Contents

Chapter 1 Introduction 1

1.1 Need for a 3D Cadastre 3
1.2 Research Scope 6
1.2.1 Topics within the Scope of This Book 7
1.2.2 Topics outside the Scope of This Book 8
1.3 Research Objectives 8
1.4 Previous and Related Research 9
1.4.1 Related Research on 3D Cadastres 9
1.4.2 Related Research on 3D Tools and 3D Modeling 9
1.5 Contribution of the Work 10
1.6 Organization of the Book 11

Part I
Analysis of the Background **13**

Chapter 2 Scope of a 3D Cadastre 15

2.1 Elementary Cadastral Model 15
2.2 Types of Cadastral Registrations 16
2.2.1 Deed vs. Title Registration 17
2.2.2 A Centralized or Decentralized Cadastral Registration 18
2.2.3 Land Registration with Separate or Integrated Cadastre 19
2.2.4 Fiscal or Legal Cadastre 19
2.2.5 General or Fixed Boundaries 20
2.2.6 Financed by Government or Cost Recovery 20
2.3 3D Cadastral Recordings and Private Law 20
2.3.1 Right of Ownership 21
2.3.2 Right of Superficies 23
2.3.3 Right of Long Lease 23
2.3.4 Right of Easement 24
2.3.5 Apartment Right and Strata Title 24
2.3.6 Joint Ownership via Other Real Estate Objects 27
2.4 3D Cadastral Recordings and Public Law 27
2.4.1 Belemmeringenwet Privaatrecht 28
2.4.2 Law on Monuments 28
2.4.3 Law on Soil Protection 29
2.5 Conclusions 30

Chapter 3 3D Recordings in Current Cadastral Registrations 33

3.1 The Netherlands 35
3.1.1 Underground Objects in the Cadastral Registration 35
3.1.2 Telecom Networks in the Cadastral Registration 35
3.1.3 Case Studies in the Netherlands 36
3.1.4 Evaluating 3D Cadastre in the Netherlands 48
3.2 Norway 49
3.2.1 Evaluating 3D Cadastre in Norway 51
3.3 Sweden 51
3.3.1 Evaluating 3D Cadastre in Sweden 53
3.4 Queensland, Australia 54
3.4.1 Restricted, Building, and Volumetric Parcels 54
3.4.2 A Case Study in Queensland 56
3.4.3 Evaluating 3D Cadastre in Queensland 57
3.5 British Columbia, Canada 60
3.5.1 Evaluating 3D Cadastre in British Columbia 63
3.6 The United States 63
3.6.1 Case Studies in the United States 65
3.6.2 Evaluating 3D Cadastre in the United States 75
3.7 Argentina 76
3.7.1 A Case Study in Argentina 77
3.7.2 Evaluating 3D Cadastre in Argentina 80
3.8 Conclusions 81

Chapter 4 Needs and Opportunities for a 3D Cadastre 83

4.1 Current Cadastral Registrations and 3D 83
4.1.1 Surface-Oriented Cadastral Registrations 84
4.1.2 3D Property Units in Cadastral Registrations 87
4.2 Basic Needs for a 3D Cadastre 87
4.3 Opportunities for a 3D Cadastre 88
4.4 3D Applications outside the Cadastral Domain 90
4.5 Conclusions 92

Part II

Framework for Modeling 2D and 3D Situations 95

Chapter 5 Theory of Spatial Data Modeling 97

5.1 Data Models 97
5.1.1 Data Models in GIS 99
5.1.2 Design Phases in Modeling 101
5.2 Conceptual Model 101

5.3 Logical Model 101
5.3.1 Relational Model 102
5.3.2 Object-Oriented Model 103
5.3.3 Object Relational Model 104
5.4 Physical Model 105
5.5 UML 106
5.6 Spatial Data Modeling and DBMS 110
5.7 Standardization Initiatives 111
5.7.1 OpenGeospatial Consortium 111
5.7.2 ISO TC/211 115
5.8 Conclusions 116

Chapter 6 Geo-DBMSs 119

6.1 Geometrical Primitives in DBMSs 120
6.1.1 2D Geometrical Primitives in DBMSs 120
6.1.2 3D Geometrical Primitives in DBMSs 122
6.2 Topological Structure in DBMSs 125
6.2.1 OGC, ISO and Planar Partition Topology 126
6.2.2 User-Defined DBMS Implementation of 2D Topological Structure 127
6.2.3 Commercial DBMS Implementations of 2D Topological Structure 136
6.2.4 User-Defined DBMS Implementation of 3D Topological Structure 138
6.3 Spatial Analyses in DBMSs 140
6.3.1 2D Spatial Analyses Using Geometrical Primitives 141
6.3.2 3D Spatial Analyses Using Geometrical Primitives 143
6.3.3 Spatial Analyses Using the Topological Structure 145
6.3.4 Case Study: Topological Structure or Geometrical Primitives? 146
6.4 Implementation of a 3D Geometrical Primitive in a DBMS 148
6.4.1 Definition of 3D Primitive 149
6.4.2 Validation 152
6.4.3 Spatial Indexing in 3D 156
6.4.4 3D Functions 158
6.5 Conclusions 159

Chapter 7 3D GIS and Accessing a 3D Geo-DBMS with Front Ends 163

7.1 3D GIS 163
7.1.1 Organization of 3D Data 164
7.1.2 3D Data Collection and Object Reconstruction 165
7.1.3 Visualization and Navigation in 3D Environments 166
7.1.4 3D Analyses and 3D Editing 168

7.2 Accessing a Geo-DBMS with a CAD Front End ... 168
7.2.1 Geometrical Data Initially Organized in Oracle Spatial 9i ... 169
7.2.2 Geometrical Data Initially Organized in MicroStation Design Files ... 171
7.2.3 Spatial Viewer ... 172
7.3 Accessing a Geo-DBMS with a GIS Front End ... 173
7.4 Accessing a Geo-DBMS Using Web Technology ... 177
7.4.1 VRML and X3D ... 177
7.4.2 Prototypes ... 178
7.5 Conclusions ... 187

Chapter 8 Integrating 2D Parcels and 3D Objects in One Environment ... 189

8.1 Absolute or Relative Coordinates ... 189
8.2 Introduction of a Case Study ... 190
8.2.1 Description of Data Sets ... 192
8.2.2 Combining Point Heights and 3D Objects ... 192
8.2.3 Assigning Height to Parcels ... 193
8.3 Integrated TINs of Point Heights and Parcels ... 195
8.3.1 Unconstrained TIN ... 195
8.3.2 Constrained TIN ... 198
8.3.3 Conforming TIN ... 199
8.3.4 Refined Constrained TIN ... 200
8.4 Analyzing and Querying Parcel Surfaces ... 202
8.5 Generalization of the Integrated TIN ... 204
8.5.1 Detailed-to-Coarse Approach ... 204
8.5.2 Coarse-to-Detailed Approach ... 204
8.5.3 Integrated Height and Object Generalization ... 206
8.6 Generalization Prototype ... 206
8.7 Conclusions ... 210

Part III
Models for a 3D Cadastre ... **213**

Chapter 9 Conceptual Model for a 3D Cadastre ... 215

9.1 Introduction of Possible Solutions ... 215
9.1.1 A Full 3D Cadastre ... 216
9.1.2 A Hybrid Solution ... 216
9.1.3 3D Tags in Current 2D Cadastral Registrations ... 217
9.2 A 2D Cadastre with 3D Tags ... 218
9.3 Hybrid Approach ... 218
9.3.1 Registration of Right-Volumes ... 219
9.3.2 Registration of 3D Physical Objects ... 221

9.4 Full 3D Cadastre 223
9.4.1 Combined 2D/3D Alternative 224
9.4.2 Pure 3D Cadastre 226
9.5 Evaluating the Conceptual Models 227
9.5.1 Solutions Seen from a Cadastral Point of View 227
9.5.2 Solutions Seen from a Technical Point of View 228
9.5.3 The Optimal Solution for a 3D Cadastre 230
9.6 Conclusions 231

Chapter 10 Logical Model for a 3D Cadastre 233

10.1 Right-Volumes in the DBMS 233
10.1.1 Spatial Data Model 233
10.1.2 Administrative Data Model 236
10.1.3 Data Collection 238
10.1.4 Querying 238
10.2 3D Physical Objects in the DBMS 238
10.2.1 Spatial Data Model 239
10.2.2 Administrative Data Model 240
10.2.3 Data Collection 241
10.2.4 Fundamental Issues When Linking GIS and CAD 243
10.2.5 Querying 244
10.3 Volume Parcels in the DBMS 244
10.3.1 Spatial Data Model 244
10.3.2 Administrative Data Model 245
10.3.3 Data Collection 246
10.3.4 Querying 247
10.4 Maintaining History in the 3D Cadastre 247
10.4.1 History for Right-Volumes 248
10.4.2 History for 3D Physical Objects 248
10.4.3 History in a Full 3D Cadastre 248
10.5 Conclusions 249

Part IV
Realization of a 3D Cadastre 251

Chapter 11 Prototypes Applied to Case Studies 253

11.1 Prototypes of the Hybrid Cadastre 253
11.1.1 Case Study 1: Building Complex in The Hague 254
11.1.2 Case Study 2: The Hague Central Station 256
11.1.3 Case Study 3: Apartment Complex 261
11.1.4 Case Study 4: Railway Tunnel in Urban Area 262
11.1.5 Case Study 5: Railway Tunnel in Rural Area 264
11.1.6 Evaluation of Hybrid Cadastre 267

11.2 Prototype of the Full 3D Cadastre 269
11.2.1 The Gabba Stadium in Queensland 269
11.2.2 Evaluation of Full 3D Cadastre 274
11.3 Conclusions 275
11.3.1 Hybrid Cadastre 277
11.3.2 Full 3D Cadastre 277

Chapter 12 Summary, Conclusions, and Further Research 279

12.1 Analysis of the Background 279
12.1.1 Surface-Oriented Cadastral Registrations 279
12.1.2 3D Property Units in Cadastral Registrations 280
12.1.3 Needs and Requirements for a 3D Cadastre 281
12.2 Framework for Modeling 2D and 3D Situations 282
12.2.1 2D and 3D Geo-Objects in Geo-DBMS 282
12.2.2 3D GIS 284
12.2.3 Accessing Spatial Information Organized in a DBMS 284
12.2.4 2D Parcels and 3D Geo-Objects in One 3D Environment 285
12.3 Models for a 3D Cadastre 286
12.3.1 Conceptual Solutions for a 3D Cadastre 286
12.3.2 The Optimal Solution for a 3D Cadastre 287
12.4 Realization of a 3D Cadastre 288
12.4.1 Full 3D Cadastre 288
12.4.2 Hybrid Cadastre 289
12.5 Future Directions for a 3D Cadastre 291
12.6 Further Research 292
12.6.1 Institutional Aspects of 3D Cadastral Registration 293
12.6.2 Geo-Information Infrastructure 293
12.6.3 3D in the New-Generation GIS Architecture 293
12.7 Main Results of the Research Presented in This Book 296

References 297

Appendix A Visualizing Attributes in VRML 309

Appendix B XSLT Stylesheet to Transform XML to X3D 311

Index 315