
Contents

Introduction	xv
Chapter 1. Production Models: Maximizing Profits	1
1.1 A two-variable linear program	2
1.2 The two-variable linear program in AMPL	5
1.3 A linear programming model	6
1.4 The linear programming model in AMPL	7
The basic model	8
An improved model	10
Catching errors	12
1.5 Adding lower bounds to the model	13
1.6 Adding resource constraints to the model	15
1.7 AMPL interfaces	18
Chapter 2. Diet and Other Input Models: Minimizing Costs	27
2.1 A linear program for the diet problem	27
2.2 An AMPL model for the diet problem	30
2.3 Using the AMPL diet model	32
2.4 Generalizations to blending, economics and scheduling	37
Chapter 3. Transportation and Assignment Models	43
3.1 A linear program for the transportation problem	44
3.2 An AMPL model for the transportation problem	45
3.3 Other interpretations of the transportation model	49
Chapter 4. Building Larger Models	55
4.1 A multicommodity transportation model	56
4.2 A multiperiod production model	59
4.3 A model of production and transportation	63
Chapter 5. Simple Sets and Indexing	73
5.1 Unordered sets	73

5.2	Sets of numbers	75
5.3	Set operations	76
5.4	Set membership operations and functions	78
5.5	Indexing expressions	79
5.6	Ordered sets	82
	Predefined sets and interval expressions	86
Chapter 6. Compound Sets and Indexing		91
6.1	Sets of ordered pairs	91
6.2	Subsets and slices of ordered pairs	93
6.3	Sets of longer tuples	96
6.4	Operations on sets of tuples	98
6.5	Indexed collections of sets	100
Chapter 7. Parameters and Expressions		109
7.1	Parameter declarations	110
7.2	Arithmetic expressions	111
7.3	Logical and conditional expressions	114
7.4	Restrictions on parameters	116
7.5	Computed parameters	118
7.6	Randomly generated parameters	121
7.7	Logical parameters	122
7.8	Symbolic parameters	123
Chapter 8. Linear Programs: Variables, Objectives and Constraints		129
8.1	Variables	129
8.2	Linear expressions	132
8.3	Objectives	134
8.4	Constraints	137
Chapter 9. Specifying Data		143
9.1	Formatted data: the <code>data</code> command	143
9.2	Data in lists	145
	Lists of one-dimensional sets and parameters	145
	Lists of two-dimensional sets and parameters	146
	Lists of higher-dimensional sets and parameters	148
	Combined lists of sets and parameters	151
9.3	Data in tables	154
	Two-dimensional tables	154
	Two-dimensional slices of higher-dimensional data	156
	Higher-dimensional tables	157
	Choice of format	159
9.4	Other features of data statements	160
	Default values	160
	Indexed collections of sets	161
	Initial values for variables	162

9.5	Reading unformatted data: the <code>read</code> command	163
Chapter 10.	Database Access	169
10.1	General principles of data correspondence	169
10.2	Examples of table-handling statements	174
10.3	Reading data from relational tables	180
	Reading parameters only	180
	Reading a set and parameters	182
	Establishing correspondences	184
	Reading other values	185
10.4	Writing data to relational tables	186
	Writing rows inferred from the data specifications	186
	Writing rows inferred from a key specification	189
10.5	Reading and writing the same table	191
	Reading and writing using two <code>table</code> declarations	192
	Reading and writing using the same <code>table</code> declaration	193
10.6	Indexed collections of tables and columns	193
	Indexed collections of tables	193
	Indexed collections of data columns	196
10.7	Standard and built-in table handlers	197
	Using the standard ODBC table handler	198
	Using the standard ODBC table handler with Access and Excel	200
	Built-in table handlers for text and binary files	201
Chapter 11.	Modeling Commands	203
11.1	General principles of commands and options	203
	Commands	204
	Options	204
11.2	Setting up and solving models and data	206
	Entering models and data	206
	Solving a model	207
11.3	Modifying data	209
	Resetting	209
	Resampling	209
	The <code>let</code> command	210
11.4	Modifying models	212
	Removing or redefining model components	213
	Changing the model: <code>fix</code> , <code>unfix</code> ; <code>drop</code> , <code>restore</code>	214
	Relaxing integrality	215
Chapter 12.	Display Commands	219
12.1	Browsing through results: the <code>display</code> command	219
	Displaying sets	220
	Displaying parameters and variables	220
	Displaying indexed expressions	224
12.2	Formatting options for <code>display</code>	227

Arrangement of lists and tables	227
Control of line width	229
Suppression of zeros	231
12.3 Numeric options for <code>display</code>	232
Appearance of numeric values	233
Rounding of solution values	236
12.4 Other output commands: <code>print</code> and <code>printf</code>	238
The <code>print</code> command	238
The <code>printf</code> command	239
12.5 Related solution values	240
Objective functions	240
Bounds and slacks	241
Dual values and reduced costs	243
12.6 Other display features for models and instances	245
Displaying model components: the <code>show</code> command:	246
Displaying model dependencies: the <code>xref</code> command	247
Displaying model instances: the <code>expand</code> command	247
Generic synonyms for variables, constraints and objectives	249
Resource listings	250
12.7 General facilities for manipulating output	251
Redirection of output	251
Output logs	251
Limits on messages	252
Chapter 13. Command Scripts	255
13.1 Running scripts: <code>include</code> and <code>commands</code>	255
13.2 Iterating over a set: the <code>for</code> statement	258
13.3 Iterating subject to a condition: the <code>repeat</code> statement	262
13.4 Testing a condition: the <code>if-then-else</code> statement	264
13.5 Terminating a loop: <code>break</code> and <code>continue</code>	266
13.6 Stepping through a script	268
13.7 Manipulating character strings	270
String functions and operators	270
String expressions in AMPL commands	273
Chapter 14. Interactions with Solvers	275
14.1 Presolve	275
Activities of the presolve phase	276
Controlling the effects of presolve	278
Detecting infeasibility in presolve	279
14.2 Retrieving results from solvers	282
Solve results	282
Solver statuses of objectives and problems	286
Solver statuses of variables	287
Solver statuses of constraints	291
AMPL statuses	293

14.3	Exchanging information with solvers via suffixes	295
	User-defined suffixes: integer programming directives	296
	Solver-defined suffixes: sensitivity analysis	298
	Solver-defined suffixes: infeasibility diagnosis	299
	Solver-defined suffixes: direction of unboundedness	300
	Defining and using suffixes	302
14.4	Alternating between models	304
14.5	Named problems	309
	Defining named problems	311
	Using named problems	314
	Displaying named problems	315
	Defining and using named environments	316
Chapter 15. Network Linear Programs		319
15.1	Minimum-cost transshipment models	319
	A general transshipment model	320
	Specialized transshipment models	323
	Variations on transshipment models	326
15.2	Other network models	328
	Maximum flow models	328
	Shortest path models	329
	Transportation and assignment models	330
15.3	Declaring network models by <code>node</code> and <code>arc</code>	333
	A general transshipment model	334
	A specialized transshipment model	335
	Variations on transshipment models	336
	Maximum flow models	337
15.4	Rules for <code>node</code> and <code>arc</code> declarations	340
	<code>node</code> declarations	340
	<code>arc</code> declarations	340
	Interaction with objective declarations	341
	Interaction with constraint declarations	342
	Interaction with variable declarations	342
15.5	Solving network linear programs	343
Chapter 16. Columnwise Formulations		353
16.1	An input-output model	354
	Formulation by constraints	354
	A columnwise formulation	355
	Refinements of the columnwise formulation	357
16.2	A scheduling model	359
16.3	Rules for columnwise formulations	362
Chapter 17. Piecewise-Linear Programs		365
17.1	Cost terms	366
	Fixed numbers of pieces	366

Varying numbers of pieces	368
17.2 Common two-piece and three-piece terms	369
Penalty terms for “soft” constraints	369
Dealing with infeasibility	373
Reversible activities	377
17.3 Other piecewise-linear functions	379
17.4 Guidelines for piecewise-linear optimization	382
Forms for piecewise-linear expressions	382
Suggestions for piecewise-linear models	383
Chapter 18. Nonlinear Programs	391
18.1 Sources of nonlinearity	392
Dropping a linearity assumption	393
Achieving a nonlinear effect	396
Modeling an inherently nonlinear process	397
18.2 Nonlinear variables	397
Initial values of variables	398
Automatic substitution of variables	399
18.3 Nonlinear expressions	400
18.4 Pitfalls of nonlinear programming	403
Function range violations	403
Multiple local optima	407
Other pitfalls	410
Chapter 19. Complementarity Problems	419
19.1 Sources of complementarity	419
A complementarity model of production economics	420
Complementarity for bounded variables	423
Complementarity for price-dependent demands	425
Other complementarity models and applications	426
19.2 Forms of complementarity constraints	427
19.3 Working with complementarity constraints	428
Related solution values	428
Presolve	429
Generic synonyms	431
Chapter 20. Integer Linear Programs	437
20.1 Integer variables	438
20.2 Zero-one variables and logical conditions	439
Fixed costs	440
Zero-or-minimum restrictions	444
Cardinality restrictions	445
20.3 Practical considerations in integer programming	448

Appendix A. AMPL Reference Manual	453
A.1 Lexical rules	453
A.2 Set members	454
A.3 Indexing expressions and subscripts	455
A.4 Expressions	455
A.4.1 Built-in functions	458
A.4.2 Strings and regular expressions	459
A.4.3 Piecewise-linear terms	460
A.5 Declarations of model entities	461
A.6 Set declarations	461
A.6.1 Cardinality and arity functions	462
A.6.2 Ordered sets	463
A.6.3 Intervals and other infinite sets	463
A.7 Parameter declarations	465
A.7.1 Check statements	465
A.7.2 Infinity	466
A.8 Variable declarations	466
A.8.1 Defined variables	467
A.9 Constraint declarations	468
A.9.1 Complementarity constraints	469
A.10 Objective declarations	470
A.11 Suffix notation for auxiliary values	470
A.11.1 Suffix declarations	471
A.11.2 Statuses	473
A.12 Standard data format	473
A.12.1 Set data	473
A.12.2 Parameter data	475
A.13 Database access and tables	477
A.14 Command language overview	479
A.14.1 Options and environment variables	481
A.15 Redirection of input and output	481
A.16 Printing and display commands	482
A.17 Reading data	484
A.18 Modeling commands	485
A.18.1 The <code>solve</code> command	485
A.18.2 The <code>solution</code> command	487
A.18.3 The <code>write</code> command	487
A.18.4 Auxiliary files	487
A.18.5 Changing a model: <code>delete</code> , <code>purge</code> , <code>redeclare</code>	488
A.18.6 The <code>drop</code> , <code>restore</code> and <code>objective</code> commands	489
A.18.7 The <code>fix</code> and <code>unfix</code> commands	489
A.18.8 Named problems and environments	489
A.18.9 Modifying data: <code>reset</code> , <code>update</code> , <code>let</code>	490
A.19 Examining models	491
A.19.1 The <code>show</code> command	491

A.19.2	The <code>xref</code> command	492
A.19.3	The <code>expand</code> command	492
A.19.4	Generic names	492
A.19.5	The <code>check</code> command	492
A.20	Scripts and control flow statements	492
A.20.1	The <code>for</code> , <code>repeat</code> and <code>if-then-else</code> statements	493
A.20.2	Stepping through commands	495
A.21	Computational environment	495
A.21.1	The <code>shell</code> command	495
A.21.2	The <code>cd</code> command	495
A.21.3	The <code>quit</code> , <code>exit</code> and <code>end</code> commands	496
A.21.4	Built-in timing parameters	496
A.21.5	Logging	496
A.22	Imported functions	497
A.23	AMPL invocation	499
Index		501