April 11, 2014

Phil Shaver, Chair
Faculty Executive Committee
College of Letters & Science

RE: Establishment of New Major in Mathematical Analytics and Operations Research

The Davis Division of the Academic Senate forwarded the proposal for review to all Divisional standing committees as well as Faculty Executive Committees within each college/professional school and then to Undergraduate Council (UGC).

After careful review, at its meeting on April 3, 2014, the Undergraduate Council voted unanimously in support of the proposal to establish the Major in Mathematical Analytics and Operations Research.

By copy of this memo to Interim Vice Provost de le Pena, the Davis Division provides notification that the Division has completed its review; thus transferring responsibility to the Vice Provost's Office to coordinate review by the Council of Deans and Vice Chancellors.

Respectfully,

Matthew Traxler, Chair
Davis Division Academic Senate Undergraduate Council

Enclosure: Proposal to Establish the Mathematical Analytics & Operations Research Major

cc: Bruno Nachtergaele, Chair, Davis Division Academic Senate
        Gina Anderson, Executive Director, Davis Division Academic Senate
        Carolyn de la Pena, interim Vice Provost, Undergraduate Education
        Alexandra Navrotsky (Interim) Dean, Division of Mathematical and Physical Sciences

January 16, 2014

Bruno Nachtergaele, Chair
Davis Division of the Academic Senate

       Subject: Establishment of New Major in Mathematical Analytics and Operations
                      Research

Dear Professor Nachtergaele,

       The faculty of the department of Mathematics has proposed establishing a major in
Mathematical Analytics and Operations Research. In accordance with the provisions of PPM
200-20, the proposal has been reviewed by Dean Alexandra Navrotsky – Mathematical and
Physical Sciences, who has expressed support for the proposed action.

       After careful review the College of Letters and Science Executive Committee has
recommended approval of the proposal to establish the major in Mathematical Analytics and
Operations Research. On behalf of the Executive Committee, I am hereby forwarding the
proposal to you for review and action by the Davis Division.

                                   Sincerely,

                                   Phillip Shaver, Chair
                                   Executive Committee
                                   College of Letters and Science

cc: B. Floyd, Director
       Undergraduate Education and Advising
       College of Letters & Science

March 20, 2014

Matthew Traxler, Professor & Chair
Undergraduate Council

Dear Council Chair Traxler,

The Division of Mathematical and Physical Sciences is in full support of the proposed Major in Mathematical Analytics and Operations Research (MAOR) to be offered by the Department of Mathematics. This major addresses a new and important area of scientifically-trained professionals being sought by industries dealing with big data and planning. These new professionals need to not only be able to extract data, but go one step further in making solid models for forecasting, optimizing decisions, and long-term planning. In the critical challenges facing big data management, big data analytics, or scientific discovery processes, society's new professionals need to be aware of (and trained in) problem-solving techniques and methodologies of advanced mathematical nature (e.g., convex and integer optimization, geometric tools for machine learning and clustering).

Mathematics is well-poised to offer this new major. The necessary courses involving operations research have been taught in Mathematics for several years now. This accumulated experience with teaching the essential courses has resulted in a thoughtful design of the curriculum for the proposed MAOR major. The design is economical in simply re-adjusting existing courses rather than proposing many new courses. Another relevant consideration is that this new major establishes yet another connection to the work of faculty colleagues in the College of Engineering, College of Agricultural and Environmental Sciences, and the Graduate School of Management.   These cross-college connections in offering a more diverse curriculum with new innovative majors are the future for UC Davis students. MPS looks forward to start offering this new major in 2014-15.

Sincerely,

Alexandra Navrotsky
Interim Dean
Mathematical & Physical Sciences

AN/tl

Cc: MPS Undergraduate Faculty Assistant De Loera

Proposal for a new major in "Mathematical Analytics and Operations Research"

Matthias Köppe   Jesús De Loera   Albert Fannjiang

November 25, 2009

Contents

0   Introduction

The 2009–2014 academic plan asks to establish a new major or emphasis in "Mathematics for Forecasting, Planning, and Decision Making" (working title). This proposal contains the proposed details of such a major. The hope is that the new major can be approved and implemented quickly, with the first students to enroll or declare major in the 2010–2011 academic year.

The proposal is driven by the observation that undergraduate and graduate programs such as Operations Research and Industrial Engineering, in which quantitative decision-making techniques are covered, are missing at UC Davis. Moreover, while UC Davis does have a business school (Graduate School of Management), it does not offer an undergraduate business program but only an M.B.A. degree. Programs like these are present at nearly all major universities, including several UC campuses. The closest undergraduate programs on campus (apart from the majors in Mathematics) are the B.A. in Economics and the B.S. in Managerial Economics (see subsection 2.2 for details).

The Mathematics department is in the unique position on this campus to fill this gap in the program of UC Davis, from a distinctively mathematical perspective.

This proposal describes a rigorous mathematics program, which will provide a possible career path towards a Ph. D. in Mathematics or Applied Mathematics. At the same time, a variety of other career paths should be opened by the program, such as careers in industry; possibly, a professional master's degree in mathematics; professional degrees such as M.B.A.; graduate school in Operations Research, Statistics, or Economics.

We argue that the greater mathematical sophistication (compared to most programs in Operations Research) is necessary to prepare students in a way to keep up with a trend towards deeper mathematical tools (including combinatorics, probability, functional analysis, numerical linear algebra, geometry, algebra, and computational topology) that are used successfully in various applications, including web search engines, social network analysis, computational economics, and epidemiology. The increased mathematical sophistication is reflected in the proposed name of the major, *B.S. in Mathematics of Operations Research*.

The proposal draws its inspiration from various sources, including programs in business and engineering departments at Cornell, Waterloo, CMU, U British Columbia, NYU, and UC Berkeley; the success of *Wirtschaftsmathematik* programs ("Economathematics", meaning Mathematics in business and industry and/or Mathematics for Economics) that are run by many Mathematics departments in Germany; and some similar programs on other UC campuses (in particular Los Angeles; see subsection 2.1).

1 Current Resources and Projections

1.1 Current Faculty Resources and Connections

This area has strong connections to research of several members of the department. The faculty members whose areas of research are closely related to this effort are Jesus De Loera, Albert Fannjiang, Roland Freund, Janko Gravner, Matthias Köppe, Ben Morris, Steve Shkoller, and Craig Tracy. Many others have expressed interest.

The department already runs several classes closely related to this topic (Math 168 Mathematical Programming, Math 135AB Probability, Math 133 Mathematical Finance). Faculty members serve in several Ph.D. committees that require these themes and in fact some of our students work on this area.

1.2 Projections on Enrollment Numbers

In the short term (first two years), we think it is realistic to expect 10 to 15 students. In the medium term, we project to attract about 35 students.

For sure some students, who would now go for a B.S. Mathematics, will choose the new major. However, we expect the majority of these students to come from the outside, i.e., they will be students that would otherwise choose Economics or Managerial Economics, or some engineering as a major.

In the medium term, we also expect students that would otherwise go for a business major at a different university, to choose this new major at UCD.

These projections are based on the following quantitative data.

- *Statistical data on the declared majors of students in the 21A course that started their studies at UC Davis in the years 2000 through 2002.* (The data was kindly provided by Andrew Waldron, UPC Chair.)

  In the degree programs on *Economics* and *Managerial Economics*, students have the choice for the 16 series (a basic sequence of Calculus) or the 21 series (an advanced sequence of Calculus; required for all Math majors). The large number of students who decide to take the 21 series (as indicated by these numbers for 21A) suggests that there is a large number of students who are interested in these subjects related to this proposal and in a mathematical rigor and sophistication greater than the one that is required by their degree programs.

- *Statistical data on combinations of majors and minors at UC Davis from 2000 to 2008.* (These data were obtained from Frank Wada, University Registrar.)

  The data (Table 2) shows that every year there are several students (in the past five years, between 3 and 9) who declare a double major, combining a flavor of Mathematics with Economics or Managerial Economics.

- *Experiences with similar majors at different UC campuses.*

Table 1: Students of relevant majors taking class 21A

	Start year at UC Davis		
	2000	2001	2002
Economics	145	104	102
Managerial Economics	63	69	55

Table 2: Declared combinations of majors and minors

Major	2000	'01	'02	'03	'04	'05	'06	'07	'08
Mathematics Major (any flavor) combined with:									
Economics	3			5	2		6	9	5
Manager. Econ.		1	2	1	2	3			1
Mathematics Minor combined with:									
Economics								2	3

According to Peter Petersen, Undergraduate Vice Chair at UC LA
Mathematics, the interdepartmental major B.S. Mathematics/Economics

> "[. . .] was created about 16 years ago. It was pretty much an instant success. We graduate about 30–50 people every year. I think we have about 130 students in the major at any given time. This is a little more that we have in either pure or applied math. However, you have to be aware that it is an interdepartmental major. It is essentially run [by] the math department, but we only have it because the econ department gets complaints about not having a pipeline to econ graduate school every time they have external reviews. So we've essentially become that pipeline with this major." (e-mail of March 15, 2009)

1.3   No Additional Resources Required

The major will only require one course change. Affected is only one course (148, Discrete Math), The course will receive a revised syllabus that is very important for the major, but at the same time very solid Discrete Math material that will be suitable and interesting for other math majors.

For the other courses required or recommended by the major, on the basis of current and historical enrollment data and current caps, there is enough capacity for the projected additional students, at least for the above short-term

projection.

1.4 Cooperation with Other Departments: at UC Davis, in the UC system, Nationally and Internationally

A number of required and optional courses would come from the Statistics and Economics departments, so this may require some coordination with these departments.

Cooperation with other campuses in the UC system or with other U.S. universities are not necessary for this undergraduate program, as courses in the necessary depth and breadth can be offered by existing UC Davis faculty in Mathematics, Statistics, and Economics.

An interesting addition to the proposed program will be to set up international exchange programs. A first contact with the Dept. of Mathematics at University of Bayreuth, Germany, has been established. They run a program in "Economathematics" and are interested in setting up an exchange program for their students with UC Davis. It may be useful find additional contacts with other universities abroad. We plan to explore these possibilities with the Education Abroad Center.

2 Related Programs

2.1 Mathematics Majors on Other UC Campuses

UC Berkeley has a Major in Mathematics and a Major in Applied Mathematics. Applied Math majors need to select a "cluster of electives"; the clusters closest to this proposal are "Actuarial Science", "Economics", and "Operations Research".

UC Irvine offers a B.S. degree in Mathematics, with 5 different "tracks", including the "Concentration in Mathematics for Economics" and the "Specialization in Applied and Computational Mathematics".

UC Los Angeles offers a Mathematics major, an Applied Mathematics major, Mathematics of Computation major, and a Mathematics/Applied Science major. The latter major offers several plans, including the "Actuarial Plan". In addition, an interdepartmental major "Math/Economics" is offered – this is quite close to this proposal.

UC Merced offers a B.S. in Applied Mathematical Sciences with several emphasis tracks, one of which is Economics.

UC Riverside offers a B.S. in Mathematics, which splits into programs on Pure Mathematics, Computational Mathematics, and Applied Mathematics. The latter has an Economics option.

UC San Diego offers a variety of undergraduate degrees in Mathematics that are meant for various different career paths; this includes: B.A. in Mathematics (career paths include Math Ph.D.), B.A. in Applied Mathematics (career path: Applied Math Ph.D.), B.S. in Mathematics-Probability and Statistics (career

paths include graduate school), B.S. in Mathematics-Scientific Computation, B.A. in Mathematics-Applied Science (specifically without a career path to a Math Ph.D.) and a B.A. in Mathematics/Economics (career path: graduate study in Economics, professional degree programs such as an M.B.A., other managerial studies).

UC Santa Barbara offers two Mathematics majors (B.A. and B.S.) as well as a B.A. Economics/Mathematics and a B.S. Financial Mathematics and Statistics. Note that the B.A. Economics/Mathematics has a strong weight on the economics part; the only required upper-level mathematics courses are Math
108A-B (Linear Algebra) and Math 117 (Methods of Analysis).

UC Santa Cruz has a major program leading to a B.A. in Mathematics, with 3 different tracks, including the Pure Track and the Computational Track.

2.2   Existing Related Majors on Campus

The existing programs on campus closest to this proposal, outside the Department of Mathematics, are the B.A. in Economics (College of Letters and Sciences) and the B.S. in Managerial Economics (College of Agricultural and Environmental Sciences).

The B.S. in Managerial Economics only requires 16A–C or 21AB as mathematics classes. The Department of Agricultural and Resource Economics offers the following undergraduate classes related to this proposal.

- ARE 155 (Quantitative Analysis for Business Decisions), with some topics in operations research and mathematical programming

- ARE 156 (Introduction to Mathematical Economics), which includes some discussion of optimality conditions in optimization problems

- ARE 157 (Analysis for Production Management), which covers some aspect of scheduling and production planning

Of these classes, ARE 155 is a required class, and ARE 156 is an elective in the B.S. in Managerial Economics only requires 16A–C or 21AB as mathematics classes.

The B.A. in Economics only requires 16AB or 21AB as mathematics classes, and does not require any classes related to (quantitative) decision making. The elective class ECN 106 (Decision Making) has no mathematical content. ARE 156 (see above) is, however, an elective.

None of these two existing majors has the mathematical sophistication and depth necessary for the goals of this proposal.

2.3   Previous Efforts

In 2001, two new majors (*B.S. in Applied Mathematics*, *B.S. in Mathematical and Scientific Computation)* were proposed and later implemented by the Mathematics Department.

The experiences with these majors have been taken into consideration for the design of the proposed new major.

As we have explained above, we will separate the target group of the proposed new major clearly from all other majors (in particular from that of the *B.S. in Applied Mathematics*). Moreover, we will make sure that this clear separation (and the associated career paths) is obvious from the marketing materials for the new major.

2.4   Competing Efforts

The Dept. of Statistics and the Dept. of Economics currently propose to add a new major, B.S. in Statistical Finance. This program is very narrowly focused on methods from statistics for financial applications. It requires the following courses from Mathematics: MAT 21A–C, MAT 67, and MAT 133 (Math. Finance). The list of optional courses from Mathematics is MAT 135B (Stoch. Processes) MAT 168 (Optimization). The lack of required courses in algebra and real analysis shows that this program is not intended to be a rigorous program in mathematics that has a career path towards a Ph.D. in Mathematics or Applied Mathematics. This fact and the narrow focus of the B.S. Statistical Finance program make it sufficiently different from the program of this proposal.

3   Design Considerations

3.1   New Major, Not Just a New Emphasis

There are two possible main strategies to implement a new undergraduate program.

1. **Modifying the major in Applied Mathematics or Mathematical and Scientific Computation to add a new Emphasis.**

   The B.S. in Mathematical and Scientific Computation currently has two emphases, "Computational and Mathematical Biology Emphasis" and "Computational and Mathematics Emphasis". The two emphases only differ in 2 courses (8 units) in the enrichment, and are otherwise identical.

   The B.S. in Applied Mathematics currently does not have emphases, but has some flexibility to cover different specializations, by choosing different enrichment courses.

   One implementation strategy would be to modify one of the two programs to include an option for a "Decision Making Emphasis".

   The proposed major requirements (see section 4) are, however, quite different from these two programs (and from the B.S. Math program). It neither requires the full numerical analysis cycle (128ABC) as the *B.S. Mathematical and Scientific Computation* does, nor does it require complex analysis (185A) and ODEs (119A), as the *B.S. Applied Mathematics* does.

This makes it difficult to implement the proposed program as an emphasis of either of the two other programs, without sacrificing the current clear structure that program. This is particularly true for the *B.S. Applied Mathematics*, which has a very clear and simple structure.

2. **Establishing a new major.**

This strategy, of course, gives the greatest flexibility in setting the requirements of the new program.

The success of the proposed new program requires that the pro- gram can be marketed separately to its target group. With the proposed program, we wish to attract students who would, for a variety of reasons, not consider enrolling in a major in *Mathematics*, *Applied Mathematics*, or *Mathematics and Scientific Computation*. These reasons include that the students, at the time of their decision for the major, cannot envision a research career in pure mathematics. Also, that the students are not interested in the "sciences" or engineering, which is the focus of both the majors in *Applied Mathematics* and *Mathematics and Scientific Computation*.

To market the proposed new program of studies to this group of students, the new program must be clearly separated from the other undergraduate mathematics program. Designing the new program as a new emphasis of an existing major would not provide this separation, and will severely limit the possible impact and chances of success for the proposed program.

Another important aspect is what the degree will look like on the CV or résume of a student. A degree such as "B.S. in Mathematics of Operations Research" (see also the discussion below in subsection 3.2) will give a clear picture, as "Operations Research" is a well-established term for a field that is well-known and highly regarded across the industry. This will be very useful for students of this major, in terms of their **career opportunities (**see also the discussion in section 5). This is in contrast to a degree in "Applied Mathematics", which connotes classical applied mathematics with its applications in engineering and the sciences, and thus an entirely different career path. The same is true for *Mathematics and Scientific Computation*. This is regardless of whatever "emphasis" is denoted in the CV or resumé as a modifier.

For these reasons, this proposal strongly urges to establish a new major, rather than an emphasis of an existing program.

3.2 Name of the New Major

The working title "Mathematics for Forecasting, Planning, and Decision Making" is too complicated; it will be an obstacle to the goal of attracting students.

We propose the title "**Mathematical Analytics and Operations Research**".

Operations Research is a well-established term for a field (brand name) that is well-known across the industry. Therefore, a degree of "B.S. in Mathematical Analytics

and Operations Research" on a student's CV or resumé would be very useful for a student to have, in terms of career options.

The title *Mathematical Analytics and Operations Research* both expresses the greater mathematical sophistication of this degree program, again for the benefit of the chances of the student on the job market.

4 Proposed Major Requirements

4.1 Preparatory Subject Matter

We describe the proposed major requirements in the preparatory subject matter by comparing them to those of the Applied Mathematics major.

- Instead of the 7 to 10 units reserved for courses from an application field, we include 8 units of courses from basic economic theory: ECN 1A (Microeconomics) and ECN 2A (Macroeconomics).

- We drop the requirement for ECS 40 (Software Development and Object-Oriented Programming).

  The rationale is that the typical computational tools are mathematical modeling and optimization systems such as GAMS and AMPL, or statistical tools such as R. Software development skills, in particular object- oriented programming, are not as important for students of this major as they are for majors in Applied Mathematics or Mathematical and Scientific Computation.

- This gives room to adding an introductory class in Statistics as a requirement. At the choice of the student, this introductory class can be Stat 13, 102 or 103.

  This provides basic knowledge in statistics, i.e., "how to deal with data". This course also sets the foundation for other courses from Statistics that are possible enrichment courses for this major.

In total, there are 43–46 required units of preparatory subject matter; see Table 3.

4.2 Depth Subject Matter

We describe the new major by comparing them to those of the Applied Mathematics major.

- *Algebra:*
  Like the Applied Math major, the proposed major includes a course in modern algebra, 150A. It is a core component of a rigorous program in mathematics.

- *Real Analysis:*
  Like the Applied Math major and all other mathematics majors, the proposed major includes two courses in real analysis, 125AB. It is a core component of a rigorous program in mathematics.

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Table 3: Proposed Major Requirements (Preparatory Subject Matter)

	B.S. Math	Math-Sci Com	Appl Math	*New Major*	u
Math	12	12	12	12	0–3
Calculus	21ABCD, 25	21ABCD, 25	21ABCD, 25	21ABCD, 25	19
Diff. eqns	22B	22B	22B	22B	4
Lin. Alg.	67	67	67	67	4
Comp. Sci.	CSE 30 or ENG 6	CSE 30, 40	CSE 30, 40	CSE *30*	4
	Physics (4 u)		Appl. (7–10 u)		
Microecon.				ECN 1A	4
Macroecon.				ECN 1B	4
Statistics				Stat 13/102/103	4
Total	34–38 u	35–38 u	42–48 u	43–46 u	

- *Numerical Analysis:*

  We include only one (not two) courses from Numerical Analysis, 128A. We don't include 128B (Numerical Analysis of Equations).

- *Complex Analysis, Ordinary Differential Equations:*

  These two courses are dropped from the list of required courses.

  Ordinary Differential Equations, however, is one of the recommended enrichment courses from mathematics.

- *Probability:*

  In addition to 135A (Probability), we also require 135B (Stochastic Processes), as those are an important modeling tool in Operations Research.

- *New required class in "Algorithmic Discrete Mathematics":*

  This is a newly (re)designed c l a s s ; see below in subsection 4.5.

- *Mathematical Programming:*

  This becomes a required class. A possible mild redesign is discussed in subsection 4.5.

- *Enrichment:*

  We require 16 units of enrichment courses from Mathematics and Statistics, and 8 units of enrichment courses from Economics.

  See below in subsection 4.4.

Table 4: Proposed Major Requirements (Depth Subject Matter, Core Mathematics)

	B.S. Math	Math-Sci Com	Appl Math	*New Major*	u
Entry level		. . . one of 108/114/115A/141/145. . .			0–4
Core					
Algebra	150ABC	150A	150A	150A	4
Real Analysis	125AB	125AB	125AB	125AB	8
Complex Analysis	185A		185A		0
Probability	135A	135A	135A	135A**B**	8
Numerical Anal.		128ABC	128AB	128**A**	4
ODE			119A		0
Algorithmic Discrete Mathematics				148 (*revised*)	4
Mathematical Programming				168	4
Enrichment courses from Math & Statistics					16
Enrichment courses from Economics					8
Total	48–52 u	48–52 u	48–52 u	56–60 u	

In total, there are 56–60 required units of depth subject matter. This is slightly more than the number of required units of the other majors; see Table 4.

4.3   Exception from Letters and Sciences Limitations

The proposed major requirements exceed the limitation on the number of upper-division units of 52, imposed by the College of Letters and Sciences. (We remark that Stat 102/103, though used as preparatory subject matter in our proposal, still counts as upper-division units, and thus adds to a total of 60 to 64 upper-division units.)

We seek approval for an exception from Letters and Sciences limitations, on the basis that both the program and the field of Operations Research intrinsically are of interdisciplinary nature, involving components from Mathematics, Economics, and Statistics.

4.4   Enrichment Courses

From Mathematics:

- Convex Geometry (114), Partial Differential Equations (118ABC), Ordinary Differential Equations (119AB), Numerical Analysis in Solutions

of Equations (128B), Mathematical Finance (133), Combinatorics (145), Mathematics and Computers (165), Applied Linear Algebra (167)

From Statistics:

- Introduction to Mathematical Statistics (131BC), Applied Time Series Analysis (137), Financial Data Analysis (180), Statistics in Finance (181)

From Economics:

- Intermediate Micro Theory (100), Industrial Organization (121AB), Theory of Games and Strategic Behavior (122), Financial Economics (134), Econometrics (140), Transportation Economics (145)

From Agricultural and Resource Economics:

- ARE 155 (Quantitative Analysis for Business Decisions), ARE 156 (Introduction to Mathematical Economics), ARE 157 (Analysis for Production Management)

4.5 Course Changes

It is necessary to make course changes, to be able to teach core topics of Operations Research and Decision Making in sufficient breadth and depth. These topics include:

- *Mathematical* **methods:** Deterministic and probabilistics modeling, discrete and continuous optimization, and simulation

- **Applications:** These applications should be predominantly non-engineering, non-science applications. Applications should include those from business (production planning, logistics) and finance.

We propose the following plan:

- The recently established course **133 (Mathematical Finance) will** be taught for the first time in the Spring quarter 2009 by Fannjiang. This course is an important enrichment course for the new major. We expect that 133 may be revised in the near future, based on Fannjiang's experiences with the class and possible input from the Department of Statistics, who have an interest in the Mathematical Finance in the context of their proposed major in Statistical Finance (see subsection 2.3).

- Our proposal is to redesign **148 (Discrete Mathematics) to** include algorithmic topics that are relevant for the new major; the name of the course should be adjusted accordingly ("Algorithmic Discrete Mathematics"). Whether this will be implemented as a new course or a revised syllabus will be decided in conjunction with UPC.

  New material suitable for the course was tried out during the Winter quarter 2009 by Köppe, in the undergraduate topics class *Mathematics*

of Decision Making: An Introduction. The material included mathematical modeling with integer (in particular binary) variables, including an introduction to an AMPL-like algebraic modeling language, fundamental algorithms in graph theory and combinatorial optimization (shortest paths, maximum flows, minimum-cost flows), computational complexity, and combinatorial duality (matchings and covers; paths and potentials; flows and cuts). Further suitable material could include matroids and in- dependence systems, and the associated optimization and approximation algorithms. We note that this material can and should be taught in a way that it is completely independent from 168 (Mathematical Programming).

- Since minimum-cost flows are currently also briefly covered in **168 (Mathematical Programming)** as an application of linear programming, 168 could be mildly redesigned to reduce this in favor of an introduction to integer and mixed-integer programming, including the cutting plane method and branch-and-cut. The new material should be tried out in class, before the 168 is formally redesigned.

4.6 Considerations for Double Majors

It is desirable that the new program is suitable for combining it with a major in Economics to a full double major program. We describe here a sample double-major study plan that meets the requirements of the multiple major approval process. These are the requirements:

- For each major, 80% of the upper-division courses uses to satisfy units and course requirements must be unique, i.e., they cannot be applied toward the completion of the requirements of the other major.

- When the unit requirements of the majors differ, the major with the smaller number of upper-division units will be used for the above criterion.

- The program must normally be completed within 225 units.

The Economics major requires 17 units of lower-division and 44 units for upper division course work. The proposed Mathematics of Operations Research major requires 43 units of lower-division and 56 units of upper division course work. The maximum allowed upper-division overlap by the above requirement will thus be 20% of the 44 units, i.e., 9 units.

A sample study plan that meets these requirements is shown in Table 5. (A remark is that Stat 13, rather than Stat 102/103, needs to be chosen, to meet the requirements in this case.) It has a total of 43 lower-division units and 92 upper-division units; together (135) this is still well below even the minimum number of units every UCD student needs to graduate (180).

Table 5: Sample Double-Major Study Plan

		Counts Towards			
		Math. O.R.	Both	Econ.	Total
Lower-Division Courses					
Calculus	21AB		8		
Calculus	21CD, 25	11			
Diff. eqns	22B	4			
Lin. Alg.	67	4			
Comp. Sci.	CSE 30	4			
Microecon.	ECN 1A		4		
Macroecon.	ECN 1B		4		
Statistics	Stat 13		4		
Total		23	20		39
Upper-Division Courses					
Algebra	150A	4			
Real Analysis	125AB	8			
Probability	135AB	8			
Numerical Anal.	128A	4			
Algor. Disc. Math.	148	4			
Math. Prog.	168	4			
Micro-/macroecon.	ECN 100, 101		8		
Econ. Data Anal.	ECN 102			4	
Econ. History	ECN 110A			4	
Enrichment from Math & Statistics		16			
Advanced courses from Economics				16	
Elective courses from Economics				12	
Total		48	8	36	92

5 Marketing

5.1 The Story of Mathematical Analytics and Operations Research

It is essential to clearly explain the benefits and career options of the new major to prospective students, in particular the conceptions of employers based on the name of the degree (B.S. in Mathematical Analytics and Operations Research).

The Institute for Operations Research and Management Sciences (INFORMS) has great material that explains the career options and application fields of the general area, which could, at least, be a source of inspiration for the presentation on our webpages.

INFORMS also uses powerful slogans (**O.R.: The Science of 'Better'**) and success stories that will be useful in getting the students' attention for the field and the degree program.

5.2 Presentation in the Department Webpages

This presentation should be done carefully on the Department webpages, and, to the extent possible, in the General Catalog (note the space limits there).

Here UC San Diego Mathematics provides a very useful example; their website very clearly describes the career paths that are intended with its various majors in Mathematics.

5.3 Recruitment and Outreach Events

We will create advertising materials (flyers, posters, etc.) that explains the benefits and career options of the new major. We will work with the campus Admissions Office and the campus Advising Services Office, so they will be able to convey these ideas to prospective new students and to freshmen who have not declared majors yet.

In particular, we will make sure that the new major (as well as the other mathematics degree programs) will be represented competently and enthusiastically during events such as *Preview Day* and *Decision UC Davis Day* (for admitted students) run by the campus Admissions Office.

We will also use activities such as *Picnic Day* and the outreach activities targeted to current high school students (such as the ones currently run in the framework of the VIGRE program.

5.4 Directories

INFORMS maintains a directory of academic programs in this area at http://www.informs.org/index.php?c=742&kat=ORMS+Programs+in+the+US+by+Type+of+Program. When established, the new program should be listed here.

5.5 Perseverance in Marketing Efforts

It is important that these activities are run continuously in every year, for the program to be successful. The Management Committee (section 6) will appoint individuals to be in charge of the above activities for a term of one year each. The Management Committee will oversee the success of the activates, and make the necessary adjustments for the future.

6 Management Plan

6.1 Before the Creation of the Major

We have formed an ad-hoc committee (Köppe, De Loera, and Fannjiang) to oversee the process of the creation of the major. We will work in close connection to UPC and FRC.

6.2 After the Creation of the Major

After the formal creation of the major, it will be managed at the discretion of the Department of Mathematics. We emphasize that in the first few years it will be important to "nurture" this new major. To oversee this, we intend to create a departmental committee of 3 faculty (determined by departmental committee assignments) and ex-officio members (including the UPC Chair). We assume that after 10 years, this committee will no longer be needed and its tasks can be taken over by UPC.

This *Management Committee* will be in charge for the implementation of the program, organizing the recruitment activities, an ongoing monitoring and performance evaluation of the program, and for conducting any necessary changes. The Management Committee will meet at least once every quarter.

The Management Committee will appoint individuals that will be in charge of specific activities for a period of one year, reporting to the Management Committee. These functions include:

- Maintenance of web pages and advertising materials;

- organizing events and participating in specific events such as *Preview Day;*

- *Advisor for Mathematical Analytics and Operations Research*

The Advisor will keep close contact to the students enrolled in the major through activities such as a biweekly *Mathematical Analytics and Operations Research Tea*. The purpose of these activities will be twofold:

1. The program is a high-caliber degree program of relatively high workload. By having a designated advisor for a relatively small group and organized activities, students will feel rewarded for their hard work, which will increase their motivation and academic performance.

2. It allows us to monitor whether the program is running smoothly, from the perspective of the enrolled students, and find out what are the changes necessary to improve the program. This is particularly important in the first few years of the program.