0
Language of tuition	Dutch
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	dr. B.W. Rink
Teaching staff	dr. B.W. Rink
Teaching method(s)	Lecture, Seminar
Level	300

Course objective
Het leren van de theorie en praktijk van niet-lineaire gewone differentiaalvergelijkingen.

Course content
Dit college is gewijd aan de theorie van niet-lineaire differentiaalvergelijkingen. Aan de orde komen existentie en uniciteit van oplossingen, methoden voor het expliciet berekenen van oplossingen en kwalitatieve aspecten van de oplossingsverzameling. Aan de hand van een aantal concrete voorbeelden wordt geïllustreerd hoe men dergelijke problemen aanpakt.

Form of tuition
De cursus wordt gegeven in college- en werkcollegevorm, waarbij een aanwezigheidsplicht geldt.

Type of assessment
Inleveropgaven en deeltentamens. De eerste inleveropgave telt voor 10% mee in het eindcijfer, het eerste deeltentamen voor 30%, de tweede inleveropgave voor 10% en het tweede deeltentamen voor 50%. Tevens dient de student bij 75% van alle colleges en werkcolleges aanwezig te zijn geweest.

Course reading
Steven Strogatz, "Nonlinear dynamics and chaos: with applications to physics, biology, chemistry and engineering", paperback edition, Westview Press, 1st ed, 2001

Recommended background knowledge
Eerstejaars cursussen Calculus en Analyse

Target group
2W, 2W-B, 2-WN, 3BA, mBA, CHW-doorstroom

Remarks

Actuele informatie over dit vak kan worden gevonden op Blackboard.

Performance of Networked Systems

Course code	X_405105 ()
Period	Period 4
Credits	6.0
Language of tuition	English
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	prof. dr. R.D. van der Mei
Teaching staff	dr. ing. T. Kielmann, prof. dr. R.D. van der Mei
Teaching method(s)	Lecture
Level	400

Course objective
The student will acquire basic knowledge of:

• performance aspects of software and hardware systems,
• performance aspects of networked systems and services,
• performance engineering principles and methods,
• quantitative models for predicting and optimizing the performance of networked systems,
• quantitative models planning capacity of networked systems.

The student will gain experience in engineering and planning performance of networked systems, and will learn how to tackle practical performance problems arising in the ICT industry.

Course content
Over the past few decades the use of information and communication technology (ICT) has been experiencing tremendous growth, which is not likely to slow down in the near future. As a consequence, our information and communication systems are expected to process huge amounts of (digital) information, which puts a tremendous burden on our ICT infrastructure. At the same time, our modern society has become largely dependent on the well-functioning of our ICT systems; large-scale system failures and perceivable Quality of Service (QoS) degradation may completely disrupt our daily lives and have huge impact on our economy. Motivated by this, the course will focus on the following performance related issues of networked systems:

- How can we design and engineer networked systems for performance?
- How can we plan capacity in networked systems?
- How can we predict and optimize the performance of networked systems?

In addition to basic theory of performance models and engineering for networked systems, the application of the theory to solve practical problems will play a central role.

Form of tuition
Classroom lectures and practical homework assignments.

Type of assessment
The assessment will be based on both homework assignments and a written exam.

Course reading
A textbook, supplemented with a number of subject-matter research papers.

Textbook:
D.A. Menasce, V.A.F. Almeida and L.W. Dowdy
Performance by Design - Computer Capacity Planning by Example
Prentice Hall PTR, Upper Saddle River, NJ 07458
ISBN 0-13-090673-5

Target group
mBA, mCS, mPDCS, mEct

Project Optimization of Business Processes

Course code	X_400213 (400213)
Period	Period 3
Credits	6.0
Language of tuition	English
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	dr. R. Bekker
Teaching staff	dr. R. Bekker
Teaching method(s)	Lecture, Practical
Level	500

Course objective
To acquire skills related to Decision Support Systems, and to learn to apply relevant scientific knowledge.

Course content
Project optimization of business processes concerns the construction and/or design of (part of) a decision support system that:
- is designed and built in a scientifically sound way;
- can be used in practice.
The result will be made publicly available on the internet.

Form of tuition
Project

Type of assessment
Individual test for VBA, individual grade for participation in group project based on observed participation and a short oral exam.

Course reading
None.

Recommended background knowledge
Applied Stochastic Modeling (X_400392).

Target group
mBA, mBA-D

Research Paper Business Analytics

Course code	X_400206 (400206)
Period	Ac. Year (September)
Credits	6.0
Language of tuition	English
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	drs. H.J.M. van Goor-Balk
Teaching staff	drs. H.J.M. van Goor-Balk
Teaching method(s)	Lecture
Level	500

Course objective
The objective of the report is to demonstrate the student's ability to describe a problem in a clear manner (the report should therefore be concise and 'to the point') for the benefit of an expert manager.

Course content
As part of the BA programme, students are required to produce a 'thesis'. This is an account of a research project undertaken by the student further to a specific problem statement. The input for this research may involve the use of computer-generated data, although it can also be drawn from the existing literature.

The student records his or her findings in a written report - the research paper - and also gives a verbal presentation. The paper should emphasize the business-related aspects of the programme as well as the more fundamental aspects of mathematics or computer science.

Form of tuition
Supervision by a staff member of preferably the Faculty of Science.

Type of assessment
A written report and a verbal presentation (both in English).

Target group
mBA, mBA-D

Remarks
Students should consult the coordinator to find a topic and a supervisor. If you are planning to write your paper within two months, please make an appointment with Annemieke van Goor (H.J.M.van.Goor-Balk@vu.nl).
More information:
- http://www.few.vu.nl/nl/studenten/project-en-stage/stagebureau-wiskunde-informatica/research-paper-ba/index.asp (NL)
http://www.few.vu.nl/en/current-students/internship-office-for-mathematics-and-computer-science/ba-paper/index.asp (EN)

Scientific Writing in English

Course code	X_400512 ()
Period	Period 4
Credits	3.0
Language of tuition	English

Faculty	Faculteit der Exacte Wetenschappen
Coordinator	M. van den Hoorn
Teaching method(s)	Lecture
Level	400

Course objective
The aim of this course is to provide the writing student with the essential linguistic means for producing English academic texts which are effective, idiomatically and stylistically appropriate and grammatically correct.

Course content
The initial focus in the course lies on the form of scientific texts in the Exact Sciences:
• Abstract (or summary)
• Introduction
• Methods
• Results
• Discussion

General course outline
Introducing the topics
- Academic and technical writing in English
- The characteristics of different kinds of scientific texts
- How scientific writing is judged and assessed
- Where do you find your information and how do you present it?
- How to avoid committing plagiarism
Who am I writing for? What do I want to say?
- Your readership
- Key parts of an academic article: title, abstract, introduction, methods, results and discussion
Writing the actual article
- Paragraph and sentence construction: how do I link paragraphs together?
- Writing simple and complex sentences. Active and passive sentences.
- Argumentation : how do I put an argument? How do I frame my own opinion?
Should I use "I" or "we"?
Writing correct English
- Use of apostrophes and colons
- Word order, verb tenses, time and tense
- Avoiding mistakes typically made by Dutch writers
- Common spelling mistakes

You will be making considerable use of peer assessment: examining fellow students' written work and giving them feedback. This method provides useful insights into how a text might be improved. The process of providing someone else with feedback on their text is something that you will find very instructive.

Form of tuition
The course is focused on self-tuition. The plenary sessions concentrate on the process of writing and the product of writing. Homework is part of the course. With each topic, participants work through a phased series of exercises that usually conclude with the requirement to write a short piece of text. The instructor will append extensive written remarks to this text.

Type of assessment
There will be no examination. However, students will receive their credits only when they have participated in all classes (presence is obligatory) and also when they have handed in the assignments satisfactorily. Students will receive a 'pass' when they have finished the course.

Course reading
For this course you need the book Effective Scientific Writing: an advanced learner's guide to better English (A. Bolt & W. Bruins, ISBN 978 90 8659 6171). This book can be obtained at the VU bookstore, which is located in the VU main building. The costs are € 27,95 per book. For questions contact the Taalcentrum-VU at 020 - 598 9804.

Entry requirements
Bachelor Exact Sciences

Target group
mBA, mSFM en mMath

Statistical Models

Course code	X_400418 (400418)
Period	Period 1+2
Credits	6.0
Language of tuition	English
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	dr. E.N. Belitser
Teaching staff	prof. dr. M.C.M. de Gunst, dr. E.N. Belitser
Teaching method(s)	Lecture
Level	400

Course objective
The student will be able to accurately apply several common statistical models in valid settings, and will demonstrate understanding of the the theoretical foundation for each model.

Course content
Analysis of Variance, Generalized Linear Models, Non-linear Models, Time Series Models

Form of tuition
Course of lectures, exercises and tutorial
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Type of assessment
Course of lectures, exercises and tutorial.

Course reading
"Statistical Models" by Prof. dr. M.C.M. de Gunst

Entry requirements
Algemene Statistiek (X_400004) and Statistische Data Analysis (X_401029). A sufficient mark for the exercises is required for entry to

the written examination.

Recommended background knowledge
Algemene Statistiek (X_400004) and Statistische Data Analysis (X_401029). A sufficient mark for the exercises is required for entry to the written examination.

Target group
mBA, mBA-D, mMath

Stochastic Optimization

Course code	X_400336 (400336)
Period	Period 1+2
Credits	6.0
Language of tuition	English
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	dr. S. Bhulai
Teaching staff	dr. S. Bhulai
Teaching method(s)	Lecture
Level	400

Course objective
The goal of the course is to discuss techniques from the field of stochastic optimization and their applications.

Course content
This course deals with the theory and algorithms for stochastic optimization with an application to controlled stochastic systems (e.g., call center management, inventory control, optimal design of communication networks). We discuss aspects of semi-Markov decision theory and their applications in certain queueing systems. In a programming assignment, students learn to implement optimization algorithms and experiment with them. Experience with and insight into the more theoretical subject is obtained through homework exercises.

Form of tuition
Lectures.

Type of assessment
Programming and written exercises, final examination.

Course reading
Lecture notes will be posted on BlackBoard

Entry requirements
Stochastische Methoden (400391) or equivalent and a programming language.

Recommended background knowledge
Stochastische Processen (X_401026) and Wachtrijmodellen (X_401061) or equivalent courses on Stochastic Processes en Queueing Theory and a programming language.

Target group
mBA, mBa-D, mMath, mSFM

Stochastic Processes for Finance

Course code	X_400352 (400352)
Period	Period 1+2
Credits	6.0
Language of tuition	English
Faculty	Faculteit der Exacte Wetenschappen
Coordinator	prof. dr. J. van den Berg
Teaching staff	prof. dr. J. van den Berg, dr. E.N. Belitser
Teaching method(s)	Lecture, Seminar
Level	400

Course objective
Learn basics of stochastic processes in continuous time, including the concepts of martingales and stochastic integration. Apply these concepts to price options on stocks and interest rates by the no-arbitrage principle.

Course content
Financial institutions trade in risk, and it is therefore essential to measure and control such risks. Financial instruments such as options, swaps, forwards, caps and floors, etc. play an important role in risk management, and to handle them one needs to be able to price them. This course gives an introduction to the mathematical tools and theory behind risk management.
A "stochastic process" is a collection of random variables, indexed by a set T. In financial applications the elements of T model time, and T is the set of natural numbers (discrete time), or an interval in the positive real line (continuous time). "Martingales" are processes whose increments over an interval in the future have zero expectation given knowledge of the past history of the process. They play an important role in financial calculus, because the price of an option (on a stock or an interest rate) can be expressed as an expectation under a so-called martingale measure. In this course we develop this theory in discrete and continuous time. Most models for financial processes in continuous time are based on a special Gaussian process, called Brownian motion. We discuss some properties of this process and introduce "stochastic integrals" with Brownian motion as the integrator. Financial processes can next be modeled as solutions to "stochastic differential equations". After developing these mathematical tools we turn to finance by applying the concepts and results to the pricing of derivative instruments and other matters. Foremost, we develop the theory of no-arbitrage pricing of derivatives, which are basic tools for risk management.

Form of tuition
Lectures and exercises.

Type of assessment
Homework assignments / written examination.

Course reading
Shreve, S.E., Stochastic Calculus for Finance I: The Binomial Asset Pricing Model. Springer.

Shreve, S.E., Stochastic Calculus for Finance II: Continuous-time models. Springer.

In addition, it is useful to have the following book:
Bjork, T., Arbitrage Theory in Continuous Time, third edition. Oxford University Press.

Entry requirements
Introductory probability theory and statistics, calculus.

Recommended background knowledge
Introductory probability theory and statistics, calculus.

Target group
mBA, mBA-D, mMath, mSFM, master Econometrics, Quantitative Finance

Remarks
A significant part of the course is used to introduce mathematical subjects and techniques like Brownian motion, stochastic integration and Ito calculus. In view of this, the course is NOT meant for students who already followed the master course "Stochastic Integration". On the other hand, after following this course (Stochastic processes for finance), students may be motivated to follow the other one (Stochastic Integration) to study the above mentioned mathematical subjects in a deeper and more rigorous way.