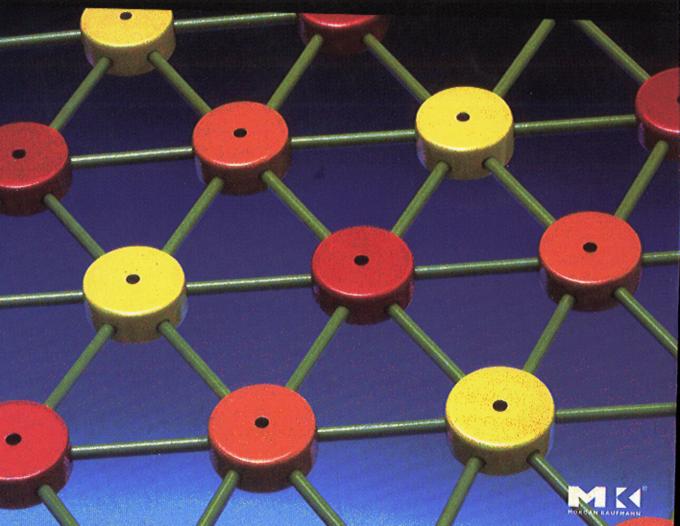


DATA MODELING ESSENTIALS Third Edition

Graeme C. SIMSION • Graham C. WITT



Contents

Preface xxiii

	The Basics 1
	Chapter 1 What Is Data Modeling? 3
1.1	Introduction 3
1.2	A Data-Centered Perspective 3
1.3	A Simple Example 4
1.4	Design, Choice, and Creativity 6
1.5	Why Is the Data Model Important? 8 1.5.1 Leverage 8 1.5.2 Conciseness 9 1.5.3 Data Quality 10 1.5.4 Summary 10
1.6	What Makes a Good Data Model? 10 1.6.1 Completeness 10 1.6.2 NonRedundancy 11 1.6.3 Enforcement of Business Rules 11 1.6.4 Data Reusability 11 1.6.5 Stability and Flexibility 12 1.6.6 Elegance 13 1.6.7 Communication 14 1.6.8 Integration 14 1.6.9 Conflicting Objectives 15
1.7	Performance 15
1.8	Database Design Stages and Deliverables161.8.1Conceptual, Logical, and Physical Data Models161.8.2The Three-Schema Architecture and Terminology17

1.9	Where Do Data Models Fit In? 20 1.9.1 Process-Driven Approaches 20 1.9.2 Data-Driven Approaches 20 1.9.3 Parallel (Blended) Approaches 22 1.9.4 Object-Oriented Approaches 22 1.9.5 Prototyping Approaches 23 1.9.6 Agile Methods 23
1.10	Who Should Be Involved in Data Modeling? 23
7.11	Is Data Modeling Still Relevant? 24 1.11.1 Costs and Benefits of Data Modeling 25 1.11.2 Data Modeling and Packaged Software 26 1.11.3 Data Integration 27 1.11.4 Data Warehouses 27 1.11.5 Personal Computing and User-Developed Systems 28 1.11.6 Data Modeling and XML 28 1.11.7 Summary 28
1.12	Alternative Approaches to Data Modeling 29
1.13	Terminology 30
1.14	Where to from Here?—An Overview of Part I 31
1.15	Summary 32
	Chapter 2 Basics of Sound Structure 33
2.1	Introduction 33
2.2	An Informal Example of Normalization 34
2.3	Relational Notation 36
2.4	A More Complex Example 37
2.5	Determining Columns 40 2.5.1 One Fact per Column 40 2.5.2 Hidden Data 41 2.5.3 Derivable Data 41 2.5.4 Determining the Primary Key 41
2.6	Repeating Groups and First Normal Form 2.6.1 Limit on Maximum Number of Occurrences 43 2.6.2 Data Reusability and Program Complexity 43 2.6.3 Recognizing Repeating Groups 44 2.6.4 Removing Repeating Groups 45

	2.6.5 Determining the Primary Key of the New Table 46 2.6.6 First Normal Form 47
2.7	Second and Third Normal Forms 47 2.7.1 Problems with Tables in First Normal Form 47 2.7.2 Eliminating Redundancy 48 2.7.3 Determinants 48 2.7.4 Third Normal Form 51
2.8	Definitions and a Few Refinements 53 2.8.1 Determinants and Functional Dependency 53 2.8.2 Primary Keys 54 2.8.3 Candidate Keys 54 2.8.4 A More Formal Definition of Third Normal Form 55 2.8.5 Foreign Keys 55 2.8.6 Referential Integrity 56 2.8.7 Update Anomalies 57 2.8.8 Denormalization and Unnormalization 58 2.8.9 Column and Table Names 59
2.9	Choice, Creativity, and Normalization 60
2.10	Terminology 62
2.11	Summary 63
	Chapter 3 The Entity-Relationship Approach 65
3.1	Introduction 65
3.2	A Diagrammatic Representation 65 3.2.1 The Basic Symbols: Boxes and Arrows 66 3.2.2 Diagrammatic Representation of Foreign Keys 67 3.2.3 Interpreting the Diagram 68 3.2.4 Optionality 69 3.2.5 Verifying the Model 70 3.2.6 Redundant Arrows 71
3.3	The Top-Down Approach: Entity-Relationship Modeling 72 3.3.1 Developing the Diagram Top Down 74 3.3.2 Terminology 75
3.4	Entity Classes 76 3.4.1 Entity Diagramming Convention 77 3.4.2 Entity Class Naming 78 3.4.3 Entity Class Definitions 80

3.5	Relationships 82
	3.5.1 Relationship Diagramming Conventions 82
	3.5.2 Many-to-Many Relationships 87
	3.5.3 One-to-One Relationships 923.5.4 Self-Referencing Relationships 93
	3.5.4 Self-Referencing Relationships 93 3.5.5 Relationships Involving Three or More Entity Classes 96
	3.5.6 Transferability 98
	3.5.7 Dependent and Independent Entity Classes 1023.5.8 Relationship Names 103
3.6	Attributes 104
	3.6.1 Attribute Identification and Definition 1043.6.2 Primary Keys and the Conceptual Model 105
3.7	Myths and Folklore 105
	 3.7.1 Entity Classes without Relationships 106 3.7.2 Allowed Combinations of Cardinality and Optionality 106
3.8	Creativity and E-R Modeling 106
3.9	Summary 109
4	Chapter 4
	Subtypes and Supertypes 111
4.1	Introduction 111
4.2	Different Levels of Generalization 111
4.2 4.3	Different Levels of Generalization 111 Rules versus Stability 113
4.3	Rules versus Stability 113
4.3 4.4	Rules versus Stability 113 Using Subtypes and Supertypes 115 Subtypes and Supertypes as Entity Classes 116 4.5.1 Naming Subtypes 117 Diagramming Conventions 117
4.3 4.4 4.5	Rules versus Stability 113 Using Subtypes and Supertypes 115 Subtypes and Supertypes as Entity Classes 116 4.5.1 Naming Subtypes 117
4.3 4.4 4.5	Rules versus Stability 113 Using Subtypes and Supertypes 115 Subtypes and Supertypes as Entity Classes 116 4.5.1 Naming Subtypes 117 Diagramming Conventions 117 4.6.1 Boxes in Boxes 117 4.6.2 UML Conventions 118
4.3 4.4 4.5 4.6	Rules versus Stability 113 Using Subtypes and Supertypes 115 Subtypes and Supertypes as Entity Classes 116 4.5.1 Naming Subtypes 117 Diagramming Conventions 117 4.6.1 Boxes in Boxes 117 4.6.2 UML Conventions 118 4.6.3 Using Tools That Do Not Support Subtyping 119

4.10	170	
	4.10.1 Ignoring Real-World Overlaps 123	
	4.10.2 Modeling Only the Supertype 124	
	4.10.3 Modeling the Roles as Participation in Relationships 124	
	4.10.4 Using Role Entity Classes and One-to-One Relationships 125	
	4.10.5 Multiple Partitions 126	
4.11	Hierarchy of Subtypes 127	
4.12	Benefits of Using Subtypes and Supertypes 128	
	4.12.1 Creativity 129	
	4.12.2 Presentation: Level of Detail 129	
	4.12.3 Communication 130	
	4.12.4 Input to the Design of Views 132	
	4.12.5 Classifying Common Patterns 132	
	4.12.6 Divide and Conquer 133	
4.13	When Do We Stop Supertyping and Subtyping? 134	
	4.13.1 Differences in Identifiers 134	
	4.13.2 Different Attribute Groups 135	
	4.13.3 Different Relationships 135	
	4.13.4 Different Processes 136	
	4.13.5 Migration from One Subtype to Another 136	
	4.13.6 Communication 136	
	4.13.7 Capturing Meaning and Rules 137	
	4.13.8 Summary 137	
4.14	Generalization of Relationships 138	
	4.14.1 Generalizing Several One-to-Many Relationships to a Single Many	-to
	Many Relationship 138	
	4.14.2 Generalizing Several One-to-Many Relationships	
	to a Single One-to-Many Relationship 139	
	4.14.3 Generalizing One-to-Many and Many-to-Many Relationships 141	
4.15	Theoretical Background 142	
4.16	Summary 143	
3	Chapter 5	
	Attributes and Columns 145	
5.1	Introduction 145	
5.2	Attribute Definition 146	

5.3	5.3.1	ibute Disaggregation: One Fact per Attribute 147 Simple Aggregation 148
	5.3.2	Conflated Codes 150
	5.3.3	Meaningful Ranges 151
	5.3.4	Inappropriate Generalization 151
5.4	Туре	s of Attributes 152
	5.4.1	DBMS Datatypes 152
	5.4.2	The Attribute Taxonomy in Detail 154
	5.4.3 5.4.4	Attribute Domains 158
	5.4.5	Column Datatype and Length Requirements 162 Conversion Between External and Internal Representations 166
5.5	Attri	bute Names 166
	5.5.1	Objectives of Standardizing Attribute Names 166
	5.5.2	Some Guidelines for Attribute Naming 168
5.6	~	bute Generalization 171
	5.6.1	Options and Trade-Offs 171
	5.6.2	Attribute Generalization Resulting from Entity Generalization 172
	5.6.3 5.6.4	The High Linky Classes 1/3
	5.6.5	Timber to 12
5.7	Sumi	
	Chap	ter 6
	Prim	ary Keys and Identity 183
6.1	Basic	Requirements and Trade-Offs 183
6.2	Basic	Technical Criteria 185
	6.2.1	Applicability 185
	6.2.2	Uniqueness 186
	6.2.3	Minimality 188
	6.2.4	Stability 189
6.3		gate Keys 191
	6.3.1	Performance and Programming Issues 191
	6.3.2 6.3.3	Matching Real-World Identifiers 191
	6.3.4	Should Surrogate Keys Be Visible? 192 Subtypes and Surrogate Keys 193
6.4	Struct	ured Keys 194
	6.4.1	When to Use Structured Keys 196
	6.4.2	Programming and Structured Keys 197
	6.4.3	Performance Issues with Structured Keys 198
	6.4.4	Running Out of Numbers 199

6.5	Multiple Candidate Keys 201 6.5.1 Choosing a Primary Key 201 6.5.2 Normalization Issues 201
6.6	Guidelines for Choosing Keys 202 6.6.1 Tables Implementing Independent Entity Classes 202 6.6.2 Tables Implementing Dependent Entity Classes and Many-to-Many Relationships 203
6.7	Partially-Null Keys 204
6.8	Summary 206
	Chapter 7
	Extensions and Alternatives 207
<i>7</i> .1	Introduction 207
7.2	Extensions to the Basic E-R Approach 7.2.1 Introduction 209 7.2.2 Advanced Attribute Concepts 210
<i>7</i> .3	The Chen E-R Approach 216 7.3.1 The Basic Conventions 216 7.3.2 Relationships with Attributes 217 7.3.3 Relationships Involving Three or More Entity Classes 217 7.3.4 Roles 218 7.3.5 The Weak Entity Concept 219 7.3.6 Chen Conventions in Practice 220
7.4	Using UML Object Class Diagrams 220 7.4.1 A Conceptual Data Model in UML 221 7.4.2 Advantages of UML 222
7.5	Object Role Modeling 227
7.6	
	Part II Putting It Together 229
	Chapter 8 Organizing the Data Modeling Task 231
8.1	Data Modeling in the Real World 231

Key Issues in Project Organization

Recognition of Data Modeling 233

Clear Use of the Data Model 234

233

8.2

8.2.1

8.2.2

	8.2.3 Access to Users and Other Business Stakeholders 8.2.4 Conceptual, Logical, and Physical Models 235 8.2.5 Cross-Checking with the Process Model 236 8.2.6 Appropriate Tools 237	234
8.3	Roles and Responsibilities 238	
8.4	Partitioning Large Projects 240	
8.5	Maintaining the Model 242 8.5.1 Examples of Complex Changes 242 8.5.2 Managing Change in the Modeling Process 247	
8.6	Packaging It Up 248	
8.7	Summary 249	
₩ <u>₩</u>	Chapter 9 The Business Requirements 251	
9.1	Purpose of the Requirements Phase 251	
9.2		
9.3	Interviews and Workshops 254 9.3.1 Should You Model in Interviews and Workshops? 2 9.3.2 Interviews with Senior Managers 256 9.3.3 Interviews with Subject Matter Experts 257 9.3.4 Facilitated Workshops 257	55
9.4	Riding the Trucks 258	
9.5	Existing Systems and Reverse Engineering 259	
9.6	Process Models 261	
9. <i>7</i>	9.7.1 Classifying Object Classes 263 9.7.2 A Typical Set of Top-Level Object Classes 265 9.7.3 Developing an Object Class Hierarchy 267 9.7.4 Potential Issues 270 9.7.5 Advantages of the Object Class Hierarchy Technique	270
9.8	Summary 270	

i. i	Chapter 10.
	Conceptual Data Modeling 273
10.1	Designing Real Models 273
10.2	Learning from Designers in Other Disciplines 275
10.3	Starting the Modeling 276
10.4	Patterns and Generic Models 277 10.4.1 Using Patterns 277 10.4.2 Using a Generic Model 278 10.4.3 Adapting Generic Models from Other Applications 279 10.4.4 Developing a Generic Model 282 10.4.5 When There Is Not a Generic Model 284
10.5	Bottom-Up Modeling 285
10.6	Top-Down Modeling 288
10. <i>7</i>	When the Problem Is Too Complex 288
10.8	Hierarchies, Networks, and Chains 290 10.8.1 Hierarchies 291 10.8.2 Networks (Many-to-Many Relationships) 293 10.8.3 Chains (One-to-One Relationships) 295
10.9	One-to-One Relationships 295 10.9.1 Distinct Real-World Concepts 296 10.9.2 Separating Attribute Groups 297 10.9.3 Transferable One-to-One Relationships 298 10.9.4 Self-Referencing One-to-One Relationships 299 10.9.5 Support for Creativity 299
10.10	Developing Entity Class Definitions 300
10.11	Handling Exceptions 301
10.12	The Right Attitude 302 10.12.1 Being Aware 303 10.12.2 Being Creative 303 10.12.3 Analyzing or Designing 303 10.12.4. Being Brave 304 10.12.5 Being Understanding and Understood 304
10.13	Evaluating the Model 305
10.14	Direct Review of Data Model Diagrams 306

10.15	Comparison with the Process Model 308
10.16	
10.1 <i>7</i>	Prototypes 309
10.18	The Assertions Approach 309 10.18.1 Naming Conventions 310 10.18.2 Rules for Generating Assertions 311
10.19	Summary 319
	Chapter 11 Logical Database Design 321
11.1	Introduction 321
11.2	Overview of the Transformations Required 322
11.3	Table Specification 32511.3.1The Standard Transformation 32511.3.2Exclusion of Entity Classes from the Database 32511.3.3Classification Entity Classes 32511.3.4Many-to-Many Relationship Implementation 32611.3.5Relationships Involving More Than Two Entity Classes 32811.3.6Supertype/Subtype Implementation 328
11.4	Basic Column Definition 334 11.4.1 Attribute Implementation: The Standard Transformation 33- 11.4.2 Category Attribute Implementation 335 11.4.3 Derivable Attributes 336 11.4.4 Attributes of Relationships 336 11.4.5 Complex Attributes 337 11.4.6 Multivalued Attribute Implementation 337 11.4.7 Additional Columns 339 11.4.8 Column Datatypes 340 11.4.9 Column Nullability 340
11.5	Primary Key Specification 341
11.6	Foreign Key Specification 342 11.6.1 One-to-Many Relationship Implementation 343 11.6.2 One-to-One Relationship Implementation 346 11.6.3 Derivable Relationships 347 11.6.4 Optional Relationships 348

	11.6.6 Split Foreign Keys 352
11.7	Table and Column Names 354
11.8	Logical Data Model Notations 355
11.9	Summary 357
	Chapter 12 Physical Database Design 359
12.1	Introduction 359
12.2	Inputs to Database Design 361
12.3	Options Available to the Database Designer 362
12.4	Design Decisions Which Do Not Affect Program Logic 12.4.1 Indexes 363 12.4.2 Data Storage 370 12.4.3 Memory Usage 372
12.5	Crafting Queries to Run Faster 372 12.5.1 Locking 373
12.6	Logical Schema Decisions 374 12.6.1 Alternative Implementation of Relationships 374 12.6.2 Table Splitting 374 12.6.3 Table Merging 376 12.6.4 Duplication 377 12.6.5 Denormalization 378 12.6.6 Ranges 379 12.6.7 Hierarchies 380 12.6.8 Integer Storage of Dates and Times 382 12.6.9 Additional Tables 383
12.7	Views 384 12.7.1 Views of Supertypes and Subtypes 385 12.7.2 Inclusion of Derived Attributes in Views 385 12.7.3 Denormalization and Views 385 12.7.4 Views of Split and Merged Tables 386
12.8	Summary 386

14.2.2

Process Rules 420

	Part III Advanced Topics 389
	Chapter 13 Advanced Normalization 391
13.1	Introduction 391
13.2	Introduction to the Higher Normal Forms 392 13.2.1 Common Misconceptions 392
13.3	Boyce-Codd Normal Form 394 13.3.1 Example of Structure in 3NF but not in BCNF 394 13.3.2 Definition of BCNF 396 13.3.3 Enforcement of Rules versus BCNF 397 13.3.4 A Note on Domain Key Normal Form 398
13.4	Fourth Normal Form (4NF) and Fifth Normal Form (5NF) 398 13.4.1 Data in BCNF but not in 4NF 399 13.4.2 Fifth Normal Form (5NF) 401 13.4.3 Recognizing 4NF and 5NF Situations 404 13.4.4 Checking for 4NF and 5NF with the Business Specialist 405
13.5	
13.6	Other Normalization Issues 408 13.6.1 Normalization and Redundancy 408 13.6.2 Reference Tables Produced by Normalization 410 13.6.3 Selecting the Primary Key after Removing Repeating Groups 411 13.6.4 Sequence of Normalization and Cross-Table Anomalies 414
13. <i>7</i>	Advanced Normalization in Perspective 415
	Summary 416
	Chapter 14 Modeling Business Rules 417
14.1	Introduction 417
14.2	Types of Business Rules 418 14.2.1 Data Rules 418

	14.2.3	What Rules are Relevant to the Data Modeler? 420
14.3	Discove	ery and Verification of Business Rules 420
	14.3.1	Cardinality Rules 420
	14.3.2	Other Data Validation Rules 421
	14.3.3	Data Derivation Rules 421
14.4	Docum	entation of Business Rules 422
	14.4.1	Documentation in an E-R Diagram 422
	14.4.2	Documenting Other Rules 422
	14.4.3	Use of Subtypes to Document Rules 424
14.5	Implen	nenting Business Rules 427
	14.5.1	Where to Implement Particular Rules 428
	14.5.2	Implementation Options: A Detailed Example 433
	14.5.3	Implementing Mandatory Relationships 436
	14.5.4	Referential Integrity 438
	14.5.5	Restricting an Attribute to a Discrete Set of Values 439
	14.5.6	Rules Involving Multiple Attributes 442
	14.5.7	Recording Data That Supports Rules 442
	14.5.8	Rules That May Be Broken 443
	14.5.9	Enforcement of Rules Through Primary Key Selection 445
14.6	Rules o	n Recursive Relationships 446
	14.6.1	Types of Rules on Recursive Relationships 447
	14.6.2	Documenting Rules on Recursive Relationships 449
	14.6.3	Implementing Constraints on Recursive Relationships 449
	14.6.4	Analogous Rules in Many-to-Many Relationships 450
14.7	Summo	ıry 450
	Chapte	r 15
	<u>.</u> .	
	ııme-ı	Dependent Data 451
15.1	The Pro	blem 451
15.2	When I	Oo We Add the Time Dimension? 452
15.3	Audit T	rails and Snapshots 452
	15.3.1	The Basic Audit Trail Approach 453
	15.3.2	Handling Nonnumeric Data 458
	15.3.3	The Basic Snapshot Approach 458
15.4	Sequen	ces and Versions 462
15.5	Handlir	ng Deletions 463
15.6	Archivi	ng 463

16.5.4

16.5.5

15.7	Modeling Time-Dependent Relationships 464 15.7.1 One-to-Many Relationships 464 15.7.2 Many-to-Many Relationships 466 15.7.3 Self-Referencing Relationships 468			
15.8	Date Tables 469			
15.9	Temporal Business Rules 469			
15.10	Changes to the Data Structure 473			
15.11	Putting It into Practice 473			
15.12	Summary 474			
205	Chapter 16 Modeling for Data Warehouses and Data Marts 475			
16.1	Introduction 475			
16.2	Characteristics of Data Warehouses and Data Marts 16.2.1 Data Integration: Working with Existing Databases 478 16.2.2 Loads Rather Than Updates 478 16.2.3 Less Predictable Database "Hits" 479 16.2.4 Complex Queries—Simple Interface 479 16.2.5 History 480 16.2.6 Summarization 480			
16.3	Quality Criteria for Warehouse and Mart Models 16.3.1 Completeness 480 16.3.2 Nonredundancy 481 16.3.3 Enforcement of Business Rules 482 16.3.4 Data Reusability 482 16.3.5 Stability and Flexibility 482 16.3.6 Simplicity and Elegance 483 16.3.7 Communication Effectiveness 483 16.3.8 Performance 483			
16.4	The Basic Design Principle 483			
16.5	Modeling for the Data Warehouse 484 16.5.1 An Initial Model 484 16.5.2 Understanding Existing Data 485 16.5.3 Determining Requirements 485			

Determining Sources and Dealing with Differences 485

Shaping Data for Data Marts 487

16.6	Modeling for the Data Mart 488 16.6.1 The Basic Challenge 488 16.6.2 Multidimensional Databases, Stars and Snowflakes 488 16.6.3 Modeling Time-Dependent Data 494		
16. <i>7</i>	1/1		
نيو أ	Chapter 17		
	Enterprise Data Models and Data Management 4		
1 <i>7</i> .1	Introduction 499		
17.2	Data Management 500 17.2.1 Problems of Data Mismanagement 500 17.2.2 Managing Data as a Shared Resource 501 17.2.3 The Evolution of Data Management 501		
1 <i>7</i> .3	Classification of Existing Data 503		
17.4	A Target for Planning 504		
17.5	A Context for Specifying New Databases 506 17.5.1 Determining Scope and Interfaces 506 17.5.2 Incorporating the Enterprise Data Model in the Development Life Cycle 506		
17.6	Guidance for Database Design 508		
17.7	Input to Business Planning 508		
1 <i>7</i> .8	Specification of an Enterprise Database 509		
1 <i>7</i> .9	Characteristics of Enterprise Data Models 511		
17.10	Developing an Enterprise Data Model 512 17.10.1 The Development Cycle 512 17.10.2 Partitioning the Task 513 17.10.3 Inputs to the Task 514 17.10.4 Expertise Requirements 515 17.10.5 External Standards 515		
1 <i>7</i> .11	Choice, Creativity, and Enterprise Data Models 516		
17.12	Summary 517 Further Reading 519		