Developing Technology Solutions to Support Academic Career Planning and Student Scheduling

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Presentation available online: http://uaps.ucf.edu

Goals for Presentation

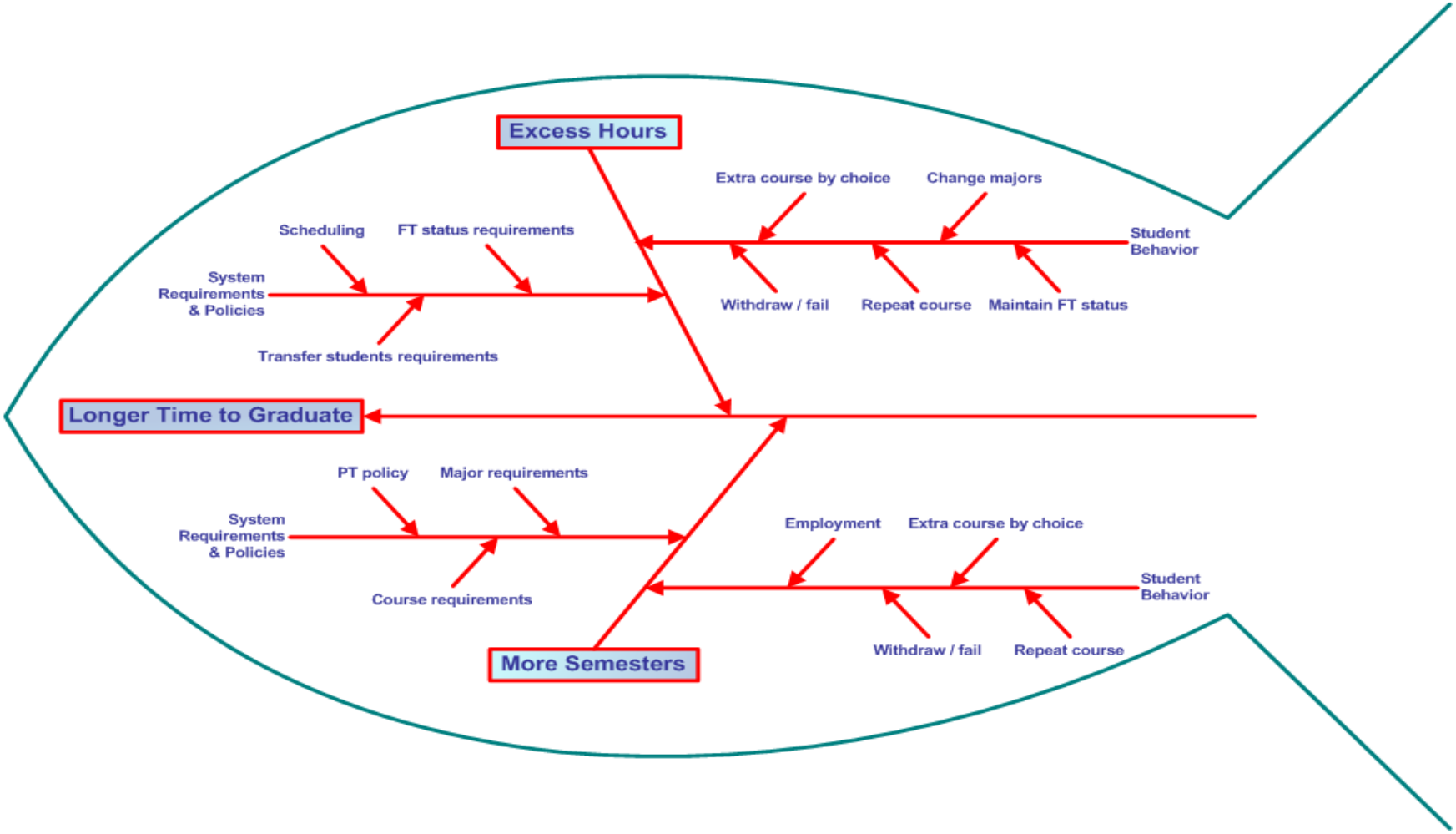
- Describe the need for program of study planning and class scheduling assistance for students and advisors
- Describe how computerized modeling and optimization tools can form a potential solution
- Demonstrate how SAS and SAS/OR can be used for customized model generation and solutions of program of study planning models
- Demonstrate how Excel and Excel Solver can be used to test class scheduling feasibility and build alternative schedules
- Highlight the potentials for integration and further developments

The University of Central Florida

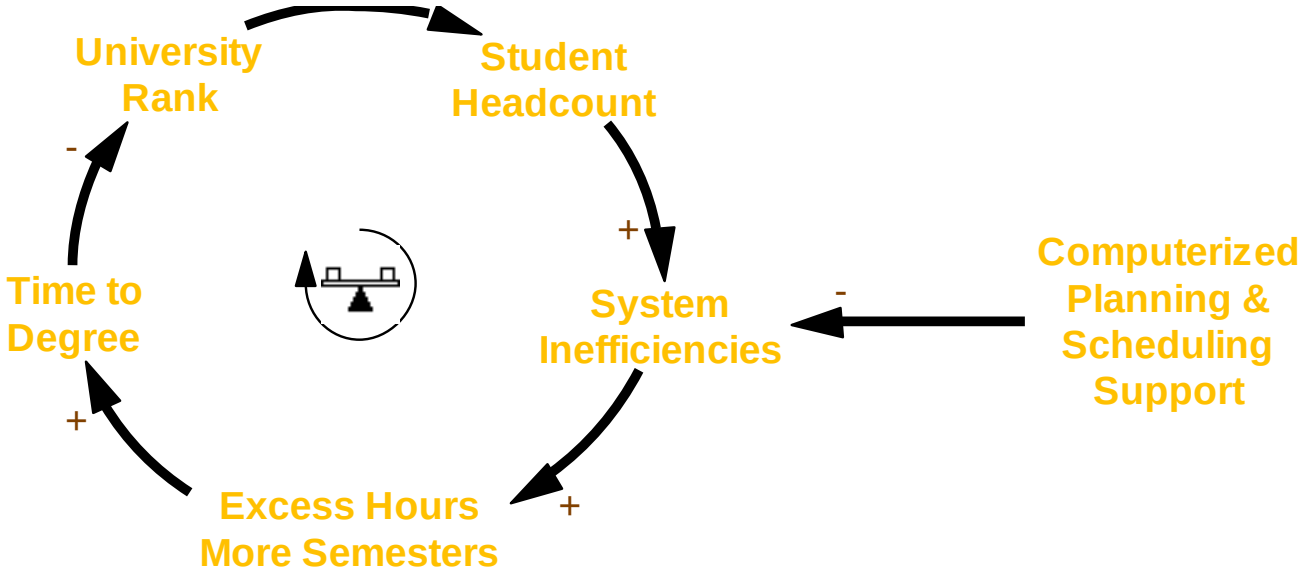
Stands for Opportunity

- Established in 1963 (first classes in 1968), Metropolitan Research University
- Grown from 1,948 to 46,907 students in 38 years
  - 39,679 undergrads and 7,228 grads
  - 11 colleges
  - 12 regional campus sites
  - 6th largest public university in U.S.
  - 92% of lower division and 67% of upper division students are full-time
- Carnegie classification:
  - Undergraduate: Professions plus arts & sciences, high graduate coexistence
  - Graduate: Comprehensive doctoral (no medical) [Medical college approved]
- 95 Bachelors, 97 Masters, 3 Specialist, and 28 PhD programs
- Largest undergraduate enrollment in state
- Approximately 1,300 full-time faculty; 9,800 total employees

Delayed Graduation Problem

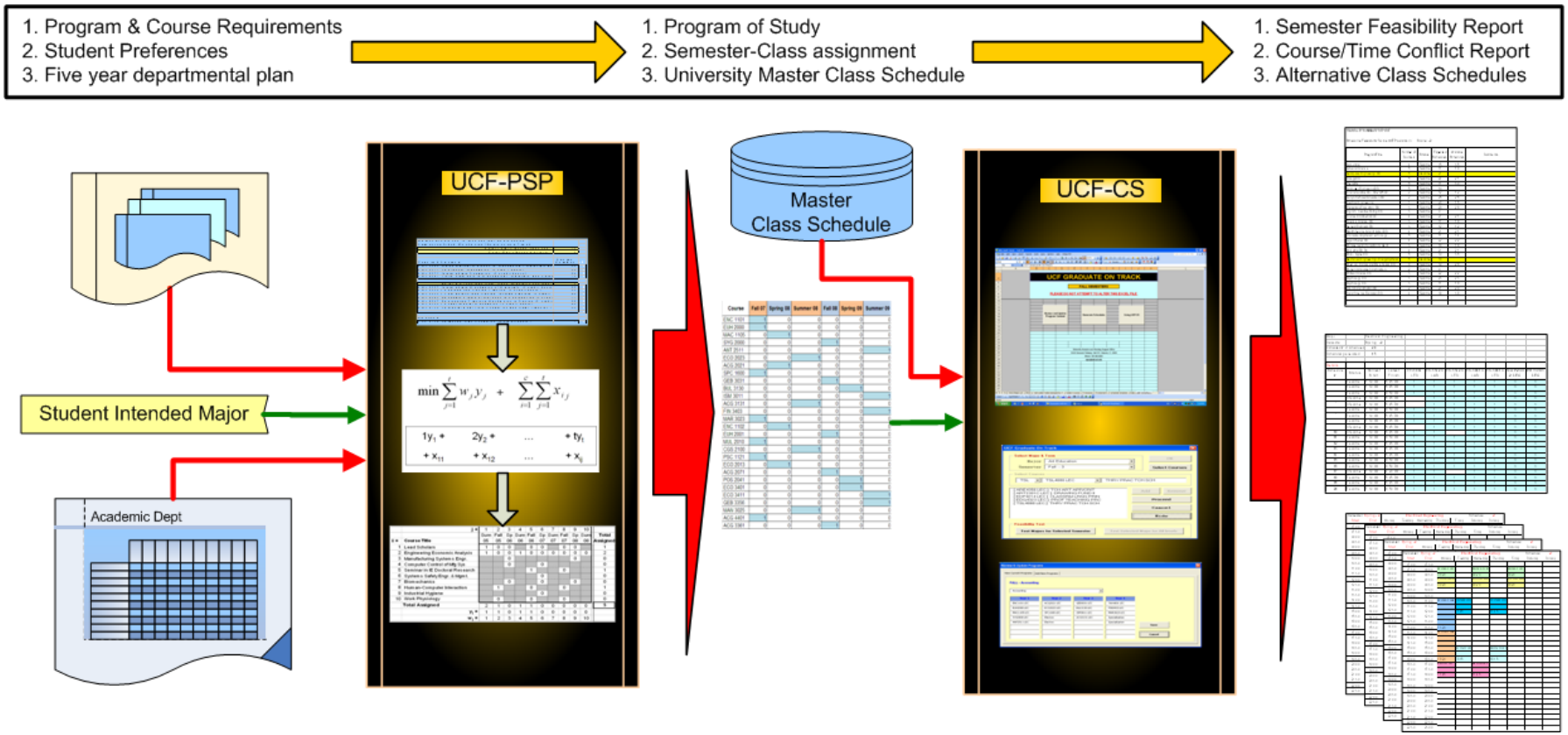


Delayed Graduation Problem



- Computerized support tools: Planning and Scheduling
- A function only of how well-designed tools are
- Can reveal current inefficiencies and assist fixing them

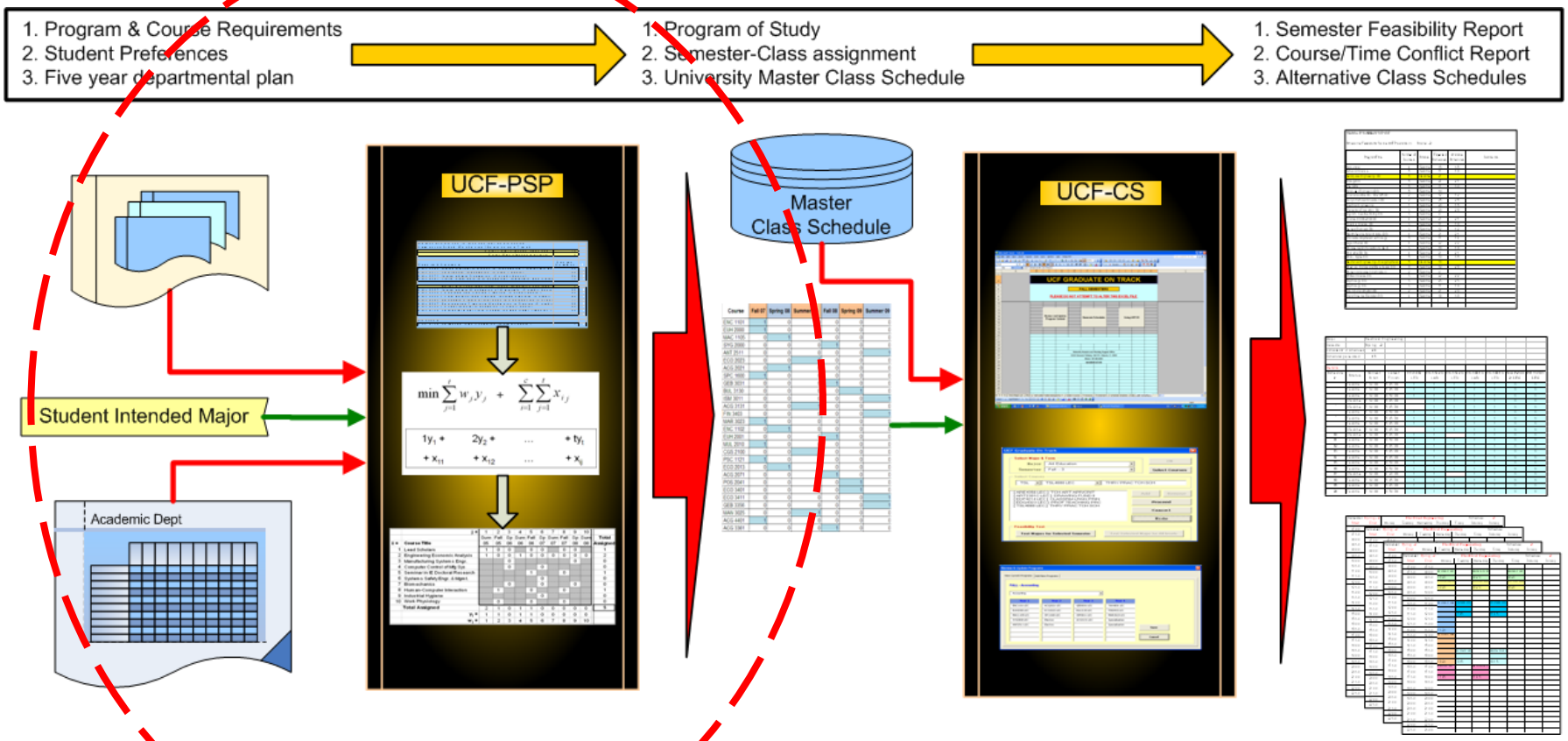
Program Planning & Class Scheduling System



Components of Optimization Model

- Decision variables: activities that the decision maker can control
- Constraints: restrictions on the decision variables
- Non-negativity constraints: decision variables must not be negative
- Objective function: a performance measurement for the entire system to be maximized or minimized while satisfying all constraints
- Example applications: production planning, scheduling, trim-loss problems, product-mix, transportation, blending and financial portfolio selection

Program Planning & Class Scheduling System



Assisting Students in Program of Study Planning

- Current planning tools:
  - Generic flow-chart containing the path to graduation for a typical student
  - Five year course plan describes when all classes are planned to be offered
- Does not address program disruptions
- Does not address unique academic situations

Program of Study Optimization Model

- Help students determine the fastest route to graduation
- Account for factors such as:
  - Desired number of credit hours per semester
  - Prerequisites ordering
  - Transfer-in credits
  - Semesters preference (summer classes)
  - Starting semester (students entering in the spring or summer)
  - Selection among a set of elective courses

Practical Considerations

- Data requirements
  - Need good schedule of planned course offerings over planning horizon
  - Need good list of course co-requisites and prerequisites
- Solution software
  - Any linear optimization solver will work
    - Excel “Solver”
    - SAS/OR
  - Challenge is data handling and accuracy

SAS/OR

- Full capability to handle integer linear programs
- Capability of developing input data files in required format
- Use requires understanding of linear optimization and SAS language
- Automatic data file generation provides opportunity for creating an online tool for student use

Conceptual Considerations

- Objective function
  - Minimize time to completion—courses should be completed in earlier semesters
  - Minimize total number of courses taken
- Decision variables
  - Describe whether a specified course is scheduled in a semester
    - $x_{ij} \epsilon \{1,0\}$ = 1 if course i is assigned to semester j; 0 otherwise
    - $y_j \epsilon \{1,0\}$ = 1 if any course is assigned in semester j; 0 otherwise
  - "Binary" program = decision variables are binary

Objective Function

$$\min \sum_{j=1}^{t} w_j y_j \quad + \quad \sum_{i=1}^{c} \sum_{j=1}^{t} x_{ij}$$

$1y_1 +$	$2y_2 +$	…	$+ ty_t$
$+ x_{11}$	$+ x_{12}$	…	$+ x_{ij}$

- j = 1,2…t; wj = 1,2,…t; i = 1, 2, …, c
- Constraint: Integer (binary) constraints on the decision variables: $x_{ij} \in \{1,0\}$ and $y_j \in \{1,0\}$

Constraints

- A: Semester assignment $\sum_{i=1}^{c} x_{ij} \leq My_j \quad \forall j$
- B: Course non-repetition $\sum_{j=1}^{t} x_{ij} \leq 1 \quad \forall i$
- C: Courses per semesters limit $\sum_{i=1}^{c} x_{ij} \leq n \quad \forall j$
- D: Required course assignments $\sum_{j=1}^{t} x_{rj} = 1 \quad \forall r \in R$
- E: Elective course assignments $\sum_{i \in N} \sum_{j=1}^{t} x_{ij} \geq k$
- F: Prerequisite ordering $x_{an} \leq \sum_{i=1}^{n-1} x_{bi} \quad x_{a1} < x_{b1}$
- G: Comply with planned course offering $x_{ab} = 0 \quad x_{ab} \notin I(j)$

Developing the Model

	j =	1	2	3	4	5	6	7	8	9	10	
		Sum	Fall	Sp	Sum	Fall	Sp	Sum	Fall	Sp	Sum	**Total**
i =	**Course Title**	05	05	06	06	06	07	07	07	08	08	**Assigned**
1	Lead Scholars	1	0	0		0	0		0	0		1
2	Engineering Economic Analysis	1	0	0	1	0	0	0	0	0	0	2
3	Manufacturing Systems Engr.			0						0		0
4	Computer Control of Mfg Sys			0			0					0
5	Seminar in IE Doctoral Research					1			0			1
6	Systems Safety Engr. & Mgmt.						0					0
7	Biomechanics			0			0			0		0
8	Human-Computer Interaction		1			0			0			1
9	Industrial Hygiene						0					0
10	Work Physiology		0			0			0			0
	Total Assigned	2	1	0	1	1	0	0	0	0	0	**5**
	y_j =	1	1	0	1	1	0	0	0	0	0	
	w_j =	1	2	3	4	5	6	7	8	9	10	

- Example: 25 course assignments over 15 semesters = 25*15 + 15 = 390 decision variables

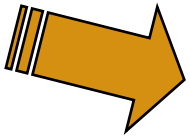
SAS/OR: Requires MPS Format

- MPS format required
  - Input format that is common to several linear programming software packages
- Sparse MPS Format for Flexibility

Objective Function

$1y_1 + \quad 2y_2 + \quad \ldots \quad + ty_t$

$+ x_{11} \quad + x_{12} \quad \ldots \quad + x_{ij}$



Data Set

	type	_row_	_col_	_coef_
1	min	time_to_degree		
2		time_to_degree	x44_1	1
3		time_to_degree	y1	1
4	binary	binary_constraint	x44_1	1
5	binary	binary_constraint	y1	2

```
proc lp
data = model sparsedata
run;
```

User Interface

Input

Solution

Master of Science in Mechanical Engineering			
Computer-Aided Mechanical Engineering Track			
Enter Total Classes Required:	12		
Enter Max classes per term:	4		
Required Courses:	**Course Number**		**Solution Semester**
EML 5060 Mathematical Methods in Mechanical, Materials an	44		1
EML 5211 Continuum Mechanics (3 credit hours)	49		1
EML 5271 Intermediate Dynamics (3 credit hours)	54		5
EML 6067 Finite Elements in Mechanical, Materials and Aeros	72		8
Enter # of courses from track specialty courses:	**2**		
EML 5237 Intermediate Mechanics of Materials (3 credit hours	52		5
EML 5025C Engineering Design Practice (3 credit hours)	43		-
EML 5532C Computer-Aided Design for Manufacture (3 credit l	60		5
EML 6062 Boundary Element Methods in Engineering (3 credit	71		-
EML 6547 Engineering Fracture Mechanics in Design (3 credit	90		-
EML 6305C Experimental Mechanics (3 credit hours)	89		-
EML 6725 Computational Fluid Dynamics and Heat Transfer I (	93		-
			-
Electives			
EAS 6138 Advanced Gas Dynamics (3 credit hours)	7		8

Ordering Prerequisites Increased Time to Degree

- Example with prerequisite ordering

Fall 05	Spring 06	Sum 06	Fall 06	Spring 07	Sum 07	Fall 07	Spring 08
EML 5060		EML 5713		EML 5271			EML 6067
EML 5211				EML 5237			EAS 6138
EML 5402				EML 5532			EAS 6185
EML 6971							EML 6085

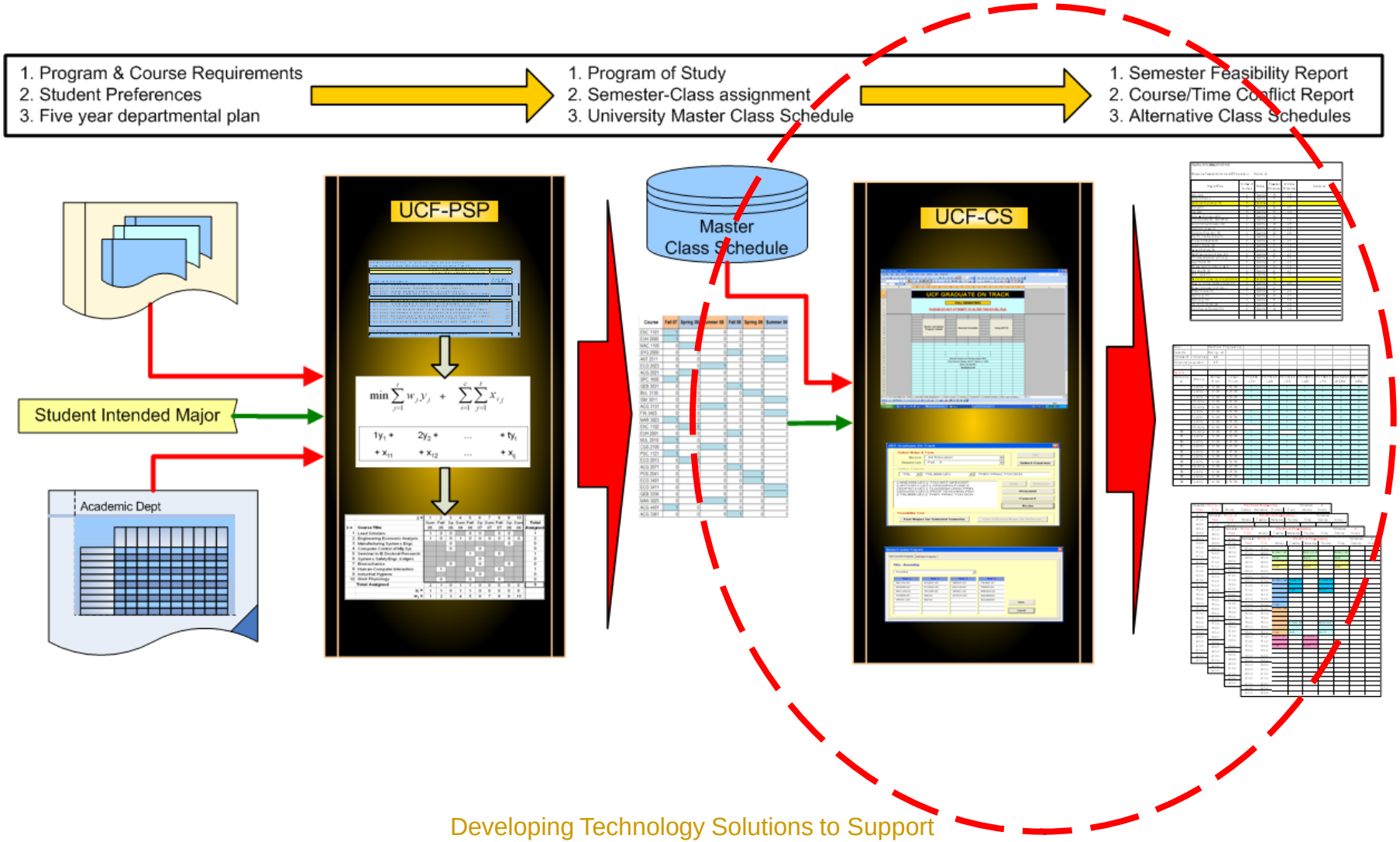
- Without prerequisite ordering

Fall 05	Spring 06	Sum 06	Fall 06	Spring 07	Sum 07	Fall 07	Spring 08
EML 5060	EML 5271	EML 5025					
EML 5211	EML 6067	EML 5532					
EML 6547	EML 6725	EML 5713					
EML 6712	EML 5131	EML 6971					

In Summary: Program of Study Planning

- This demonstrates a prototype SAS tool
  - Accepts parameters
  - Generates customized linear program MPS data for solving with SAS/OR procedures
- Increase the flexibility of the user input interface
  - Enter preferences for sets of electives over others
  - User-friendly interface that checks parameters and prompts for corrections
- Producing several optional programs of study
  - May be more than one optimal solution
- May be used for course offering planning

Program Planning & Class Scheduling System



Scheduling

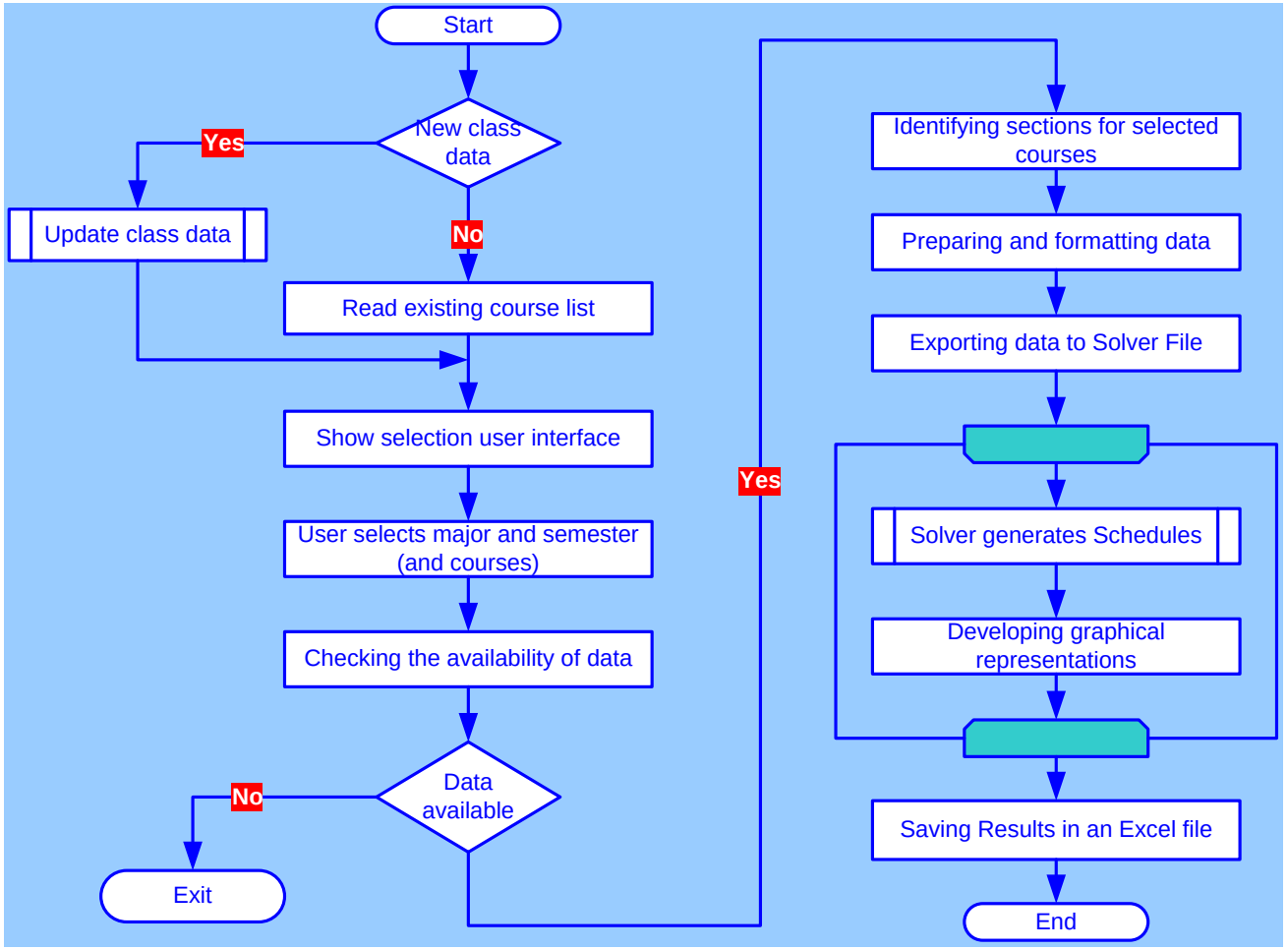
- Inputs:
  - POS: which courses in which semesters
  - University class schedule
- Objective:
  - Test feasibility of scheduling the POS semesters
  - Identify a feasible schedule for a given program in a given semester
- Outputs:
  - Feasibility reports
  - Alternative semester schedules

Technical Challenge

- Biology:
  - BSC 2010: 3 lecture sections, 22 lab sections
  - ENC 1101: 110 lecture sections
  - MAC 2311: 22 lecture section
- **2,555,520** combinations !!

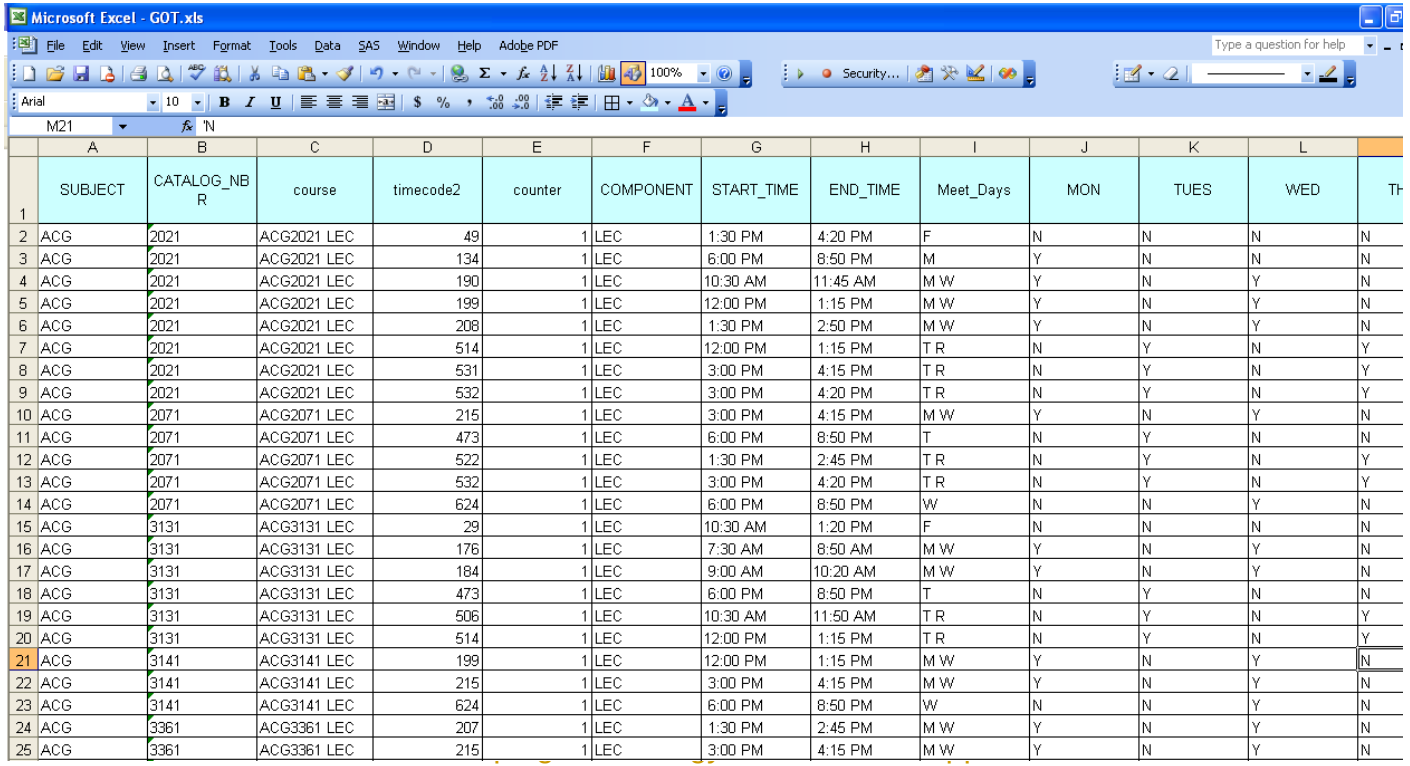
- Scheduling approaches
  - Optimization: find a feasible solution for a particular “set-covering” 0-1 integer program
  - Enumeration: develop a feasible schedule by constructing a schedule adding one course at a time

Process Flow - Optimization



University Master Schedule

- Download from PeopleSoft by a SAS code every 2 hours
- Made available to advisors on a webpage
- Imported to Excel as input to Integer Programming model



Microsoft Excel - GOT.xls

	A	B	C	D	E	F	G	H	I	J	K	L	
1	SUBJECT	CATALOG_NBR	course	timecode2	counter	COMPONENT	START_TIME	END_TIME	Meet_Days	MON	TUES	WED	TH
2	ACG	2021	ACG2021 LEC	49	1	LEC	1:30 PM	4:20 PM	F	N	N	N	N
3	ACG	2021	ACG2021 LEC	134	1	LEC	6:00 PM	8:50 PM	M	Y	N	N	N
4	ACG	2021	ACG2021 LEC	190	1	LEC	10:30 AM	11:45 AM	M W	Y	N	Y	N
5	ACG	2021	ACG2021 LEC	199	1	LEC	12:00 PM	1:15 PM	M W	Y	N	Y	N
6	ACG	2021	ACG2021 LEC	208	1	LEC	1:30 PM	2:50 PM	M W	Y	N	Y	N
7	ACG	2021	ACG2021 LEC	514	1	LEC	12:00 PM	1:15 PM	T R	N	Y	N	Y
8	ACG	2021	ACG2021 LEC	531	1	LEC	3:00 PM	4:15 PM	T R	N	Y	N	Y
9	ACG	2021	ACG2021 LEC	532	1	LEC	3:00 PM	4:20 PM	T R	N	Y	N	Y
10	ACG	2071	ACG2071 LEC	215	1	LEC	3:00 PM	4:15 PM	M W	Y	N	Y	N
11	ACG	2071	ACG2071 LEC	473	1	LEC	6:00 PM	8:50 PM	T	N	Y	N	N
12	ACG	2071	ACG2071 LEC	522	1	LEC	1:30 PM	2:45 PM	T R	N	Y	N	Y
13	ACG	2071	ACG2071 LEC	532	1	LEC	3:00 PM	4:20 PM	T R	N	Y	N	Y
14	ACG	2071	ACG2071 LEC	624	1	LEC	6:00 PM	8:50 PM	W	N	N	Y	N
15	ACG	3131	ACG3131 LEC	29	1	LEC	10:30 AM	1:20 PM	F	N	N	N	N
16	ACG	3131	ACG3131 LEC	176	1	LEC	7:30 AM	8:50 AM	M W	Y	N	Y	N
17	ACG	3131	ACG3131 LEC	184	1	LEC	9:00 AM	10:20 AM	M W	Y	N	Y	N
18	ACG	3131	ACG3131 LEC	473	1	LEC	6:00 PM	8:50 PM	T	N	Y	N	N
19	ACG	3131	ACG3131 LEC	506	1	LEC	10:30 AM	11:50 AM	T R	N	Y	N	Y
20	ACG	3131	ACG3131 LEC	514	1	LEC	12:00 PM	1:15 PM	T R	N	Y	N	Y
21	ACG	3141	ACG3141 LEC	199	1	LEC	12:00 PM	1:15 PM	M W	Y	N	Y	N
22	ACG	3141	ACG3141 LEC	215	1	LEC	3:00 PM	4:15 PM	M W	Y	N	Y	N
23	ACG	3141	ACG3141 LEC	624	1	LEC	6:00 PM	8:50 PM	W	N	N	Y	N
24	ACG	3361	ACG3361 LEC	207	1	LEC	1:30 PM	2:45 PM	M W	Y	N	Y	N
25	ACG	3361	ACG3361 LEC	215	1	LEC	3:00 PM	4:15 PM	M W	Y	N	Y	N

Program Requirement Data

- Based on POS outputs

Civil Engineering BS

2005	Fall	1	14
Course No.	Course Name	Component	Hours
AMH 2010	U S History 1492-1877	LEC	3
MAC 2311	Calculus I	LEC	4
SPC 1016	Tech Presentations	LEC	3
ECO 2013	Macroeconomics	LEC	3
EGN 1006	Intro To Eng Prof	LEC	1
2005	Fall	2	16
Course No.	Course Name		Hours
MAC 2313	Calculus III	LEC	4
CHM 2045C	Chemistry Fundamentals I	LEC	4
EGN 3613	Engineering Econ	LEC	2
ENC 1101	English Composition I	LEC	3
EGN 3310	Engineering Analysis--Statics	LEC	3
2005	Fall	3	16
Course No.	Course Name		Hours
CWR 3201	Eng Fluid Mechanics	LEC	3
CCE 4003	Intro to Const Indus	LEC	3
EGN 3343	Thermodynamics	LEC	3
CES 4100C	Structural Analysis I	LEC	4
STA 3032	Prob/Stats for Engrs	LEC	3
2005	Fall	4	14
Course No.	Course Name		Hours
ENV 4561	Env Eng-Proc Design	LEC	4
CEG 4101C	Geotechnical Engr	LEC	4
CES 4605	Steel Structures	LEC	3
Approve Project Desigr	Approve Project Design	LEC	3

Civil Engineering BS

2006	Spring	1	14
Course No.	Course Name	Component	Hours
AMH 2020	U S History 1877-present	LEC	3
MAC 2312	Calculus II	LEC	4
PHY 2048	Physics I	LEC	3
PHY 2048	Physics I lab	LAB	1
GEO1200	Physical Geography	LEC	3
EGN 1007	Eng Con & Meth	LEC	1
2006	Spring	2	12
Course No.	Course Name		Hours
MAP 2302	Differential Equations	LEC	3
CHM 2046	Chemistry Fundamentals II	LEC	3
CHM 2046L	Chemistry Fundamentals II Lab	LAB	
ENC 1102	English Composition II	LEC	3
EGN 3321	Engineering Analysis--Dynamics	LEC	3
PHY 2049	Physics II	LEC	3
PHY 2049L	Physics II Lab	LAB	
2006	Spring	3	16
Course No.	Course Name		Hours
CWR 4101C	Hydrology	LEC	3
CWR 4203C	Hydraulics	LEC	3
EGN 3373	Principles of Electrical Engineering	LEC	3
FIL 1001	Cinema Survey	LEC	3
TTE 4004	Transportation Engineering	LEC	4
2006	Spring	4	12
Course No.	Course Name		Hours
CES 4702	Reinforced Concrete	LEC	3
EGN 3365	Str. & Prop Matls	LEC	3
Approved Project Design		LEC	3
ANT 2000	General Anthropology	LEC	3

Civil Engineering BS

2006	Summer		0
Course No.	Course Name	Component	Hours
2006	Summer		9
Course No.	Course Name		Hours
SUR 2101	Surveying	LEC	3
EGN 3331	Mech of Materials	LEC	3
ENV 3001	Into to Environ Eng	LEC	3
2006	Summer		0
Course No.	Course Name		Hours
2006	Summer		0
Course No.	Course Name		Hours

Optimization-based Scheduler

- Student class schedule by a “set-covering” problem
  - Find the class sections that will “cover” the “set” of program requirements (courses)
- Constraints
  - No two sections can be scheduled at the same time
  - Exactly one section of each course must be scheduled during a week
  - Maximum of five hours of classes may be scheduled in a given day

Excel-Based IP Model

$$Set\ Z = 1$$

s.t.

$$\sum_i y_{ij} \le 7$$

$$\sum_j y_{ij} = 1$$

$$\sum_l x_{lk} \le 10$$

- No more than 7 courses
- 1 section per course
- 5 hours a day at most

$$y_{ij} = \begin{cases} 1 & \text{Section i of course j scheduled} \\ 0 & \text{Otherwise} \end{cases}$$

$$x_{lk} = \begin{cases} 1 & \text{Slot l of day k used} \\ 0 & \text{Otherwise} \end{cases}$$

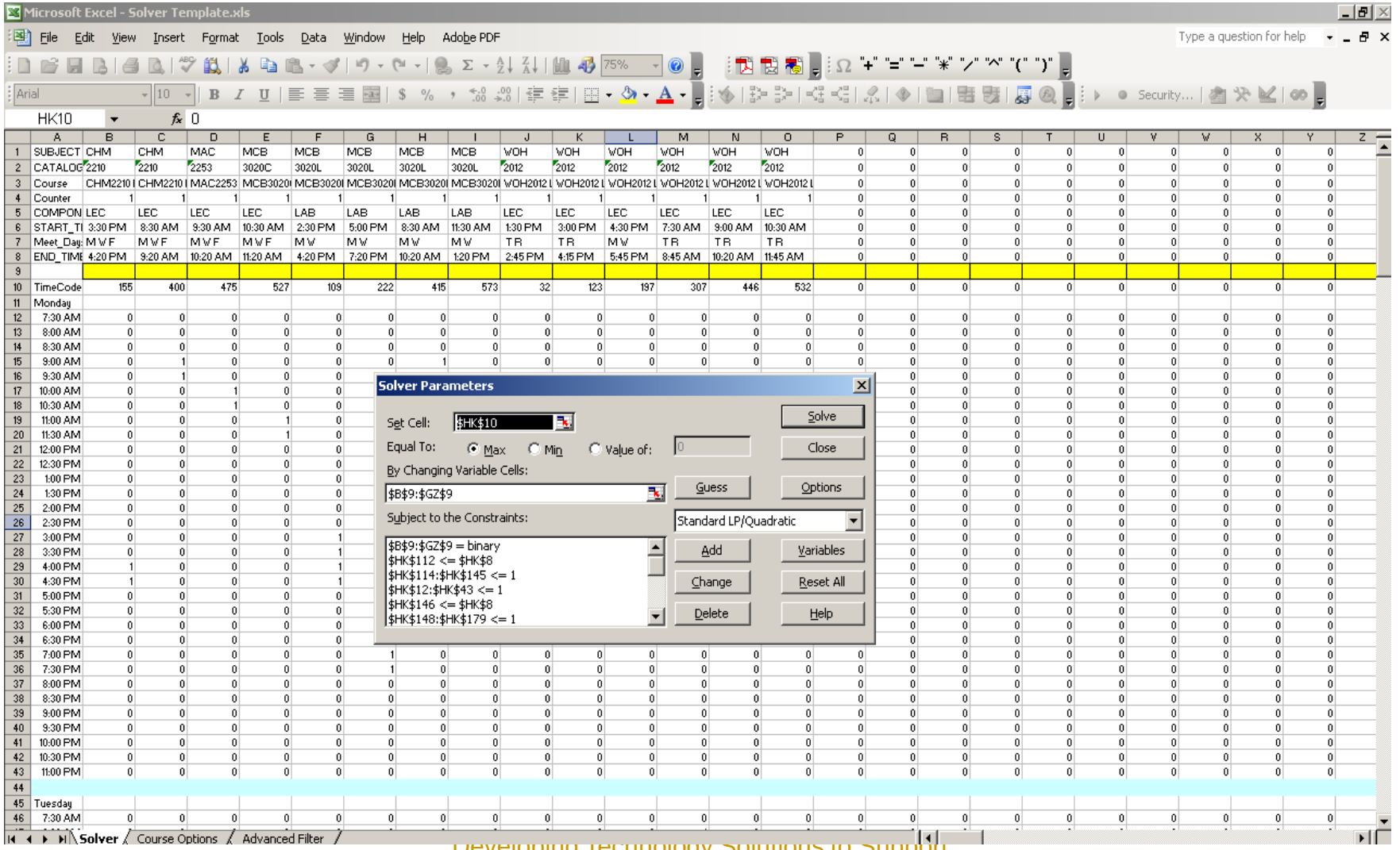
- y_{ij} : Section i of course j
- x_{lk} : Time slot l in day k

Excel Solver Setup

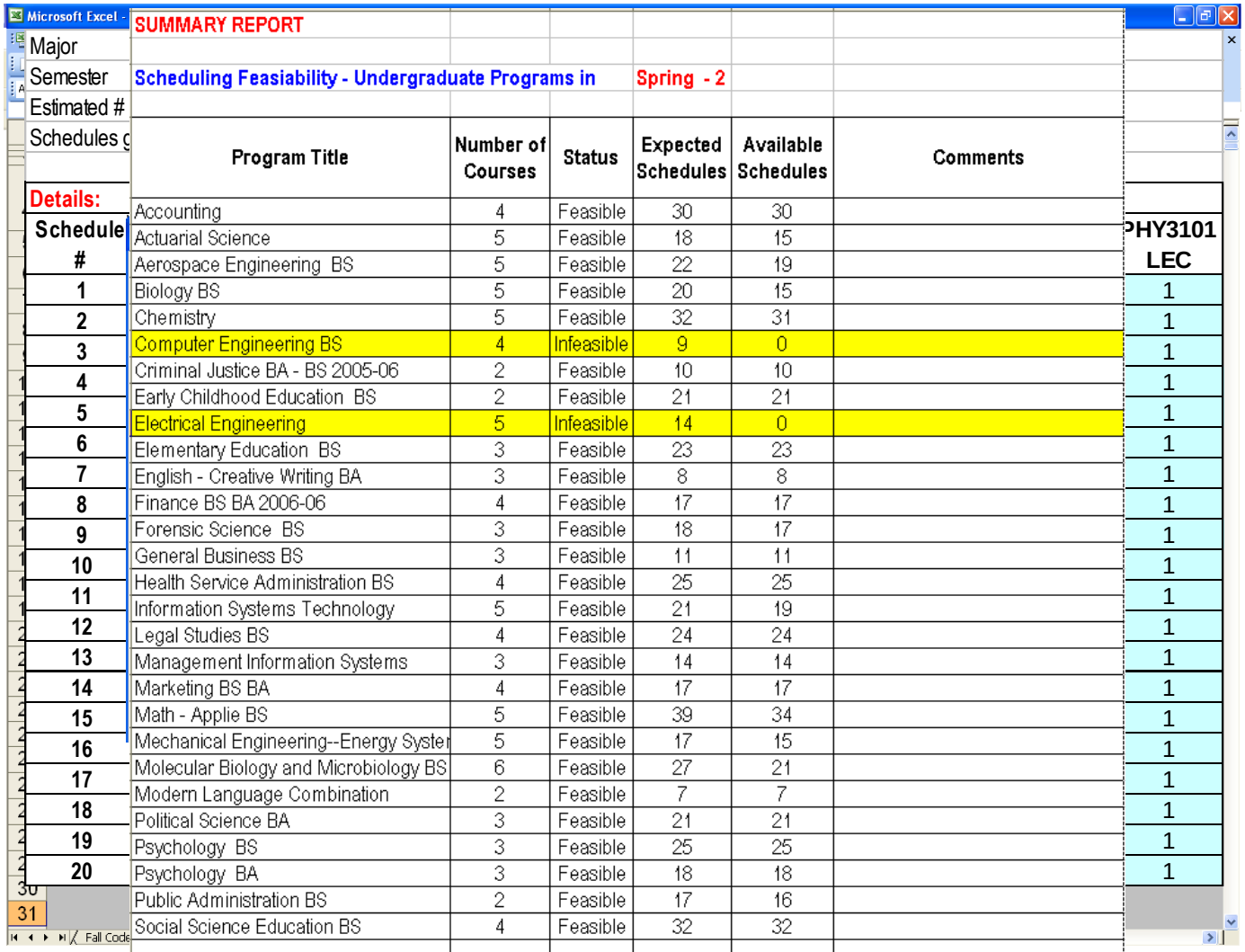
- Columns correspond to class sections offered at different times
- Rows correspond to half-hour time slots for each day of the week
- Cell values = 1 if class section is offered at that time or = 0 if section is not offered at that time
- Decision variable row cells = 1 if that section of the course is scheduled and = 0 otherwise

- SOLVER Add-in
  - Tools > Solver (go to Tools > Add-ins and check “Solver Add-in” if not loaded)
  - “Target cell” is the objective to be optimized
  - “Changing cells” are the decision variables
  - “Constraints” are the conditions to be satisfied

Solver Setup



UCF-CS GUIs & Outputs



Microsoft Excel -

Major
Semester
Estimated #
Schedules g

Details:

Schedule #
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

30
31

Fall Code

SUMMARY REPORT

Scheduling Feasiability - Undergraduate Programs in **Spring - 2**

Program Title	Number of Courses	Status	Expected Schedules	Available Schedules	Comments
Accounting	4	Feasible	30	30	
Actuarial Science	5	Feasible	18	15	
Aerospace Engineering BS	5	Feasible	22	19	
Biology BS	5	Feasible	20	15	
Chemistry	5	Feasible	32	31	
Computer Engineering BS	4	Infeasible	9	0	
Criminal Justice BA - BS 2005-06	2	Feasible	10	10	
Early Childhood Education BS	2	Feasible	21	21	
Electrical Engineering	5	Infeasible	14	0	
Elementary Education BS	3	Feasible	23	23	
English - Creative Writing BA	3	Feasible	8	8	
Finance BS BA 2006-06	4	Feasible	17	17	
Forensic Science BS	3	Feasible	18	17	
General Business BS	3	Feasible	11	11	
Health Service Administration BS	4	Feasible	25	25	
Information Systems Technology	5	Feasible	21	19	
Legal Studies BS	4	Feasible	24	24	
Management Information Systems	3	Feasible	14	14	
Marketing BS BA	4	Feasible	17	17	
Math - Applie BS	5	Feasible	39	34	
Mechanical Engineering--Energy Syste	5	Feasible	17	15	
Molecular Biology and Microbiology BS	6	Feasible	27	21	
Modern Language Combination	2	Feasible	7	7	
Political Science BA	3	Feasible	21	21	
Psychology BS	3	Feasible	25	25	
Psychology BA	3	Feasible	18	18	
Public Administration BS	2	Feasible	17	16	
Social Science Education BS	4	Feasible	32	32	

PHY3101 LEC
1
1
1
1
1
1
1
1
1
1
1
1
1
1
1
1
1
1
1
1

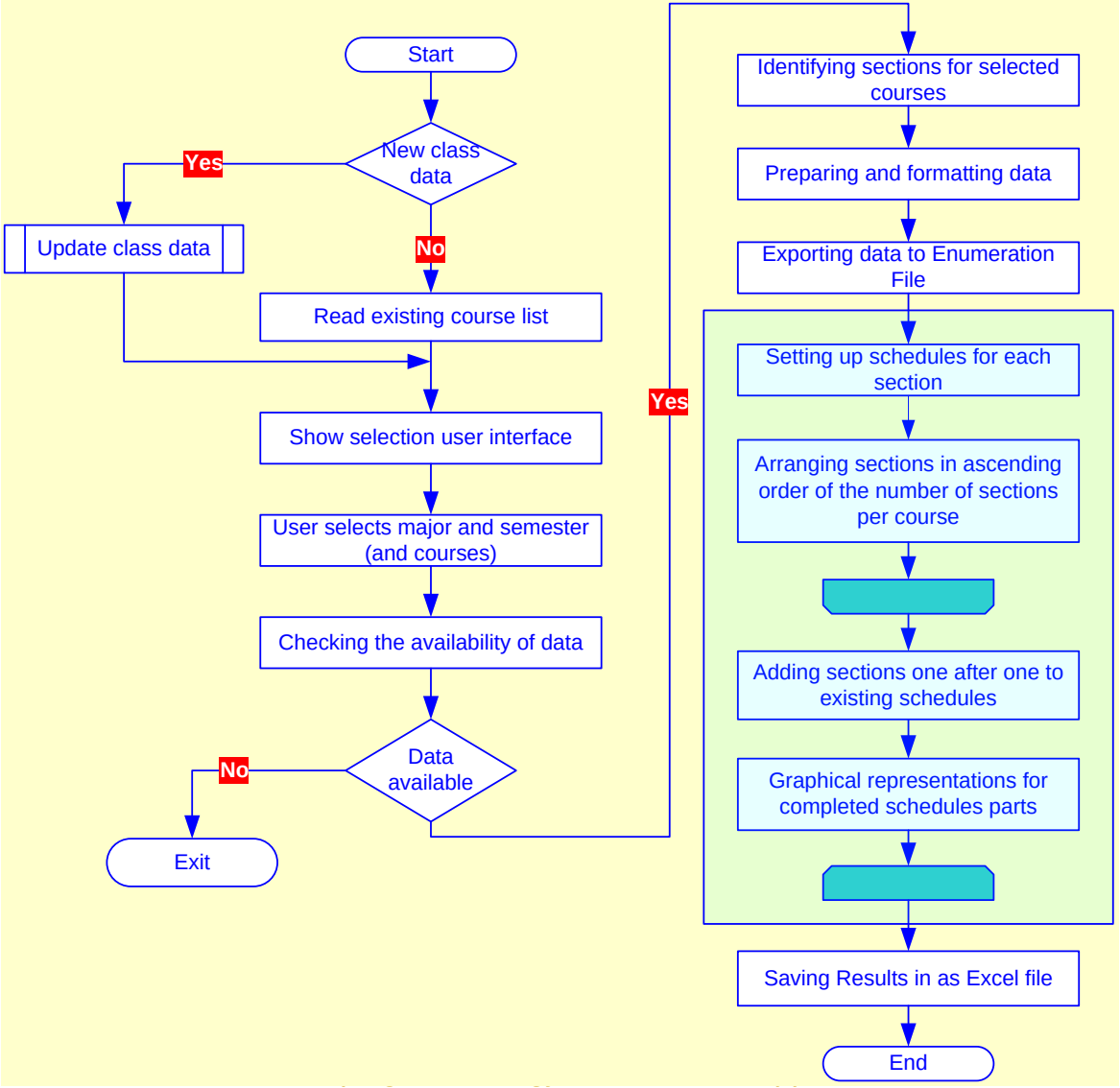
Solver Pros and Cons

- Pros
  - Generates feasible solutions
  - Modifiable to add other constraints (e.g., minimum time between classes, exclude a certain day)
  - Relatively easy to customize output
- Cons
  - Requires mathematical understanding to set up
  - Requires careful mapping of class schedule data
  - Relatively long execution times
  - Potential automation connection problems
  - Need to “trick” the set up to generate alternate schedules

Enumeration Approach

- Potential for reducing processing time
- Use existing data structure
- Constructive generation of student class schedule
  - Arrange courses assendingly by number of sections
  - Schedule most restrictive class first
  - Add next most restrictive class while satisfying time conflict constraints
- Number of feasible schedules is limited by the amount of time to be spent or number specified in advance
- Output format is same as for Solver

Enumeration Approach



Enumeration Pros and Cons

- Pros
  - Easier to set up than Solver
  - Faster (for current problem)
  - Less automation connection problems
- Cons
  - Rigid structure—must be recoded for customized results
  - Must be run until finished to get any solutions
  - Limited number of feasible solutions as coded

SAS vs. Excel

- POS Planner used SAS and Excel
- UCF-CS used Excel
- Both used IP
- SAS offers more flexibility and tools to manipulate data
- SAS generates the optimization model AND solves it
- SAS lacks ease of use in reporting and presenting capabilities
- Excel offers user interfaces and presentation capabilities
- Excel communicates with other Office and Windows applications
- Solver is rigid and requires complicated Excel preparation

- SAS and Excel work together smoothly

Contact Information

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