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Tutorial

OR with Spreadsheets

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Aims: Awareness of what can be achieved in OR with spreadsheets in order to benefit from the ubiquitous presence of spreadsheets on almost all computers.

Target audience: OR practitioners and academics in poorer countries with very limited financial resources to perform OR.

Pre-requisite: Basic knowledge of at least one spreadsheet, such as Microsoft Excel.

Learning outcomes: Awareness of what can be achieved in OR with spreadsheets, including their strengths and limitations, without using commercial add-ons.

Developing countries differ very much

- From the technologically advanced (e.g., Brazil, Chile, India, China).
- To the relatively deprived (e.g., West Africa).

Brazil & Chile:

- High availability of IT.
- Strong OR presence and university researchers.
- Sophisticated OR projects, eg, Agro-business and industry (Miguel Taube, Andrés Weintraub).
- State-of-the-Art tools, e.g., AIMMS, Cplex.

Resource-Poor Developing Countries

- Less apparent demand for OR.
- Less OR presence and fewer university researchers.
- Fewer resources for IT.

Specialist OR software

- is too expensive and maybe diff.
- has little or no local technical support.

→ Can OR make good use of spreadsheets?

Strengths of spreadsheets for OR

Powerful for quantitative analysis.

Intuitive grid-like user interface.

Omnipresent

- Widely-used in many organisations and schools
 - user familiarity and comfort
 - large knowledge base.
- Often already on a PC (Excel) → transportable.

Can be free:

- OpenOffice's Calc.
- Linux's Gnumeric and K-Office.

Strengths of spreadsheets for OR

Flexibility

Multitude of resources:

- Dynamic recalculation and chart updating
- Statistical analysis.
- Optimisation algorithms (e.g., Excel Solver).
- Programming language (e.g., VBA).
- Database connectivity
- Rapid application development with visual components.
- Availability of specialist "add-ins".

What OR can you do with spreadsheets?

- Examples: Project Scheduling, Simulation, Decision trees, Optimisation (e.g., Excel's LP/MIP/NLP Solver), Multi-criteria decision analysis.

What OR can you not do with spreadsheets?

- Too slow for larger models
- Often cumbersome to modify a model
- Flexible complex models can be difficult to implement

Paragon (AIMMS) view of Spreadsheets:

"A spreadsheet approach works well when:

- you do not need to specify a large number of relationships,
- there are only a few procedures to be written,
- the size of your data sets will remain stable,
- the need to add or remove dimensions is limited, and
- you will carry out all the maintenance activities yourself."

Limitations of spreadsheets for OR

- Easy and tempting to quickly create obscure and unintelligible models.
- Presence of errors may not be obvious, creating a dangerous over-confidence in calculation results.
- Even if detected, errors hidden in formulas can be difficult to find.

Limitations of spreadsheets for OR

- Calculation time is usually (much) slower.
- OR Functionality is more limited than in specialist software, eg
 - Simulations need to be set up from scratch.
 - Excel Solver takes only small LP/MILP/NLP models whose coefficient matrix has already been generated.
- Time consuming setup and maintenance
- Lack of prestige?

Overcoming the Limitations

Use OR Add-ins.

- These often cost money.
- but not always - free add-ins exist.

Alternative: Create your own optimising system, using spreadsheet Basic programming language and free software.

See example later.

Smith (Supply Chain Mgt Journal, vol 8, 2003)

- Simple methodology: "The modeler develops a baseline model reflecting current operations, creates alternative scenarios and compares those scenarios to the baseline"
- "logistics-specific software ... may not always provide the flexibility required. Spreadsheet software, notably Microsoft Excel, can be used very effectively to analyze logistics problems. Spreadsheets allow analysis from many different perspectives and can be continually modified and enhanced to reflect new situations and options. The user can add complexity to the model as he or she gains experience and knowledge about the process."

- "When multiple spreadsheets are integrated, they can simultaneously model the impact of business decisions on any number of variables."
- "Specialized supply chain problems such as vehicle routings and location analysis require complicated algorithmic modeling to determine optimal solutions. For such applications, specialized software can and should be used."
- "Spreadsheet modeling is a powerful tool for analyzing opportunities and calculating benefits, and can be done very successfully within the confines of current spreadsheet software. This type of modeling lends itself well to the abilities of most engineers, consultants and managers that have a comprehensive knowledge of their company or client."

Example: Decision Trees

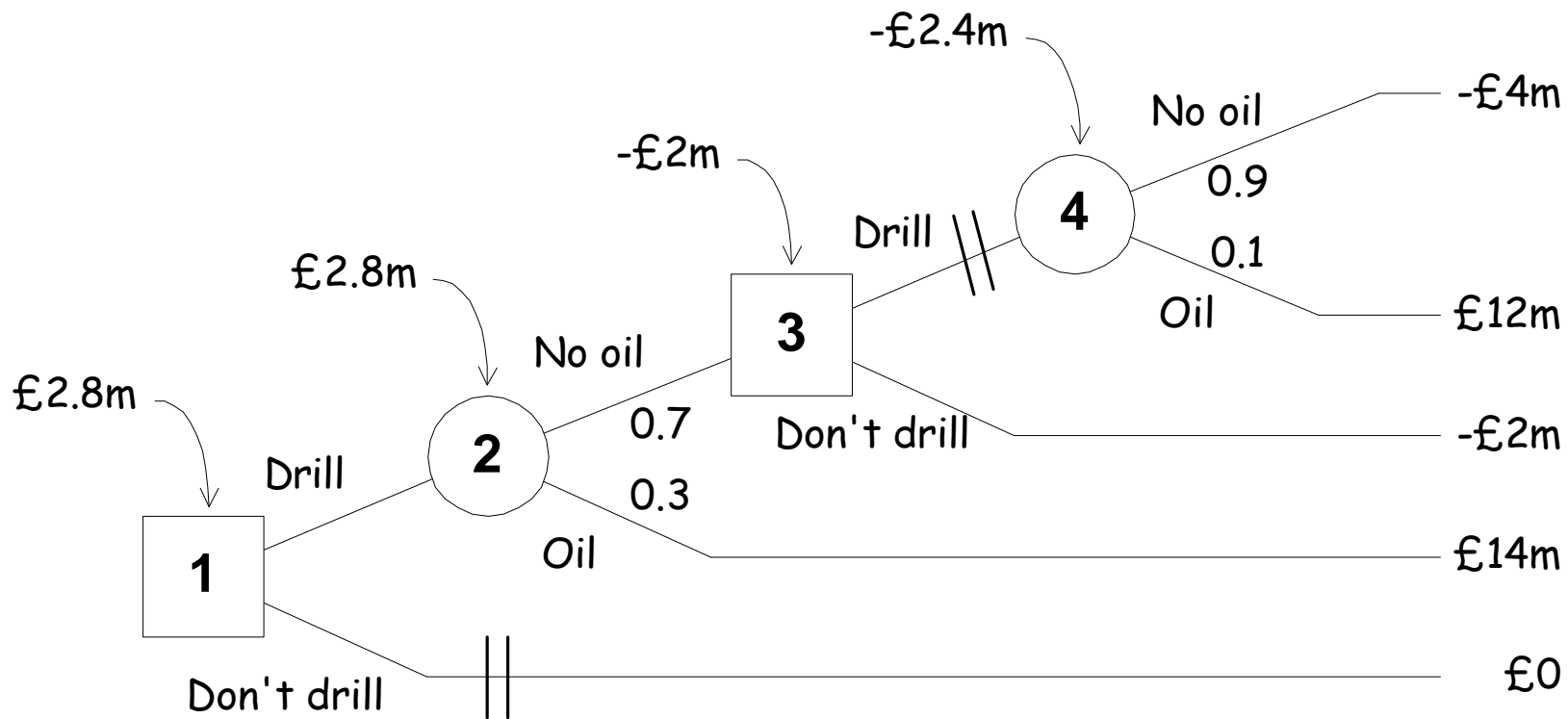
Geological survey showed a possible oil reservoir of 19 million gallons. Two suitable test sites have been identified, which will determine whether or not oil is present.

1st test drill site has a 0.3 probability of striking oil. If no oil is found then still a 0.1 probability that oil found drilling at 2nd site. If neither test drill finds oil, then no oil reservoir exists.

Each test drill will cost the oil company £2 million

If the profit from each gallon of oil is £1, should the company make any test drills, and if so, how many?

Decision Tree shows that we should drill at 1st site, but if no oil is found, we should not drill at 2nd site.



Spreadsheet Model:

Profit per gallon of oil = £1

Node	Node Type	Branch (Next Node)	Value	Probability	Prob x Value	
1	Decision	Drill (2)	£2,800,000			
		Do not drill	£0			
		<u>Maximum Expected Value =</u>		£2,800,000		
2 Drill at 1st site	Chance	No oil (3)	-£2,000,000	0.7	-£1,400,000	
		Oil	£14,000,000	0.3	£4,200,000	
		<u>Expected Value =</u>				£2,800,000
3 No oil at 1st site	Decision	Drill (4)	-£3,600,000			
		Do not drill	-£2,000,000			
		<u>Maximum Expected Value =</u>		-£2,000,000		
4 Drill at 2nd site	Chance	No oil	-£4,000,000	0.9	-£3,600,000	
		Oil	£12,000,000	0.1	£1,200,000	
		<u>Expected Value =</u>				-£2,400,000

Use spreadsheet model for sensitivity analysis.

Example: If change profit figure in spreadsheet from £1 to £1.50, then spreadsheet recalculates the expected values and automatically shows fresh decisions:

Profit per gallon of oil = £1.50

Node	Node Type	Branch (Next Node)	Value	Probability	Prob x Value	
1	Decision	Drill (2)	£5,200,000			
		Do not drill	£0			
		<u>Maximum Expected Value =</u>		£5,200,000		
2 Drill at 1st site	Chance	No oil (3)	-£2,000,000	0.7	-£1,400,000	
		Oil	£22,000,000	0.3	£6,600,000	
		<u>Expected Value =</u>				£5,200,000
3 No oil at 1st site	Decision	Drill (4)	-£3,600,000			
		Do not drill	-£2,000,000			
		<u>Maximum Expected Value =</u>		-£2,000,000		
4 Drill at 2nd site	Chance	No oil	-£4,000,000	0.9	-£3,600,000	
		Oil	£20,000,000	0.1	£2,000,000	
		<u>Expected Value =</u>				-£1,600,000

Use spreadsheet Goal Seek tool to find profit figure at which re indifferent between drilling and not drilling at first site:

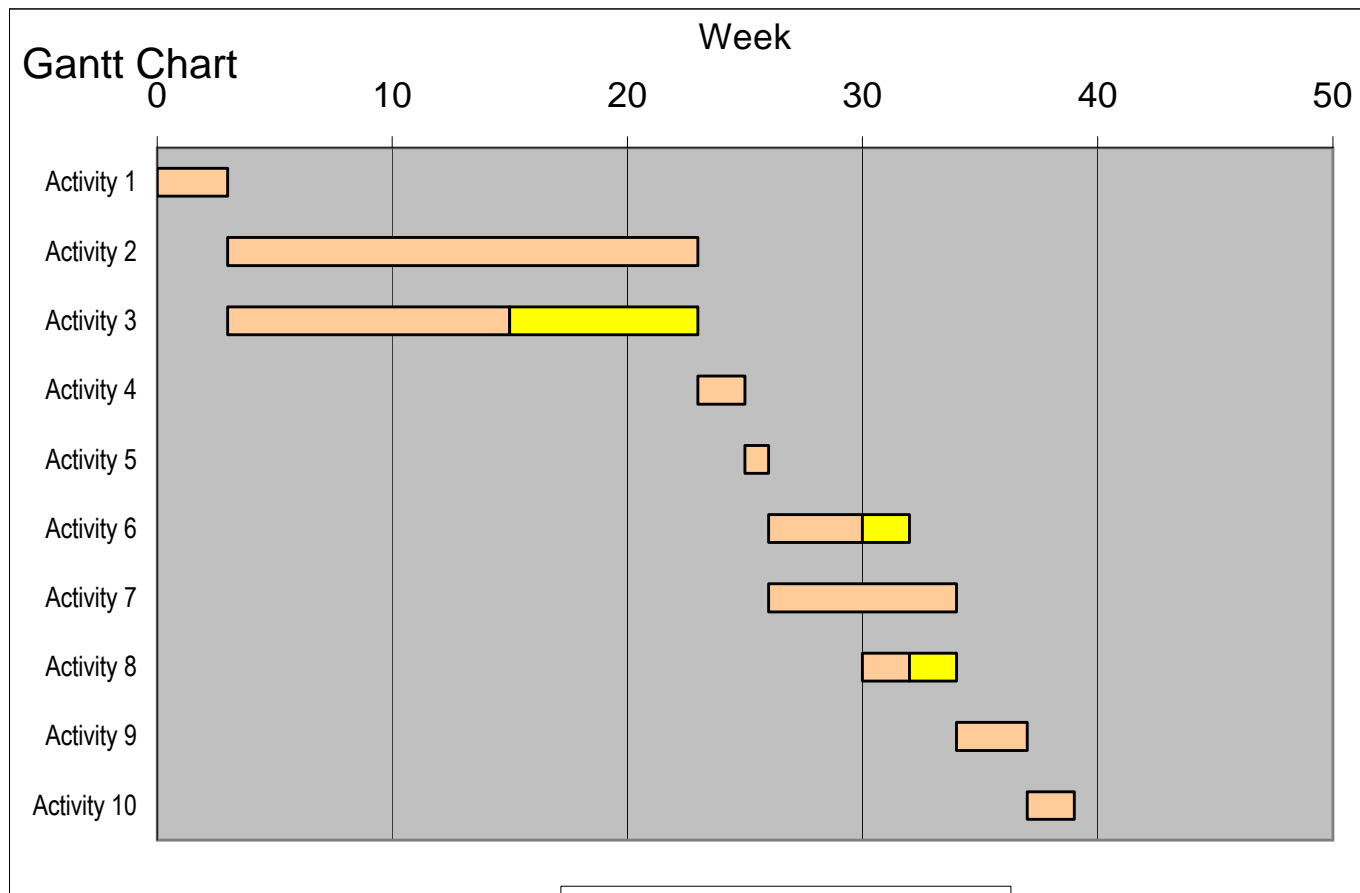
Profit per gallon of oil = £0.41667

Node	Node Type	Branch (Next Node)	Value	Probability	Prob x Value
1	Decision	Drill (2)	£0		
		Do not drill	£0		
		<u>Maximum Expected Value =</u>	£0		
2 Drill at 1st site	Chance	No oil (3)	-£2,000,000	0.7	-£1,400,000
		Oil	£4,666,666	0.3	£1,400,000
		<u>Expected Value =</u>			£0
3 No oil at 1st site	Decision	Drill (4)	-£3,600,000		
		Do not drill	-£2,000,000		
		<u>Maximum Expected Value =</u>	-£2,000,000		
4 Drill at 2nd site	Chance	No oil	-£4,000,000	0.9	-£3,600,000
		Oil	£2,666,666	0.1	£266,667
		<u>Expected Value =</u>			-£3,333,333

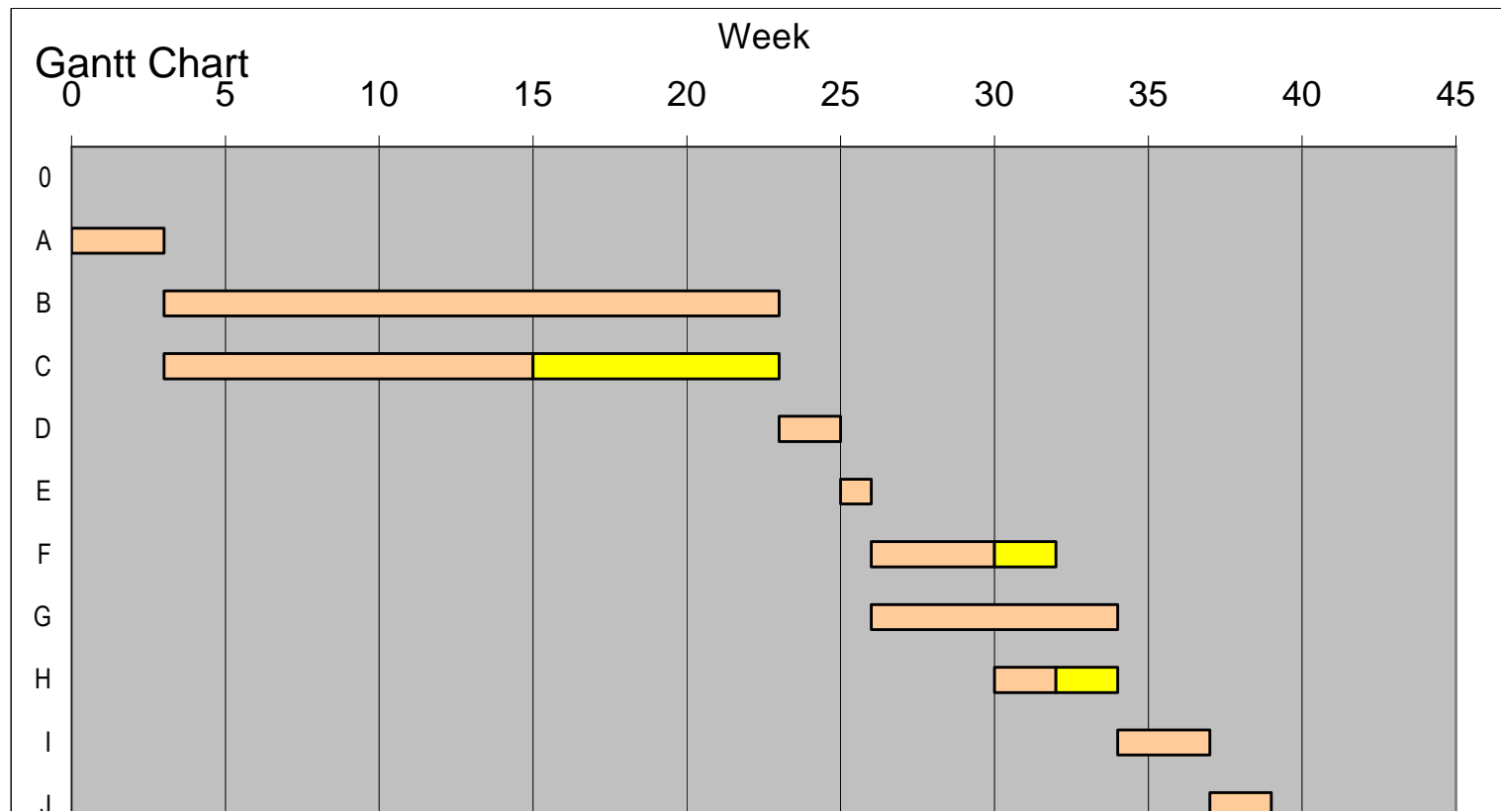
Example: Project Mgt - Critical Path Gantt

Use dynamic recalculation and chart updating

Activity	Immediate Predecessor	Duration	Forward pass		Backward pass		Slack
			EST	EFT	LST	LFT	
Activity 1		3	0	3	0	3	0
Activity 2	1	20	3	23	3	23	0
Activity 3	1	12	3	15	11	23	8
Activity 4	2,3	2	23	25	23	25	0
Activity 5	4	1	25	26	25	26	0
Activity 6	5	4	26	30	28	32	2
Activity 7	5	8	26	34	26	34	0
Activity 8	6	2	30	32	32	34	2
Activity 9	7,8	3	34	37	34	37	0
Activity 10	9	2	37	39	37	39	0
Project completion	10		39				



Activity	Duration	Immediate Predecessors	OK to automate		Diifcult to automate		Slack
			Forward pass		Backward pass		
			EST	EFT	LST	LFT	
0	0		0	0	39	39	
A	3		0	3	0	3	0
B	20	A	3	23	3	23	0
C	12	A	3	15	11	23	8
D	2	B C	23	25	23	25	0
E	1	D	25	26	25	26	0
F	4	E	26	30	28	32	2
G	8	E	26	34	26	34	0
H	2	F	30	32	32	34	2
I	3	G H	34	37	34	37	0
J	2	I	37	39	37	39	0
Project completion		J	39	39	39	39	



Optimization using Solver tool

Example: Capital budgeting - project selection

	A	B	C	D	E	F	G	H	I
1	Integer Capital Budgeting Problem								
2	Select which projects:								
3		x1	x2	x3	x4				
4	Binary 0/1 Decision Variables	0	0	1	1				
5									
6	Total Return	£0.20	£0.30	£0.50	£0.10	0.6	(max)		
7									
8						LHS		RHS	Slack
9	Funds Availability in Year 1	0.5	1.0	1.5	0.1	£1.60	<=	£ 3.10	£1.50
10	Funds Availability in Year 2	0.3	0.8	1.5	0.4	£1.90	<=	£ 2.50	£0.60
11	Funds Availability in Year 3	0.2	0.2	0.3	0.1	£0.40	<=	£ 0.40	£ -

Example: Staff scheduling

	A	B	C	D	E	F	G	H
1	Staff Scheduling Problem							
2	Shift pattern:							
3		x1	x2	x3				
4	Binary 0/1 Decision Variables	4	3	4				
5								
6	Total number of Staff required	1	1	1	11	(min)		
7								
8					LHS		RHS	Surplus
9	Cover Monday	1	1	1	11	>=	10	1
10	Cover Tuesday		1	1	7	>=	7	0
11	Cover Wednesday	1		1	8	>=	7	1
12	Cover Thursday	1	1		7	>=	7	0
13	Cover Friday	1	1	1	11	>=	9	2

Example: Transshipment (Supply chain). Observe concise layout.

	A	B	C	D	E	F	G	H
1	Transshipment Problem - Concise Layout				Infinite Cost = 999			
2								
3	Data							
4	Unit Costs From Factory							
5	To	Plant	Ports	Depot D	Depot W	Depot M	Depot S	Requirements
6	Depot D	0.5	999					
7	Depot W	0.5	0.3					
8	Depot M	1.0	0.5					
9	Depot S	0.2	0.2					
10	Customer 1	1.0	2.0	999	1.0	999	999	100
11	Customer 2	1.5	999	0.5	0.5	2.0	0.2	80
12	Customer 3	2.0	999	1.5	1.0	999	1.5	70
13	Customer 4	999	999	999	0.5	0.5	0.5	120
14	Customer 5	1.0	999	1.0	999	1.5	1.5	40
15	Max Supply	300	400	140	100	200	80	
16								
17	Solution							
18	Send From Factory							
19	To	Plant	Ports	Depot D	Depot W	Depot M	Depot S	Total received
20	Depot D	0	0					0
21	Depot W	0	100					100
22	Depot M	0	90					90
23	Depot S	80	0					80
24	Customer 1	100	0	0	0	0	0	100
25	Customer 2	0	0	0	0	0	80	80
26	Customer 3	0	0	0	70	0	0	70
27	Customer 4	0	0	0	30	90	0	120
28	Customer 5	40	0	0	0	0	0	40
29	Total sent	220	190	0	100	90	80	
30								
31	Total Cost = £ 377							

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O						
1	Transshipment Problem Concise Layout																				
2																					
3	Unit Costs	From Plant										Solution									
4	To	A	B	C	Depot D1	Depot D2	Demand						Send	From Plant							
5	Depot D1	11.40	11.30	11.50									Depot D1	20.0	70.0	25.0			115.0		
6	Depot D2				0.70								Depot D2				115.0			115.0	
7	Customer 1	12.80	13.20	14.40		0.70	40						Customer 1	40.0	0.0	0.0		0.0		40.0	
8	Customer 2	13.10	15.60	15.60		0.90	35						Customer 2	0.0	0.0	0.0		35.0		35.0	
9	Customer 3	14.40	14.50	12.40		1.10	25						Customer 3	0.0	0.0	25.0		0.0		25.0	
10	Customer 4	15.50	13.40	15.20		0.80	20						Customer 4	0.0	0.0	0.0		20.0		20.0	
11	Customer 5	13.80	12.80	13.60		0.60	60						Customer 5	0.0	0.0	0.0		60.0		60.0	
12	Customer 6	14.30	15.00	12.80		0.90	30						Customer 6	0.0	0.0	30.0		0.0		30.0	
13	Max Prod	60.00	70.00	80.00											Total sent	60.0	70.0	80.0	115.0	115.0	
14																					
15	Total Cost = £ 2,676.50																				

Metaheuristics in Excel

Simulated Annealing of Travelling Salesman Problem

Start:

Initial Solution										Total
1	2	3	4	5	6	7	8	9	10	105.00

Best Solution										0.00
0	0	0	0	0	0	0	0	0	0	

Current Solution										Distances										
1	2	3	4	5	6	7	8	9	10	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 1	sum
1	2	3	4	5	6	7	8	9	10	8	9	7	3	18	9	8	11	10	22	105
2	1	3	4	5	6	7	8	9	10	8	5	7	3	18	9	8	11	10	22	101

Swop			New Distances																	cool=							
This	With	This	New Permutation										1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 1	sum	Prob	Rand	Accept	Temp
6	10	10	1	2	3	4	5	10	7	8	9	6	8	9	7	3	15	11	8	11	8	14	94	1	0.26	1	50
4	8	8	1	2	3	8	5	10	7	4	9	6	8	9	12	6	15	11	10	15	8	14	108	0.75	0.88	0	49

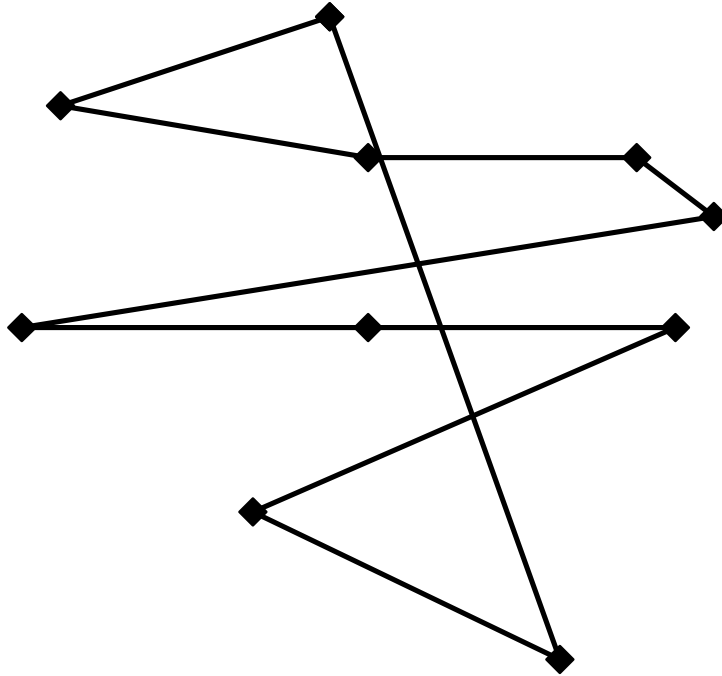
Initial Solution										Total
1	2	3	4	5	6	7	8	9	10	105.00

Best Solution										80.00
8	10	9	6	7	3	2	1	4	5	

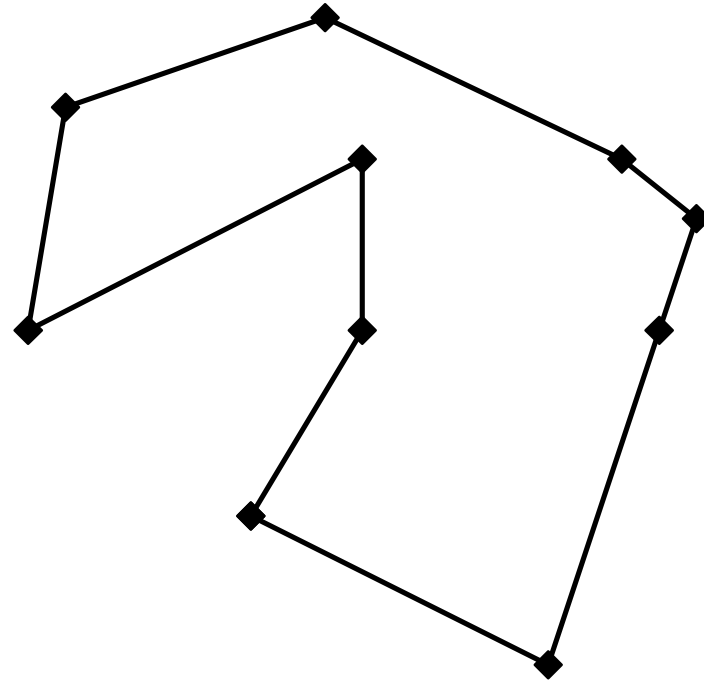
Current Solution	Distances										Swop			New Distances										Prob RandAccept			Temp											
	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 1	sum	This	With	This	New Permutation										1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 1	sum	Prob	Rand	Accept
1 2 3 4 5 6 7 8 9 10	8	9	7	3	18	9	8	11	10	22	105	3	2	2	1 3 2 4 5 6 7 8 9 10	5	9	15	3	18	9	8	11	10	22	110	0.9	0.58	1	50								
1 3 2 4 5 6 7 8 9 10	5	9	15	3	18	9	8	11	10	22	110	10	2	2	1 3 10 4 5 6 7 8 9 2	5	17	18	3	18	9	8	11	14	8	111	0.98	0.01	1	49								
1 3 10 4 5 6 7 8 9 2	5	17	18	3	18	9	8	11	14	8	111	6	7	7	1 3 10 4 5 7 6 8 9 2	5	17	18	3	10	9	14	11	14	8	109	1	0.82	1	48								
1 3 10 4 5 7 6 8 9 2	5	17	18	3	10	9	14	11	14	8	109	3	9	9	1 9 10 4 5 7 6 8 3 2	17	10	18	3	10	9	14	12	9	8	110	0.98	0.81	1	47.1								
1 9 10 4 5 7 6 8 3 2	17	10	18	3	10	9	14	12	9	8	110	10	8	8	1 9 8 4 5 7 6 10 3 2	17	11	7	3	10	9	16	17	9	8	107	1	0.6	1	46.1								
1 9 8 4 5 7 6 10 3 2	17	11	7	3	10	9	16	17	9	8	107	9	9	10	1 10 8 4 5 7 6 9 3 2	22	11	7	3	10	9	8	12	9	8	99	1	0.62	1	45.2								
1 10 8 4 5 7 6 9 3 2	22	11	7	3	10	9	8	12	9	8	99	9	7	7	1 10 8 4 5 9 6 7 3 2	22	11	7	3	15	8	9	7	9	8	99	1	0.43	1	44.3								
1 10 8 4 5 9 6 7 3 2	22	11	7	3	15	8	9	7	9	8	99	8	6	6	1 10 6 4 5 9 8 7 3 2	22	16	17	3	15	11	8	7	9	8	116	0.68	0.82	0	43.4								
1 10 8 4 5 9 6 7 3 2	22	11	7	3	15	8	9	7	9	8	99	4	9	9	1 10 8 9 5 4 6 7 3 2	22	11	11	15	3	17	9	7	9	8	112	0.74	0.57	1	42.5								
1 10 8 9 5 4 6 7 3 2	22	11	11	15	3	17	9	7	9	8	112	7	2	2	1 10 8 9 5 4 6 2 3 7	22	11	11	15	3	17	8	9	7	12	115	0.93	0.6	1	41.7								
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1 9 8 10 5 4 6 2 3 7	17	11	11	15	3	17	8	9	7	12	110	10	6	6	1 9 8 6 5 4 10 2 3 7	17	11	14	18	3	18	22	9	7	12	131	0.59	0.05	1	40								
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1 9 8 5 6 4 10 2 3 7	17	11	6	18	17	18	22	9	7	12	137	6	7	7	1 9 8 5 7 4 10 2 3 6	17	11	6	10	10	18	22	9	11	14	128	1	0.72	1	38.5								
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9 1 8 5 7 4 10 2 3 6	17	16	6	10	10	18	22	9	11	8	127	9	9	10	10 1 8 5 7 4 9 2 3 6	22	16	6	10	10	15	14	9	11	16	129	0.95	0.72	1	36.9								
10 1 8 5 7 4 9 2 3 6	22	16	6	10	15	14	9	11	16	129	3	10	10	3 1 8 5 7 4 9 2 10 6	5	16	6	10	10	15	14	22	16	11	125	1	0.26	1	36.2									
3 1 8 5 7 4 9 2 10 6	5	16	6	10	10	15	14	22	16	11	125	4	7	7	3 1 8 5 4 7 9 2 10 6	5	16	6	3	10	6	14	22	16	11	109	1	0.55	1	35.5								
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3 1 7 5 4 8 6 9 10 2	5	12	10	3	7	14	8	10	22	9	100	7	4	4	3 1 4 5 7 8 6 9 10 2	5	9	3	10	8	14	8	10	22	9	98	1	0.04	1	31.4								
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3 4 1 8 7 5 6 9 10 2	7	9	16	8	10	18	8	10	22	9	117	3	5	5	5 4 1 8 7 3 6 9 10 2	3	9	16	8	7	11	8	10	22	17	111	1	0.76	1	29.6								
5 4 1 8 7 3 6 9 10 2	3	9	16	8	7	11	8	10	22	17	111	8	6	6	5 4 1 6 7 3 8 9 10 2	3	9	14	9	7	12	11	10	22	17	114	0.9	0.62	1	29								
5 4 1 6 7 3 8 9 10 2	3	9	14	9	7	12	11	10	22	17	114	1	10	10	5 4 10 6 7 3 8 9 1 2	3	18	16	9	7	12	11	17	8	17	118	0.87	0.54	1	28.4								
5 4 10 6 7 3 8 9 1 2	3	18	16	9	7	12	11	17	8	17	118	10	5	5	10 4 5 6 7 3 8 9 1 2	18	3	18	9	7	12	11	17	8	22	125	0.78	0.11	1	27.8								
10 4 5 6 7 3 8 9 1 2	18	3	18	9	7	12	11	17	8	22	125	7	10	10	7 4 5 6 10 3 8 9 1 2	10	3	18	16	17	12	11	17	8	11	123	1	0.94	1	27.3								
7 4 5 6 10 3 8 9 1 2	10	3	18	16	17	12	11	17	8	11	123	2	9	9	7 4 5 6 10 3 8 2 1 9	10	3	18	16	17	12	18	8	17	6	125	0.93	0.49	1	26.7								
7 4 5 6 10 3 8 2 1 9	10	3	18	16	17	12	18	8	17	6	125	2	6	6	7 4 5 2 10 1 8 6 1 9	10	3	17	22	17	12	14	14	17	6	132	0.77	0.61	1	26.2								
7 4 5 2 10 3 8 6 1 9	10	3	17	22	17	12	14	14	17	6	132	1	3	3	7 4 5 2 10 1 8 6 3 9	10	3	17	22	22	16	14	11	12	6	133	0.96	0.83	1	25.7								
7 4 5 2 10 1 8 6 3 9	10	3	17	22	22	16	14	11	12	6	133	8	10	10	7 4 5 2 8 1 10 6 3 9	10	3	17	18	16	22	16	11	12	6	131	1	0.45	1	25.2								
7 4 5 2 8 1 10 6 3 9	10	3	17	18	16	22	16	11	12	6	131	6	4	4	7 6 5 2 8 1 10 4 3 9	9	18	17	18	16	22	18	7	12	6	143	0.61	0.54	1	24.7								
7 6 5 2 8 1 10 4 3 9	9	18	17	18	16	22	18	7	12	6	143	1	10	10	7 6 5 2 8 10 1 4 3 9	9	18	17	18	11	22	9	7	12	6	129	1	0.54	1	24.2								
7 6 5 2 8 10 1 4 3 9	9	18	17	18	11	22	9	7	12	6	129	9	2	2	7 6 5 9 8 10 1 4 3 2	9	18	15	11	11	22	9	7	9	11	122	1	0.05	1	23.7								
7 6 5 9 8 10 1 4 3 2	9	18	15	11	11	22	9	7	9	11	122	1	3	3	7 6 5 9 8 10 3 4 1 2	9	18	15	11	11	17	7	9	8	11	116	1	0.41	1	23.2								
7 6 5 9 8 10 3 4 1 2	9	18	15	11	11	17	7	9	8	11	116	7	7	8	8 6 5 9 7 10 3 4 1 2	14	18	15	6	11	17	7	9	8	18	123	0.74	0.34	1	22.7								
8 6 5 9 7 10 3 4 1 2	14	18	15	6	11	17	7	9	8	18	123	9	6	6	8 9 5 6 7 10 3 4 1 2	11	15	18	9	11	17	7	9	8	18	123	1	0.94	1	22.3								
8 9 5 6 7 10 3 4 1 2	11	15	18	9	11	17	7	9	8	18	123	5	8	8	5 9 8 6 7 10 3 4 1 2	15	11	14	9	11	17	7	9	8	17	118	1	0.18	1	21.8								

8 5 4 3 1 2 6 7 9 10	6	3	7	5	8	8	9	6	10	11	73	7	10	10	8 5 4 3 1 2 6 10 9 7	6	3	7	5	8	8	16	10	6	8	77	0	0.09	0	0
8 5 4 3 1 2 6 7 9 10	6	3	7	5	8	8	9	6	10	11	73	4	10	10	8 5 10 3 1 2 6 7 9 4	6	15	17	5	8	8	9	6	15	7	96	0	0.24	0	0
8 5 4 3 1 2 6 7 9 10	6	3	7	5	8	8	9	6	10	11	73	9	8	8	9 5 4 3 1 2 6 7 8 10	15	3	7	5	8	8	9	8	11	10	84	0	0.47	0	0
8 5 4 3 1 2 6 7 9 10	6	3	7	5	8	8	9	6	10	11	73	8	2	2	2 5 4 3 1 8 6 7 9 10	17	3	7	5	16	14	9	6	10	22	109	0	0.65	0	0
8 5 4 3 1 2 6 7 9 10	6	3	7	5	8	8	9	6	10	11	73	9	7																	

Original Tour
105.00



Optimised Tour 79.00



VBA programming in Excel

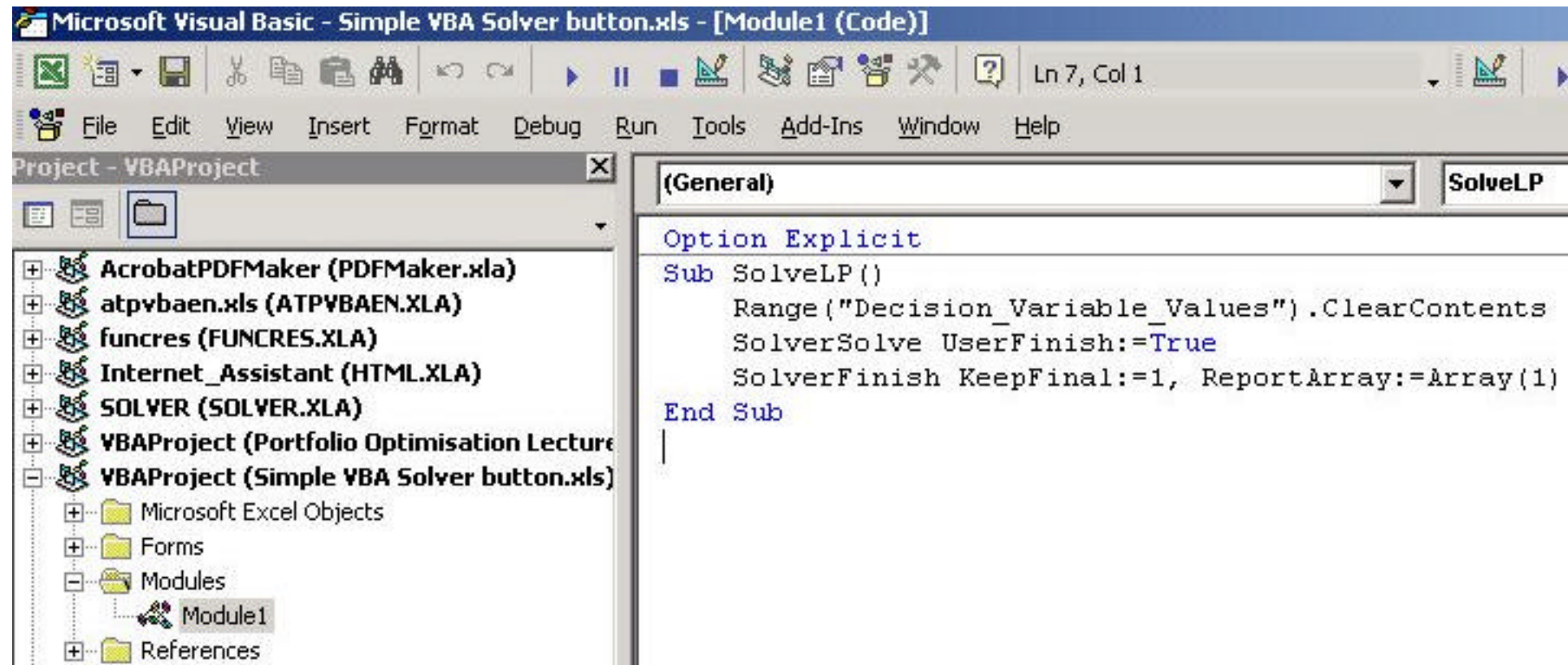
VBA = Visual Basic for Applications (used in Microsoft Office)

Example: Solve an LP by pressing button:

	A	B	C	D	E	F
1	RMC					
2	<input type="button" value="Solve LP"/>	Fuel	Solvent			
3		x1	x2			
4	Production Quantities (tonnes)	25	20	<== Values of Decision Variables		
5						
6	Production profit margins	£ 40	£ 30	£ 1,600	(max)	
7						
8				LHS		RHS
9	Availability of material 1	0.4	0.5	20	<=	20
10	Availability of material 2	0.6	0.3	21	<=	21
11	Availability of material 3	0	0.2	4	<=	5

VBA code is edited within Excel

Example: VBA code within the "Solve LP" button.



The screenshot shows the Microsoft Visual Basic editor window titled "Microsoft Visual Basic - Simple VBA Solver button.xls - [Module1 (Code)]". The window includes a menu bar (File, Edit, View, Insert, Format, Debug, Run, Tools, Add-Ins, Window, Help) and a toolbar. The Project - VBAPROJECT window on the left shows a tree view with folders for Microsoft Excel Objects, Forms, Modules, and References. The Modules folder is expanded, showing Module1. The right-hand pane displays the VBA code for the "SolveLP" button, which is currently selected in the Project window. The code is as follows:

```
Option Explicit
Sub SolveLP()
    Range("Decision_Variable_Values").ClearContents
    SolverSolve UserFinish:=True
    SolverFinish KeepFinal:=1, ReportArray:=Array(1)
End Sub
```

```

Sub SolveForwardModel()

    Dim PreviousSheetName As String, t As Integer
    Application.ScreenUpdating = False

    Rem Remember the current worksheet and then clear previous results
    PreviousSheetName = ActiveSheet.Name
    Worksheets("Results").Range("All_Production").ClearContents

    Rem Forward Pass
    For t = 1 To 13
        Worksheets("Forward Pass MIP").Activate ' or Sheets("Forward Pass MIP").Select
        Rem Copy demand data to LP RHS, and Starting & Target Inventory to LP matrix
        Sheets("Forward Pass MIP").Range("Demand_for_Forward_RHS").Value _
            = Sheets("Data").Range("Demand_" + CStr(t)).Value ' Actual (not effective) demand
        Sheets("Forward Pass MIP").Range("Starting_Inventory").Value _
            = Sheets("Results").Range("Inventory_" + CStr(t - 1)).Value ' Actual (not effective) demand
        Sheets("Forward Pass MIP").Range("Forward_Target_Inventory").Value _
            = Sheets("Results").Range("Target_Inventory_" + CStr(t)).Value
        Rem Solve the Backward LP Model
        Range("Decision_Variables").ClearContents
        SolverSolve UserFinish:=True
        SolverFinish KeepFinal:=1
        Rem Copy optimal solution Production_t and Capacity Usage to Results worksheet
        Sheets("Results").Range("Production_" + CStr(t)).Value _
            = Application.WorksheetFunction.Transpose(Range("Production_t"))
        Sheets("Results").Range("Capacity_Usage_" + CStr(t)).Value _
            = Range("Forward_Capacity_Usage").Value
        Rem Activate "Results" worksheet so that correct "Inventory_t" stock is calculated
        Worksheets("Results").Activate
    Next t

    Rem Return to the previous worksheet
    Worksheets(PreviousSheetName).Activate

End Sub

```

VBA - Advantages

Recording of Excel manual keystroke sequences

→ automation, convenience, speed, reliability.

Behind-the-worksheet processing

→ intermediate calculations are hidden off-sheet

→ clearer spreadsheet.

VBA code can replace long formulas or many cells

→ Fewer errors

VBA programme development and debugging within Excel

→ no further software is needed.

VBA can automatically integrate Excel with Word & Powerpoint.

VBA - Disadvantages

Code is often, neither obvious to understand, nor transparent
→ steep learning-curve, time-consuming, easily forgotten.

Difficult to do certain mundane tasks

- Example: it is complicated to read a text file word-by-word as in C's `fscanf` command, i.e., not line-by-line.

Martin (Journal of the OR Society, vol 15, 2000)

- "The use of VBA reduces size and complexity of the underlying spreadsheet, thus reducing likelihood of errors"
- "All [examples] require a careful consideration of design alternatives, not least the overall spreadsheet layout and the role of VBA for functionality and to support the user interface".
- "[VBA] Macros are critical to the full exploitation of the power of the spreadsheet in the context of OR problem solving."
- "VBA capabilities are likely to come into play for most non-trivial OR applications"

Ragsdale "Should MBAs Know VBA?", OR/MS Today, December 1998.

- "VBA may be the only way for ... individuals to gain access to systems that provide information needed for decision-making"
- "managers with an understanding of VBA are better equipped to create more efficient and useful decision models when they encounter problems for which Excel offers no easy built-in solution."
- "managers can use [VBA] to create true decision support systems (DSS) that were previously either too costly or too technically challenging for most managers to build."

Ragsdale, 2002, about teaching MBA students

- "managers often become so comfortable with spreadsheets that they are reluctant to adopt other software packages; even if ... more suitable for specific applications".
- "millions of business people have powerful spreadsheet packages (and the MS tools they provide) sitting at their finger tips on desktop and laptop computers; yet most have no idea of how to use their spreadsheet package to its fullest potential (Savage, 1997)."
- "regardless of their previous experience with Excel, most students have very little experience with VBA and are easily amazed by its capabilities."

Panko, 2000, on spreadsheet errors

cites research that found that organisations make important decisions with spreadsheets of all sizes"

- "Development was strongly iterative. There was a high level of confidence that the spreadsheet described was correct."
- "The spreadsheets were complex. 45% used macros. 36% had links to other spreadsheets. 21% had links to databases. 47% used IF functions. 66% used absolute referencing."
- "Many spreadsheets are large, complex, important, and affect many people. Yet development tends to be quite informal, and even trivial controls such as cell protection are not used in most cases. In programming, code inspection and data testing

are needed to reduce error rates after a module is developed. Yet code inspection is very infrequent, and while data testing is done, it lacks such rigors as the use of out-of-bounds data. In general, end user development in spreadsheeting seems to resemble programming practice in the 1950s and 1960s."

- "few organizations have policies on end user development in general, much less spreadsheet development."
- "Why is end user development in spreadsheeting so casual? The answer may be that both developers and corporations are overconfident about the accuracy of spreadsheets, despite the large amount of information to the contrary." "While such massive levels of overconfidence seem unreasonable, overconfidence is perhaps the most well-established phenomenon in the behavioral sciences."

- "In practice, as degree of difficulty increases, confidence falls, but not proportionately. Overconfidence is corrosive because it tends to blind people to the need for taking steps to reduce risks."
- "In spreadsheets, ... detailed code inspection is rare, so few developers are likely to be getting the specific feedback they need to reduce their natural overconfidence."
- "In spreadsheets, our experience observing developers is that they often enter a formula without thinking it through beforehand. Unless the results look obviously wrong, they do not try to determine if the formula is incorrect. This allows the survival of many subtle yet important errors, even when the developer really knows approximately what the correct answer should be."

- "Most prescriptive papers also discuss the importance of documentation. As we have already seen, documentation is rare in spreadsheets."
- "Unless organizations and individuals are willing to impose the requirement for code inspection or comprehensive data testing, there seems little prospect for having correct spreadsheets in organizations. In comparison, the error reduction techniques normally discussed in prescriptive spreadsheet articles probably have far lower impact."
- "few spreadsheet developers have spreadsheeting in their job descriptions at all, and very few do spreadsheet development as their main task. In addition, because spreadsheet development is so dispersed, the implementation of policies has to be left to individual department managers."

Grossman (2002) about Spreadsheet Engineering

- Spreadsheet engineering adapts the lessons of software engineering to spreadsheets.
- Spreadsheets raise issues inadequately addressed by software engineering.
- Spreadsheets are a powerful modelling language, allowing strategic rapid model change, and enabling exploratory modelling.
- Spreadsheets users learn slowly with experience because they focus on the problem domain not programming.

Integration with other software

Prevalence of Excel

→ Often straightforward communication with other software

Use as a

- user interface
- database
- visualiser of data and solutions

Example - Resource Levelling in Projects

Activity-on-Node network.

- Use spreadsheet to calculate critical path, project duration and activity ESTs/LSTs, as previously.
- If tight capacity, then user must increase LSTs to permit resource feasibility.
- Use MathProg (AMPL) model to smooth use of resource, solved optimally (and quickly) by GLPSol.

GLPSol solution

Input: 26 Activities, 3 Resources, 26 periods of Project Duration

MIP matrix:

Rows: 289

Columns: 157 (91 integer, 91 binary)

Non-zeros: 1470

INTEGER OPTIMAL SOLUTION FOUND: Time used: 0.1 secs

Objective: Total_Resource_Usage = 665.5052532 (MINimum) 657.8607231 (LP)

<i>No.</i>	<i>Column name</i>	<i>Activity</i>	<i>Lower bound</i>	<i>Upper bound</i>
1	<i>x[Activity_A,0]</i>			
	*	1	0	1
2	<i>x[Activity_A,1]</i>			
	*	0	0	1

3 *x*[Activity_A,2]

* 0 0 1

4 *x*[Activity_A,3]

* 0 0 1

Calc Free Spreadsheet

- Available for Windows and Linux.
- Part of the OpenOffice suite.
- But - no LP solver.
- Download: www.OpenOffice.org

Gnumeric Free Spreadsheet

- Available for Linux/Gnome only.
- Part of the Gnome Office package.
- Includes GNU'd GLPK solver with Excel Solver style user-interface.
- Programmable with Python language to improve GLPK interface.
- Download: www.gnumeric.org
- Note: Linux/KDE's KOffice is more limited.

Free spreadsheet resources

www.usd.edu/trio/tut/excel

www.fgcu.edu/support/office2000/excel

www.internet4classrooms.com/on-line_excel.htm