COMPARISON AND MAPPING OF THE RELATIONAL AND CODASYL DATA MODELS -- AN ANNOTATED BIBLIOGRAPHY

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Two of the best-known data models are the relational model and the CODASYL model (sometimes called the DBTG, network, or data structure set model). There have been many efforts at comparing the two models and at defining mappings between them. The publications listed in this bibliography describe some of these efforts and some related topics. I invite readers' suggestions for additional entries for possible inclusion in a future bibliography. I omit publications on the more general topic of data base conversion.

Following each reference, I describe the publication briefly, usually by quoting parts of the author's abstract and/or main text. Often I supplement or replace the author's text with my own words, enclosed in brackets ([]). I do not guarantee that an author's abstract accurately reflects the content of the publication.

I do not evaluate the publications, nor do I guarantee the truth of their statements. Each publication may reflect its author's opinions. Also, because specifications have evolved over the last ten years, some statements may be out of date. The bibliography reveals that the authors have not reached consensus on equivalence of the models, nor on the models' relative merits, nor on the spelling of "data base".

The mention or lack of mention of specific commercial products does not imply endorsement or disapproval by the National Bureau of Standards.

The reader should have some familiarity with data base management and with the two models. For background on the relational model, see sources such as:

> D. D. Chamberlin, "Relational Data-Base Management Systems", Computing Surveys, ACM, vol. 8, no. 1, Mar. 1976, pp. 43-66.
>
> E. F. Codd, "A Relational Model of Data For Large Shared Data Banks", Commun. ACM, vol. 13, no. 6, June 1970, pp. 377-387.

For background on the CODASYL model, see sources such as:

> CODASYL Data Description Language Committee, "Journal of Development", Materiel Data Management Branch, Dept. of Supply and Services, Canadian Govt., Hull, Que., Canada, Jan. 1978.
>
> CODASYL Programming Language Committee, "Data Base Task Group Report", ACM, Apr. 1971.
>
> R. W. Taylor and R. L. Frank, "CODASYL Data-Base Management Systems", Computing Surveys, ACM, vol. 8, no. 1, Mar. 1976, pp. 67-103.

For background on both models, see sources such as:

> C. J. Date, An Introduction to Database Systems, 2nd ed., Addison-Wesley, Reading, MA, 1977.
>
> J. Martin, Computer Data-Base Organization, 2nd ed., Prentice-Hall, Englewood Cliffs, NJ, 1977.

I thank John Berg, Joe Collica, Don Deutsch, Dennis Fife, Liz Fong, Len Gallagher, Alan Goldfine, Terry Hardgrave, Bel Leong-Hong, Chuck Sheppard, and Ben Shneiderman, whose libraries I raided innumerable times while amassing this bibliography. Terry Hardgrave and Matt Koll reviewed a draft of this paper. Several authors helped me obtain publications.

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The annotated bibliography follows:

M. Adiba and C. Delobel, "The Problem of the Cooperation Between Different D.B.M.S.", G. M. Nijssen (Ed.), Architecture and Models in Data Base Management Systems (Proc. IFIP TC-2 Working Conf. on Modelling in Data Base Management Syst., Jan. 1977), North-Holland, Amsterdam, Neth., 1977, pp. 165-186.

"We are investigating here the problem of the cooperation between several DBMS. This cooperation can take place, for example, via a computer network. We address ourselves especially to the description of a global view of several data bases". "We have proposed some mechanisms to transform any program written in terms of the global view in programs which can be executed at the local data base level". [See also (Adiba, Delobel, and Léonard, 1976) and (Adiba and Portal, 1978)].

M. Adiba, C. Delobel, and M. Léonard, "A Unified Approach for Modelling Data in Logical Data Base Design", G. M. Nijssen (Ed.), Modelling in Data Base Management Systems (Proc. IFIP TC-2 Working Conf. on Modelling in Data Base Management Syst., Jan. 1976), North-Holland, Amsterdam, Neth., 1976, pp. 311-338.

"Here we examine how ... conversion can be made (in both ways) between network and relational concepts, using the DBTG-CODASYL and SOCRATE systems as examples". [See also (Adiba and Delobel, 1977) and (Adiba and Portal, 1978)].

M. Adiba and D. Portal, "A Cooperation System for Heterogeneous Data Base Management Systems", Information Syst., Pergamon Press, Oxford, UK, vol. 3, no. 3, 1978, pp. 209-215.

"We propose here a functional architecture of a cooperation system for heterogeneous DBMS in a network environment". [The paper assumes] "the existence of different local data bases already in use under DBMSs like IMS, Codasyl-like systems, SOCRATE, relational systems, etc.". "The cooperation system should be able ... to provide facilities for creating and modifying a global view of these local data bases". [See also (Adiba and Delobel, 1977) and (Adiba, Delobel, and Léonard, 1976)].

M. M. Astrahan et al., "System R: Relational Approach to Database Management", ACM Trans. on Database Syst., vol. 1, no. 2, June 1976, pp. 97-137.

"System R is a database management system which provides a high level relational data interface". [One section of the paper explains that the interface] "is designed in such a way that programs can be written on top of it to simulate 'navigation oriented' database interfaces". "In general our strategy will be to represent each record type as a relation and to represent information about ordering and connections between records in the form of explicit fields in the corresponding relations". [Another section states that an] "important access path is a binary link". "Binary links are similar to the notion of an owner coupled set with manual membership found in the DBTG specifications". "The main use of binary links in System R is to connect child tuples to a parent based on value matches in one or more fields". [See also (Lorie and Nilsson, 1979)].

Auerbach Information Management Series on Data Base Management, "A Taxonomy of Data Structure Models", written by G. C. Everest, Portfolio 21-03-01, Auerbach Publishers, Pennsauken, NJ, 1979.

"This Portfolio presents a more comprehensive taxonomy of data structures; it describes the basic types of structures, highlighting their major characteristics and contrasting them through the use of a common example". [See also (Everest, 1976)].

C. W. Bachman, "The Data Structure Set Model", in (Rustin, 1974), pp. 1-10.

"The relational debate, as I see it, is over style in retrieval languages, and style, really, is only one aspect of a data base system". "I accept the relational view and the data-structure-set view as being fundamentally compatible as they are applied in practice, and I'd like to demonstrate the equivalence between the two views".

C. W. Bachman, "The Role Data Model Approach to Data Structures", Proc. Intl. Conf. on Data Bases, Heyden, London, UK, July 1980, pp. 1-18.

"This paper examines the Role data model as an evolutionary step forward in the sequence of data models" [and compares it with other data models].

C. W. Bachman, "Trends in Database Management -- 1975", Proc. Natl. Computer Conf., AFIPS, vol. 44, May 1975, pp. 569-576.

[One section says] "I consider the relational model and the data-structure-set model essentially compatible and subject to transformation from one form to the other". "The relational model and the" [data independent accessing model] "appear to be completely at odds with each other". "By comparison, the data-structure-set model seems to be an effective hybrid between these two extremes".

R. Bell and P. M. D. Gray, "Description of Access Paths for Realising Relations from a CODASYL Database", Research Rep. AUCS/TR-8001, Dept. of Computing Sci., U. of Aberdeen, Aberdeen, UK, Jan. 1980.

"The ... system generates Fortran programs to retrieve data from a CODASYL database in the form of relations". "The system generates an internal description of a relation called a 'traversal', which includes elements representing both algebraic operators and CODASYL DML commands".

H. Biller, "On the Equivalence of Data Base Schemas -- A Semantic Approach to Data Translation", Information Syst., Pergamon Press, Oxford, UK, vol. 4, no. 1, 1979, pp. 35-47.

"The equivalence of data base states and data base schemas is defined". "It is shown, how a semantic data model and data definition language (LDDL) can be used to construct a correct specification of a translation function. Finally, an example of the translation of a CODASYL data base schema to a relational data base schema is given".

S. A. Borkin, "Data Model Equivalence", Proc. 4th Intl. Conf. on Very Large Data Bases, ACM, Sept. 1978, pp. 526-534.

[This paper defines 'data model' and 'data model equivalence'. See also (Borkin, 1979)].

S. A. Borkin, "Equivalence properties of Semantic Data Models for Database Systems", Ph.D. thesis, Dept. of Elect. Engin. and Computer Sci., M.I.T., Cambridge, MA, Jan. 1979; Lab. for Computer Sci. Tech. Rep. 206; NTIS ADA056386; slightly revised as Data Models: A Semantic Approach for Database Systems, M.I.T. Press, Cambridge, MA, 1980.

[This thesis defines equivalence of data models. Motivations include multiple data models for one data base, data transfer, and a global view of different data bases in a distributed system. The author states that with some restrictions upon the relational and CODASYL models], "the 'expressive powers' of the models are equivalent". [See also (Borkin, 1978)].

J. Bradley, "An Extended Owner-Coupled Set Data Model and Predicate Calculus for Database Management", ACM Trans. on Database Syst., vol. 3, no. 4, Dec. 1978, pp. 385-416.

[In this data model,] "the logical view of the data in the database is essentially relational but with the superimposition of the owner-coupled set concept". "Extended Bachman diagrams in modified form can easily be used in the design of relational databases".

A. F. Cardenas and M. H. Pirahesh, "Data Base Communication in a Heterogeneous Data Base Management System Network", Information Syst., Pergamon Press, Oxford, UK, vol. 5, no. 1, 1980, pp. 55-79.

"An architectural approach is outlined ... in which any user in any network node can be given an integrated and tailored view or schema (e.g. hierarchical, relational), while in reality the data may reside in one single data base or in physically separated data bases, managed individually by the same type of GDBMS (e.g. CODASYL, IMS, relational) or by different GDBMS". "The entity-relationship model is fundamentally used for the highly logical model layers of the integrated system". [See also (Nahouraii, Brooks, and Cardenas, 1976)].

G. A. Champine, "Current Trends in Data Base Systems", Computer, IEEE-CS, vol. 12, no. 5, May 1979, pp. 27-41.

[In part of this paper, the author reviews different data models and describes support of multiple models on one architecture].

P. P.-S. Chen, "The Entity-Relationship Model -- Toward a Unified View of Data", Proc. [1st] Intl. Conf. on Very Large Data Bases, ACM, Sept. 1975, p. 173 (abstract); ACM Trans. on Database Syst., vol. 1, no. 1, Mar. 1976, pp. 9-36.

"A data model, called the entity-relationship model, is proposed". [One section of the paper describes how] "the entity-relationship model can be used as a basis for

unification of different views of data: the network model, the relational model, and the entity set model". "Possible ways to derive their views of data from the entity-relationship model are presented".

E. K. Clemons, "Design of a Prototype ANSI/SPARC Three-Schema Data Base System", Proc. Natl. Computer Conf., AFIPS, vol. 48, June 1979, pp. 689-696.

"This paper ... describes briefly how an ANSI/SPARC three-schema data base system prototype could be constructed". "For the internal level we propose that a CODASYL data base management system be employed. The conceptual level will be a relational system".

L. Clough, W. D. Haseman, and Y. H. So, "Designing Optimal Data Structures", Proc. Natl. Computer Conf., AFIPS, vol. 45, June 1976, pp. 829-837.

"This paper is concerned with developing a methodology for designing optimal network data base structures". [Data description begins in the form of networks, which are converted into hierarchies, then into relations, then into canonical networks, and finally into optimal networks, based upon] "the set of queries," [using] "an operations research model". [See also (De, Haseman, and Kriebel, 1978) and (Haseman and Whinston, 1977)].

E. F. Codd, "A Data Base Sublanguage Founded on the Relational Calculus", Proc. 1971 ACM-SIGFIDET [SIGMOD] Workshop on Data Description, Access, and Control, Nov. 1971, pp. 35-68; IBM Research Rep. RJ 893 (#15716), July 1971.

"Three principal types of language for data base manipulation are identified: the low-level, procedure-oriented (typified by the CODASYL-proposed DML), the intermediate level, algebraic (typified by Project MAC MacAIMS language), and the high level, relational calculus-based data sublanguage, an example of which is described". "Arguments are presented for the superiority of the calculus-based type of data base sublanguage over the algebraic, and for the algebraic over the low-level procedural".

E. F. Codd and C. J. Date, "Interactive Support for Non-Programmers: The Relational and Network Approaches", in (Rustin, 1974), pp. 11-41; IBM Research Rep. RJ 1400 (#21638), June 1974.

"General purpose support for" [non-programming] "users entails provision of an augmented relationally complete retrieval capability without branching, explicit iteration, or cursors. It is clear how this capability can be realized with the relational approach". "It is not at all clear how the network approach can reach this goal, so long as the principal schema includes owner-coupled sets 'bearing information essentially'. A relational discipline is suggested as a way out for DBTG users".

E. K. Conoley, "Use of a Hierarchical Data Model to Support a Relational Data Management System", M.A. thesis, U. of Texas, Austin, TX, Aug. 1977; NTIS ADA047602.

[This describes] "a relational interface for implementation as a front end to a hierarchical data base". "Relational operations were implemented in terms of the available hierarchical DBMS functions".

C. J. Date, "An Architecture for High-Level Language Database Extensions", Proc. ACM-SIGMOD Intl. Conf. on Management of Data, June 1976, pp. 101-122.

"The programmer is provided with the ability to handle all three of the well-known database structures (relational, hierarchical, network), in a single integrated set of language extensions". "A database is represented, not as some new kind of input/output file, but instead simply as part of the program's directly addressable storage area". [See also (Date, 1977) and (Date, 1980)].

C. J. Date, An Introduction to Database Systems, 2nd ed., Addison-Wesley, Reading, MA, 1977, Chap. 25 ("The Three Approaches Revisited"), pp. 425-461.

[One section of this chapter defines a language based upon (Date, 1976). In another section, the author argues that the relational model is simpler, and has a firmer theoretical base, than the CODASYL model. See also (Date, 1980)].

C. J. Date, "An Introduction to the Unified Database Language (UDL)", Proc. 6th Intl. Conf. on Very Large Data Bases, ACM, Oct. 1980, pp. 15-32.

"The first description of UDL was given in" [(Date, 1976)]. "The present paper provides an informal introduction to the concepts and facilities of UDL as currently defined ..., and thus forms a

replacement for the original paper". [See also (Date, 1977)].

C. J. Date and E. F. Codd, "The Relational and Network Approaches: Comparison of the Application Programming Interfaces", in (Rustin, 1974), pp. 83-113; IBM Research Rep. RJ 1401 (#21706), June 1974.

"The purpose of this paper is to give some comparisons between these two approaches (primarily from the application programming viewpoint)". "We now present a discussion of what we consider to be the relative advantages of the relational approach, under the following headings: simplicity, uniformity, completeness, data independence, integrity and security".

P. De, W. D. Haseman, and C. H. Kriebel, "Toward an Optimal Design of a Network Database From Relational Descriptions", Operations Research, Operations Research Soc. of America, Baltimore, MD, vol. 26, no. 5, Sept.-Oct. 1978, pp. 805-823.

"This paper suggests a method for building up a network database starting from relational descriptions. The network generated is optimal in terms of data item appearances and, given that, it is also optimal in terms of the number of records". "Some of the concepts ... are extensions of the ideas" [in (Clough, Haseman, and So, 1976) and (Haseman and Whinston, 1977)].

S. M. Deen, "A Canonical Schema for a Generalised Data Model With Local Interfaces", Computer J., British Computer Soc., vol. 23, no. 3, Aug. 1980, pp. 201-206.

"A global schema is proposed for a generalised data base system capable of supporting interfaces to other systems -- notably Relational, Codasyl and Adabas -- through appropriate local schemas and data manipulation languages. The proposed global schema consists of entries in the form of normalised relations".

A. Dogac and E. A. Ozkarahan, "A Generalized DBMS Implementation on a Database Machine", Proc. ACM-SIGMOD 1980 Intl. Conf. on Management of Data, May 1980, pp. 133-143.

"The design and implementation of a generalized database management system based on the RAP database machine is described". "The E/R model is chosen as the Meta Data Model (Conceptual Schema) which generates external model interfaces consisting of the relational, network, and hierarchical models".

J. Earley, "On the Semantics of Data Structures", R. Rustin (Ed.), Data Base Systems (Courant Computer Sci. Symp. 6, May 1971), Prentice-Hall, Englewood Cliffs, NJ, 1972, pp. 23-32.

[This paper compares data base usage at] "three levels of description of data structures": "(1) The implementation level or machine level, (2) A logical (semantic) level in which access paths are specified explicitly, and (3) A logical level in which only the relationships between data items are specified". [The second level is not specifically CODASYL].

C. P. Earnest, "A Comparison of the Network and Relational Data Structure Models", Computer Sciences Corp., El Segundo, CA, Apr. 1974.

"This paper attempts to bring out the similarities and differences clearly, by defining and discussing both models on a common basis of terminology". "Major conclusions are that (1) the two models are in practice not very different, (2) the relational structures are somewhat simpler than networks, but (3) the price for this is that the network model has more structural power, and more, not less, data independence than the relational".

C. P. Earnest, "Selection and Higher Level Structures in Networks", B. C. M. Douqué and G. M. Nijssen (Eds.), Data Base Description (Proc. IFIP TC-2 Special Working Conf. on Data Base Description, Jan. 1975), North-Holland, Amsterdam, Neth., 1975, pp. 215-237.

"We have shown how to superimpose higher level structures on the records and record interconnections of a database, and how to use these structures for data selection and manipulation".

R. El-Masri and G. Wiederhold, "Properties of Relationships and their Representation", Proc. Natl. Computer Conf., AFIPS, vol. 49, May 1980, pp. 319-326.

"We examined the semantic properties of a relationship between two entity classes". "We compared six data models with respect to the choices they offer for the representation of relationships".

G. C. Everest, "Basic Data Structure Models Explained With a Common Example", Proc. Fifth Texas Conf. on Computing Syst., IEEE-CS, Oct. 1976, pp. 39-46.

"This paper presents a taxonomy of basic data structures which cuts through and omits the secondary differences to highlight the most important logical differences". "The essential characteristics of each of ... six basic data structure models are described and each is exemplified using a common example". [See also (Auerbach, 1979)].

E. Falkenberg, "Concepts for the Coexistence Approach to Data Base Management", E. Morlet and D. Ribbens (Eds.), Intl. Computing Symp. 1977, North-Holland, Amsterdam, Neth., April 1977, pp. 39-50.

"The idea providing coexistence of various data models and data manipulation methods within one data base management system imposes new requirements on the design of such systems". "As a common basis for any external or internal interface, the use of a semantically complete and unique form of data -- the deep structure of data -- at the central interface is suggested". "Transformations from a deep structure into various semantically equivalent surface structures of data" [(CODASYL and relational)] "are shown".

M. Fleck, "On the Equivalence of Data Base Models", Tech. Rep. TR 25.144, IBM Laboratory, Vienna, Austria, July 1975.

"The equivalence problem between different data models of a data base system is investigated. The notions of data-equivalence and consistency-equivalence are introduced. A specific solution to gain consistency-equivalence is proposed where the necessary changes of the data models are minimal". "This report" [uses] "the relational model ... and the Codasyl DBTG model".

J. P. Fry and E. H. Sibley, "Evolution of Data-Base Management Systems", Computing Surveys, ACM, vol. 8, no. 1, Mar. 1976, pp. 7-42.

[One section briefly describes several data models and compares their terminology].

R. Gerritsen, "A Preliminary System for the Design of DBTG Data Structures", Proc. ACM-SIGMOD Intl. Conf. on Management of Data, May 1975, p. 166 (abstract); Commun. ACM, vol. 18, no. 10, Oct. 1975, pp. 551-557.

[This is based upon (Gerritsen, 1975c). See also (Gerritsen, 1975b)].

R. Gerritsen, "The Relational and Network Models of Data Bases: Bridging the Gap", Proc. 2nd USA - Japan Computer Conf., AFIPS, Aug. 1975, pp. 347-351.

"An attempt is made to lay to rest the question of supremacy of either the network or the relational model of data bases. It is argued that these two models correspond to two distinct levels of description; a relational or non-procedural level and an access path level. Hence, a translation approach is suggested whereby relational descriptions can be translated to network descriptions". [See also (Gerritsen, 1975a) and (Gerritsen, 1975c)].

R. Gerritsen, "Understanding Data Structures", Ph.D. diss., Grad. School of Industrial Admin., Carnegie-Mellon U., Pittsburgh, PA, Feb. 1975; NTIS ADA008937.

[The system described herein] "generates a DDL description from a set of queries" [expressed in HI-IQ (a not-exactly-relational language), based upon] "data relationships implied by the queries". [The system also] "translates a query to COBOL procedure augmented by Data Manipulation Language". [See also (Gerritsen, 1975a) and (Gerritsen, 1975b)].

J. Goldman, "Automated Generation of Relational Schemas for CODASYL Databases", Sperry Research Center Rep. SRC-RP-79-13, Sudbury, MA, Mar. 1979.

"A facility which translates CODASYL database schemas into relational database schemas is described". "The derived relational schema preserves the information content of the database and would support high level data sublanguage access to the database, both retrieval and update". [See also (Zaniolo, 1979a), (Zaniolo, 1979b), and (Zaniolo, 1977)].

D. Goldschmidt and A. Reiter, "An Implementation of FORAL Using IDMS", B. Shneiderman (Ed.), Databases: Improving Usability and Responsiveness (Proc. Intl. Conf. on Databases: Improving Usability

and Responsiveness, Aug. 1978), Academic Press, New York, NY, 1978, pp. 131-150.

"FORAL is a non-procedural data specification and manipulation language based on binary associations. IDMS is a commercial database management system based on a 'network' model and belonging to the CODASYL DBTG group of languages. We describe an implementation of a subset of the FORAL query language over existing IDMS databases".

W. T. Hardgrave and E. H. Sibley, "Data Model Processing: An Approach to Standardization of Database Management Systems", Tech. Rep. 45, Dept. of Info. Syst. Management, U. of Maryland, College Park, MD, July 1979.

"This paper outlines a general philosophy and framework for the specification of a data model. Extracts from scenarios that have been developed for specification of several well-known data models (e.g., DBTG, relational, TDMS) are given and discussed". "The scenarios are intended for implementation of an augmented positional processor that will be able to support different data models". [See also (Rothnie and Hardgrave, 1976)].

W. D. Haseman and A. B. Whinston, Introduction to Data Management, Richard D. Irwin, Homewood, IL, 1977, Chap. 15 ("Designing Optimal Data Structures"), pp. 333-351.

[This is similar to (Clough, Haseman, and So, 1976). See also (De, Haseman, and Kriebel, 1978)].

B. C. Housel, "QUEST: A High-Level Data Manipulation Language for Network, Hierarchical, and Relational Databases", IBM Research Rep. RJ 2588 (33488), July 1979.

"This paper describes a query language, QUEST, which provides a single interface to the three major data models. The initial development was aimed at providing a simple but powerful high-level interface for network databases. Subsequently, however, it proved straightforward to extend the semantics in a consistent way to include the hierarchical and relational models".

J. Iossiphidis, "A Translator to Convert the DDL of ERM to the DDL of System 2000", P. P.-S. Chen (Ed.), Proc. Intl. Conf. on Entity-Relationship Approach to Systems Analysis and Design, Dec. 1979, pp. 550-578; later published as Entity-Relationship Approach to Systems Analysis and Design, North-Holland, Amsterdam, Neth., 1980.

"This paper describes ERL a nonprocedural data definition language (DDL) for the entity relationship model (ERM) of a data base management system. Also described is the translator built to convert ERL programs into the DDL of SYSTEM 2000".

H. R. Johnson and J. A. Larson, "Data Management for Microcomputers", Proc. COMPCON Fall 79, IEEE-CS, Sept. 1979, pp. 191-194.

[This is similar to (Johnson, Larson, and Lawrence, 1979). See also (Johnson, Larson, and Lawrence, 1978) and (Larson, Johnson, and Lawrence, 1978)].

H. R. Johnson, J. A. Larson, and J. D. Lawrence, "Network and Relational Modelling in a Common Data Base Architecture Environment", Sperry Univac Research Rep. TMA00720, Roseville, MN, Mar. 1979.

"A common data base architecture and its applications in supporting various language file systems and data base management systems are described". "Data base management specifications of 1978 CODASYL Journals of Development and of SEQUEL 2 are extended". "Information preserving transformations between submodels within and across the models are specified". [See also (Johnson and Larson, 1979), (Johnson, Larson, and Lawrence, 1978), and (Larson, Johnson, and Lawrence, 1978)].

H. R. Johnson, J. A. Larson, and J. D. Lawrence, "Transformations Between Network and Relational Data Models", Sperry Univac Research Rep. TMA00729, Roseville, MN, Mar. 1978.

[This paper describes algorithms for translation (in both directions) between "minimally keyed" network schemas and "fully keyed" network schemas, and between fully keyed network schemas and relational schemas. See also (Johnson and Larson, 1979), (Johnson, Larson, and Lawrence, 1979), and (Larson, Johnson, and Lawrence, 1978)].

L. A. Kalinichenko, "Data Models Transformation Method Based on Axiomatic Data Model Extension", Proc. 4th Intl. Conf. on Very Large Data Bases, ACM, Sept. 1978, pp. 549-555.

"This work concentrates on the problem of incompatible data models transformation, the criteria of correctness of such transformations, and methods of construction of correct transformations being defined". [See also (Kalinichenko, 1976)].

L. A. Kalinichenko, "Relational-Network Data Structure Mapping", G. M. Nijssen (Ed.), Modelling in Data Base Management Systems (Proc. IFIP TC-2 Working Conf. on Modelling in Data Base Management Syst., Jan. 1976), North-Holland, Amsterdam, Neth., 1976, pp. 303-309.

"Mapping is considered" [between] "n-ary relations" [and] "network data". [See also (Kalinichenko, 1978)].

M. H. Kay, "An Assessment of the CODASYL DDL for Use With a Relational Subschema", B. C. M. Douqué and G. M. Nijssen (Eds.), Data Base Description (Proc. IFIP TC-2 Special Working Conf. on Data Base Description, Jan. 1975), North-Holland, Amsterdam, Neth., 1975, pp. 199-214.

"This paper investigates the possibility of accessing a DDLC database described by a DDLC schema through a subschema presenting the user with a relational view of the database". "The argument will proceed by first describing some of the ways relations might be based on network structures yielding consistent effects on retrieval, and by then considering for each of these 'derivation rules' the effect of updating a relation".

L. Kerschberg, A. C. Klug, and D. C. Tsichritzis, "A Taxonomy of Data Models", P. C. Lockemann and E. J. Neuhold (Eds.), Systems for Large Data Bases (Proc. 2nd Intl. Conf. on Very Large Data Bases, Sept. 1976), North-Holland, Amsterdam, Neth., 1977, pp. 43-64.

"This paper classifies a collection of conceptual data models within a taxonomy framework consisting of the following parameters: graph theoretic versus set theoretic models, mathematical foundations, terminology, and semantic levels of abstraction".

S. R. Kimbleton and P. S.-C. Wang, "Applications and Protocols", to appear in M. Paul and H. J. Siegert (Eds.), An Advanced Course on Distributed Systems -- Architecture and Implementation, Springer-Verlag, New York, NY, 1980.

"Accessing multiple, heterogeneous, remote Database Management Systems promises to be difficult because of differences in: i) the data model employed, ii) data structures constructed using this data model, iii) Database Management System functionality differences, iv) differences in Data Manipulation Languages used in interacting with the data structures, and v) computer system differences. Imposing a uniform user viewpoint across this collection of differences is an alternative to requiring detailed user knowledge of the characteristics of each of the accessed systems". [See also (Kimbleton, Wang, and Fong, 1979)].

S. R. Kimbleton, P. S.-C. Wang, and E. N. Fong, "XNDM: An Experimental Network Data Manager", Proc. 4th Berkeley Conf. on Distributed Data Management and Computer Networks, NTIS, Aug. 1979, pp. 3-17.

"This paper describes" [a] "research project concerned with establishing the feasibility, issues, alternatives, and a technical approach for supporting a network data manager". "The basic assumption underlying the design ... is heterogeneity of data models, data structures, DBMSs, DMLs and computer systems on which these DBMSs reside". [The paper describes] "superimposing a uniform user viewpoint". [See also (Kimbleton and Wang, 1980)].

A. C. Klug, "Theory of Database Mappings", Ph.D. thesis, Dept. of Computer Sci., U. of Toronto, Toronto, Ont., Canada, Dec. 1978; Computer Syst. Research Group Tech. Rep. 98.

"Definitions of structure and operation mappings are given". [Mappings can be between schemas, between schema and subschema, between data models, between levels (e.g., logical and physical), or between multiple-node and single-node queries in a distributed data base].

A. C. Klug and D. C. Tsichritzis, "Multiple View Support Within the ANSI/SPARC Framework", Proc. 3rd Intl. Conf. on Very Large Data Bases, ACM, Oct. 1977, pp. 477-488.

"Features for the conceptual model are discussed". [This is based upon the language described in (Tsichritzis,

1975)]. "Three external models corresponding to the hierarchical, network and relational approach are mapped onto the conceptual model". [See also (Schmid and Bernstein, 1975) and (Tsichritzis, 1975)].

J. A. Larson, H. R. Johnson, and J. D. Lawrence, "Multimodel Data Base Management", Sperry Univac Research Rep. TMA00731, Roseville, MN, Oct. 1978.

"An intermediate data model is described which acts as a stepping stone to bridge the differences between CODASYL and relational data models. Information preserving transformations are described which may be mechanically applied to data definition or data manipulation statements of one data model to obtain equivalent statements in the other data model. Using these transformations it is possible to design a multimodel DBMS which supports both network and relational data models". [See also (Johnson and Larson, 1979), (Johnson, Larson, and Lawrence, 1979), and (Johnson, Larson, and Lawrence, 1978)].

R. M. Lee, "Comparison of HI-IQ and the Relational Calculus", Dept. of Decision Sciences working paper 78-07-05, the Wharton School, U. of Pennsylvania, Philadelphia, PA, July 1978.

"Paper compares the retrieval capabilities of HI-IQ, a non-procedural query language for Network type databases, to the Relational Calculus".

R. M. Lee, "A Short Survey of Current Data Models", Dept. of Decision Sciences working paper 78-02-07, the Wharton School, U. of Pennsylvania, Philadelphia, PA, Feb. 1978.

"This paper presents a brief tutorial on several of the more popular 'data models' or logical representations used in database systems to characterize the structural aspects of the database".

R. A. Lorie and J. F. Nilsson, "An Access Specification Language for a Relational Data Base System", IBM J. Research and Development, vol. 23, no. 3, May 1979, pp. 286-298.

"We address the problem of executing high level language queries submitted to a relational data base system. As a step in the process of constructing an 'efficient' compiler for a high level language we suggest the elaboration of an intermediate level language acting as a target language for the optimizer part of the compiler". [The latter language can use tuple-at-a-time access, as does the CODASYL DML. See also (Astrahan et al., 1976)].

J. R. Lucking, "Comments on Advantages of the Data Structure Set Model", in (Rustin, 1974), pp. 115-119.

"At the declarative level of describing data, there is virtually no difference between networks and relations. At the manipulative level, the comparisons that we have seen today have been slightly unfair, in that one is comparing systems of a slightly different level of procedurality. The constraints imposed upon DBTG in defining language are the constraints imposed by COBOL".

W. C. McGee, "A Contribution to the Study of Data Equivalence", J. W. Klimbie and K. L. Koffeman (Eds.), Data Base Management (Proc. IFIP TC-2 Working Conf. on Data Base Management, Apr. 1974), North-Holland, Amsterdam, Neth., 1974, pp. 123-148.

"The paper presents a set of techniques for transforming structures of one particular" "data structure class (or DSC)" "into equivalent structures of a second DSC. As the first DSC, we will take the Flat Data Structure Class". "As the second DSC, we will take the class implicit in the data description language of the CODASYL Data Description Language Committee".

W. C. McGee, "On User Criteria for Data Model Evaluation", ACM Trans. on Database Syst., vol. 1, no. 4, Dec. 1976, pp. 370-387.

"An evaluation procedure is needed which will allow the user to evaluate alternative models in the context of a specific set of applications". "Two kinds of criteria are presented: use criteria, which measure the usability of the model; and implementation criteria, which measure the implementability of the model and the efficiency of the resulting implementation. The use of the criteria is illustrated by applying them to three specific models: an n-ary relational model, a hierarchic model, and a network model".

L. I. Mercz, "Issues in Building a Relational Interface on a CODASYL DBMS", G. Bracchi and G. M. Nijssen (Eds.), Data Base Architecture (Proc. IFIP TC-2 Working Conf. on Data Base Architecture, June 1979), North-Holland, Amsterdam, Neth.,

1979, pp. 191-211.

"The CODASYL'78 database proposals are evaluated and found to be insufficient for providing a semantically complete, formal description for the conceptual schema. Therefore, it is not possible to derive a complete relational view from a CODASYL schema. In contrast with the CODASYL'78 proposals, a procedural external schema and related data manipulation operators are outlined, which can coexist with normalized relational views on the same information base".

A. S. Michaels, B. Mittman, and C. R. Carlson, "A Comparison of the Relational and CODASYL Approaches to Data-Base Management", Computing Surveys, ACM, vol. 8, no. 1, Mar. 1976, pp. 125-151.

"Data definition, manipulation, protection, and independence, and system performance are important factors when studying and evaluating data-base management systems". "The relational and CODASYL Data Base Task Group approaches ... are compared and contrasted from these points of view. The paper concludes with the observation that since data-base management systems are to serve the needs of widely diverse communities of users, no single approach to data-base management seems either desirable or likely to emerge as dominant in the near future".

E. Nahouraii, L. O. Brooks, and A. F. Cardenas, "An Approach to Data Communication Between Different Generalized Data Base Management Systems", P. C. Lockemann and E. J. Neuhold (Eds.), Systems for Large Data Bases (Proc. 2nd Intl. Conf. on Very Large Data Bases, Sept. 1976), North-Holland, Amsterdam, Neth., 1977, pp. 117-142.

"This report discusses some of the problems and provides a methodology for communicating and exchanging information between heterogeneous models of data or DBMSs that are commercially available". "Our proposed approach to interconnecting heterogeneous DBMSs is to characterize the access paths into and through the data in a DIAM string catalog". [See also (Cardenas and Pirahesh, 1980)].

S. B. Navathe, "An Intuitive Approach to Normalize Network Structured Data", Proc. 6th Intl. Conf. on Very Large Data Bases, ACM, Oct. 1980, pp. 350-358.

[This paper describes] "a simple procedure for converting a network of record types (which may be a set of files from a file system or record types / segments in a DBMS) into a number of relations".

E. J. Neuhold, "Data Mapping: Formal Hierarchical and Relational Model", R. Rustin (Ed.), Data Base Systems (Courant Computer Sci. Symp. 6, May 1971), Prentice-Hall, Englewood Cliffs, NJ, 1972, p. 185 (abstract); "Data Mapping: A Formal Hierarchical and Relational View", Institute for Appl. Informatics, U. of Karlsruhe, Karlsruhe, W. Germany, Feb. 1973.

"The techniques developed for the formal description of the semantic of programming languages can be applied to the different data constructs found in data base systems". "This paper concentrates on hierarchical organisations ..., and compares some of their properties to the relational view of data".

G. M. Nijssen, "Data Structuring in the DDL and Relational Model", J. W. Klimbie and K. L. Koffeman (Eds.), Data Base Management (Proc. IFIP TC-2 Working Conf. on Data Base Management, Apr. 1974), North-Holland, Amsterdam, Neth., 1974, pp. 363-384.

"The main data structuring elements of the CODASYL DDL and Relational Data Model are compared. The comparison is illustrated with an example and some data descriptions. The main conclusion is that a common DDL could be specified, encompassing the main aspects of the CODASYL DDL and Relational Data Model. An instant guideline for DDL users" [for relational-like use] "and some DDL modifications are also shortly described".

T. W. Olle, The CODASYL Approach to Data Base Management, John Wiley and Sons, New York, NY, 1978, Chap. 24 ("Relational Approach"), pp. 266-279.

[This chapter defines various aspects of the relational data model and compares them with aspects of the CODASYL data model. See also (Olle, 1975)].

T. W. Olle, "Current and Future Trends in Data Base Management Systems", Proc. IFIP Congress 74, North-Holland, Amsterdam, Neth., Aug. 1974, pp. 998-1006.

[In part of this paper], "the work of the CODASYL Data Base Task Group and of the groups which it has spawned is

compared with that of the Guide-Share groups and with the emerging theories on relational data bases. The significant features of Codd's work are selected and their potential impact assessed".

T. W. Olle, "Data Definition Spectrum and Procedurality Spectrum in Data Base Management Systems", J. W. Klimbie and K. L. Koffeman (Eds.), Data Base Management (Proc. IFIP TC-2 Working Conf. on Data Base Management, Apr. 1974), North-Holland, Amsterdam, Neth., 1974, pp. 289-293.

"This paper describes two spectrums - the phys-log spectrum along which all data definition languages must lie and the procedurality spectrum along which all languages to act on a computerized data base must lie. A proposal for a multi-stage data definition process supported by different user interfaces is outlined". [See also (Olle, 1974c)].

T. W. Olle, "Data Structuring Facilities in Commercially Available DBMS", Computer Bulletin, British Computer Soc., series 2, no. 1, Sept. 1974, pp. 20-22 and 30.

"This paper introduces the new concept of a complete spectrum of data definition facilities from the purely logical to the completely physical. An indication is given of where major commercially available DBMS lie in this spectrum. The interaction with this spectrum of processing languages on various procedural levels is discussed. Finally, a potential future role for the relational database and its associated processing language is suggested". [See also (Olle, 1974b)].

T. W. Olle, "A Practitioner's View of Relational Data Base Theory", FDT, ACM SIGMOD, vol. 7, no. 3-4, 1975, pp. 29-43.

"The ... paper represents a lightly edited version of" [(Olle, 1978)].

J. B. Rothnie and W. T. Hardgrave, "Data Model Theory: A Beginning", Proc. Fifth Texas Conf. on Computing Syst., IEEE-CS, Oct. 1976, p. 47 (abstract); Tech. Rep. 10, Dept. of Info. Syst. Management, U. of Maryland, College Park, MD, Sept. 1976.

"We propose that 'data model' be used to denote: a collection of abstract entities, facilities for defining abstract entities", [and] "a collection of operations that manipulate abstract entities". "This paper represents an embrionic attempt to establish a theory of data models". [See also (Hardgrave and Sibley, 1979)].

J. B. Ruby and A. G. Carrick, "An Approach to Providing a Relational Query Processor for a Limited CODASYL Data Base Management System", Proc. 3rd USA - Japan Computer Conf., AFIPS, Oct. 1978, pp. 139-144.

"A dual Data Base Management System (DBMS) design is proposed within which both network and relational subsystems coexist. The network subsystem serves as the 'operational' DBMS with which programmers interface, while it also provides the base upon which the relational end user (query only) subsystem operates". "The basic network subsystem ... is a limited subset of the 1976 CODASYL specifications; and the proposed relational query interface is a limited subset of ... SEQUEL".

R. Rustin (Ed.), Proc. ACM SIGMOD [SIGFIDET] Workshop on Data Description, Access, and Control, vol. 2 ("Data Models: Data-Structure-Set versus Relational"), May 1974.

"This, the second volume, contains the papers and the transcript of the debate on the differences and similarities of the Data-Structure-Set Model versus the Relational Model of data between C. W. Bachman and E. F. Codd". [This includes six papers ((Bachman, 1974), (Codd and Date, 1974), (Date and Codd, 1974), (Lucking, 1974), (Sibley, 1974), and (Tsichritzis, 1974)) plus discussion].

H. A. Schmid and P. A. Bernstein, "A Multi-level Architecture for Relational Data Base Systems", Proc. [1st] Intl. Conf. on Very Large Data Bases, ACM, Sept. 1975, pp. 202-226.

"We describe a multi-level architecture for relational data base systems". [One level supports the language described in (Tsichritzis, 1976). See also (Klug and Tsichritzis, 1977) and (Tsichritzis, 1975)].

L. S. Schneider, "A Relational Query Compiler for Distributed Heterogeneous Databases", Sterling Systems Corp., Golden, CO; presented at SHARE 50 Conf., Mar. 1978.

"Information systems in which the database is distributed among many heterogeneous representations are becoming more common with the advent of computing networks". "This paper contends that a mapping from a

consistent comprehensive user-view to the semantics of each target system involved would reduce this problem to one of syntax for which known solutions may be applicable, and that such a mapping can be founded on the relational model ..., the Data Independent Accessing Model ..., and the juxtaposition of these". [See also (Schneider, 1976)].

L. S. Schneider, "A Relational View of the Data Independent Accessing Model", Proc. ACM-SIGMOD Intl. Conf. on Management of Data, June 1976, pp. 75-90.

"This paper attempts to show that the DIAM's relevance to contemporary research in database systems can be enhanced by viewing it through n-ary relations. To accomplish this, the paper first develops a redefinition of the DIAM String Level in terms of n-ary relations. It then appeals to the remaining levels of the DIAM to describe various relational implementation alternatives". [See also (Schneider, 1978)].

D. W. Shipman, "The Functional Data Model and the Data Language DAPLEX", Proc. ACM-SIGMOD 1979 Intl. Conf. on Management of Data, May 1979, p. 59 (abstract); to appear in ACM Trans. on Database Syst..

"This paper presents and motivates the DAPLEX language and the underlying data model". [One section states that] "the data modelling capabilities of DAPLEX incorporate those of the hierarchical, relational and network models".

B. Shneiderman and G. N. Thomas, "Path Expressions for Complex Queries and Automatic Database Program Conversion", Proc. 6th Intl. Conf. on Very Large Data Bases, ACM, Oct. 1980, pp. 33-44.

"Our efforts to develop an automatic database system conversion facility yielded a powerful, yet simple query language which was designed for ease of conversion". "This approach provides for a high level, relational-like facility with the visual and structural appeal of the network model". "Within a set instance the records are in ... order by the set keys" [as in a CODASYL set] "and duplicate set keys are not allowed" [as in a relation, whose tuples are unique, or a CODASYL set with duplicates not allowed].

E. H. Sibley, "On the Equivalences of Data Based Systems", in (Rustin, 1974), pp. 43-76.

"The two major approaches that have emerged may be termed the relational or set theoretic, and the data structured or procedural. There are obviously differences in these, but there are also similarities".

E. H. Sibley and L. Kerschberg, "Data Architecture and Data Model Considerations", Proc. Natl. Computer Conf., AFIPS, vol. 46, June 1977, pp. 85-96.

"In the past, attempts have been made to compare and contrast ... systems, but the greatest difficulty arises in seeking a common basis. This paper attempts to show how a generalized data system (GDS), represented by two different models, could form such a basis; it then proposes that data policy definitions can restrict the GDS to a specialized model, such as a relational or DBTG-like model".

M. R. Stonebraker and G. D. Held, "Networks, Hierarchies, and Relations in Data Base Management Systems", Proc. ACM Pacific 75 Regional Conf. (Data: Its Use, Organization, and Management), Boole and Babbage, Inc., Sunnyvale, CA, Apr. 1975, pp. 1-9.

"The three models of data that currently prevail are described. One is the relational view". "The second is the network view advanced by CODASYL". "A third view is a hierarchical one". "Non-procedural languages for all three views of data are very similar". "The expressiveness of the data structures is the same for" [relational and network].

M. R. Stonebraker and L. A. Rowe, "Observations on Data Manipulation Languages and their Embedding in General Purpose Programming Languages", Proc. 3rd Intl. Conf. on Very Large Data Bases, ACM, Oct. 1977, pp. 128-143.

"Many data base query languages, both stand-alone and coupled to a general purpose programming language, have been proposed". "Issues include the specification of performance options, side effects, implicitness, the handling of types and the time of binding". "The emphasis is on a comparative analysis".

K. Tabata, H. Matsumoto, and Y. Ohno, "A DBMS for a Composite Type of Distributed Data Base", Proc. 3rd USA - Japan Computer Conf., AFIPS, Oct. 1978, pp. 187-191.

"We propose a philosophy of a Data Base Management System (DBMS) for a composite type of distributed data base. Component data bases being to construct the distributed data base ... may have data models different from one another. We integrate various kinds of data models into the relational model to construct the distributed data base".

N. Thalmann and D. Thalmann, "A Problem-Oriented Analysis of Database Models", J. Chemical Information and Computer Sciences, American Chemical Soc., Washington, DC, vol. 19, no. 2, May 1979, pp. 86-89.

"Which is the most convenient database model considering specific applications? The goal of this paper is to try to answer this question by the use of a chemical example. Examples of requests describe the problems of insertion, deletion, and updating; these requests are analyzed for the hierarchical model and are expressed in a relational language defined by the authors and in Socrate for the network model".

D. C. Tsichritzis, "Comments on Advantages of the Relational View", in (Rustin, 1974), pp. 77-81.

"The principal advantages of the relational model are: simplicity, in terms of the data and the language; uniformity, everything is based on one concept; completeness, it is as complete as anything else; data independence, both in storage structure and growth independence for certain kinds of changes in the schema; security and integrity".

D. C. Tsichritzis, "LSL: A Link and Selector Language", Proc. ACM-SIGMOD Intl. Conf. on Management of Data, June 1976, pp. 123-133.

"This paper presents the main ideas behind the language LSL". "It can be thought of as a relational system implemented on a network environment". [See also (Klug and Tsichritzis, 1977), (Schmid and Bernstein, 1975), and (Tsichritzis, 1975)].

D. C. Tsichritzis, "A Network Framework for Relation Implementation", B. C. M. Douqué and G. M. Nijssen (Eds.), Data Base Description (Proc. IFIP TC-2 Special Working Conf. on Data Base Description, Jan. 1975), North-Holland, Amsterdam, Neth., 1975, pp. 269-282.

"A network model is defined in terms of simple relationships among data". "A network language is proposed to declare and manipulate access paths between data. It is claimed that the proposed framework can be appropriate as a basis for relation implementation". [See also (Klug and Tsichritzis, 1977), (Schmid and Bernstein, 1975), and (Tsichritzis, 1976)].

J. D. Ullman, Principles of Database Systems, Computer Science Press, Rockville, MD, 1980, Sect. 3.4 ("Comparison of the Models"), pp. 98-100.

"By the criterion of easy use, there is no doubt that the relational model is superior". "When we consider the potential for efficient implementation, the network and hierarchical models score high marks".

Y. Vassiliou and F. H. Lochovsky, "DBMS Transaction Translation", Proc. COMPSAC 80, IEEE-CS, Oct. 1980, pp. 89-96; an extended version, by Y. Vassiliou, appears in F. H. Lochovsky (Ed.), "A Panache of DBMS Ideas II", Computer Syst. Research Group Tech. Rep. 101, U. of Toronto, Toronto, Ont., Canada, May 1979, pp. 92-122.

"Data translation and transaction translation are two major problems that have to be solved in order to achieve the coexistence of heterogeneous distributed databases". "Methods for mapping a hierarchical or network schema to an equivalent relational schema are presented". "Relational operators ... are translated to equivalent hierarchical and network operations".

R. E. Westgaard, "A COBOL Data Base Facility for the Relational Data Model", Proc. ACM Pacific 75 Regional Conf. (Data: Its Use, Organization, and Management), Boole and Babbage, Inc., Sunnyvale, CA, Apr. 1975, pp. 132-139.

"The relational data model ... has been contrasted with the CODASYL DDL network model as to effectiveness in meeting the goals of data independence, flexibility in data modeling, and ease of use". "The CODASYL DDL and DML interfaces are oriented to the application programmer whereas the

relational model is oriented to the less procedural non-programmer. This paper proposes an application programmer COBOL interface for the relational model utilizing existing COBOL I/O verbs and the CODASYL DDL constructs of schema and subschema".

V. K. M. Whitney, "Relational Data Management Implementation Techniques", Proc. ACM SIGMOD [SIGFIDET] Workshop on Data Description, Access, and Control, May 1974, pp. 321-348.

[In part of this paper], "the concepts of modeling information structures with data is illustrated with the CODASYL DBTG and the relational models".

E. Wong and R. H. Katz, "Logical Design and Schema Conversion for Relational and DBTG Databases", P. P.-S. Chen (Ed.), Proc. Intl. Conf. on Entity-Relationship Approach to Systems Analysis and Design, Dec. 1979, pp. 319-329; later published as Entity-Relationship Approach to Systems Analysis and Design, North-Holland, Amsterdam, Neth., 1980.

"A variant of the Entity-Relationship model is proposed as the data model for logical design". "Mapping rules will be proposed for transforming a design schema into a corresponding schema of either relational or DBTG type". "It is shown that with relatively minor semantic augmentation of DBTG and relational data models, the mapping is reversible. As a consequence, reversible schema conversion between DBTG and relational models becomes possible".

C. Wood, R. C. Summers, and E. B. Fernandez, "Authorization in Multilevel Database Models", Information Syst., Pergamon Press, Oxford, UK, vol. 4, no. 2, 1979, pp. 155-161.

"In a multilevel database architecture, authorization rules may be written at the conceptual level or at the external level. We analyze here the consistency of authorization rules written at these two levels. We assume that the conceptual level model is of the entity-relationship type and the external model is relational".

C. A. Zaniolo, "Design of Relational Views Over Network Schemas", Proc. ACM-SIGMOD 1979 Intl. Conf. on Management of Data, May 1979, pp. 179-190; a slightly longer version is "Design of Relational Views Over a Network Schema", Sperry Research Center Rep. SCRC-RR-78-37, Sudbury, MA, July 1978.

"An algorithm is presented for designing relational views over network schemas". "The particular declarations of a CODASYL schema which supply sources of logical data definition are first identified. Then the view design algorithm is derived on the basis of a formal analysis of the semantic constraints established by these declarations. A new form of data structure diagram is also introduced to visualize these constraints". [See also (Goldman, 1979), (Zaniolo, 1979b), and (Zaniolo, 1977)].

C. A. Zaniolo, "Multimodel External Schemas for CODASYL Data Base Management Systems", G. Bracchi and G. M. Nijssen (Eds.), Data Base Architecture (Proc. IFIP TC-2 Working Conf. on Data Base Architecture, June 1979), North-Holland, Amsterdam, Neth., 1979, pp. 171-190.

"The problem of designing and supporting relational and hierarchical views over CODASYL network schemas is considered". "A solution is proposed based on the integrity constraints on logical data resulting from certain declarations in the CODASYL Data Definition Language". [See also (Goldman, 1979), (Zaniolo, 1979a), and (Zaniolo, 1977)].

C. A. Zaniolo, "Relational Views in a Data Base System: Support for Queries", Proc. COMPSAC 77, IEEE-CS, Nov. 1977, pp. 267-275.

"The relational model is extended to include null values and operations on relations containing null values. These concepts allow the definition of information preserving relational views over a network schema. A mechanism is presented to support queries on these views without duplication of actual data". [See also (Goldman, 1979), (Zaniolo, 1979a), and (Zaniolo, 1979b)].

K. Zimmermann, "Different Views of a Data Base: Coexistence Between Network Model and Relational Model", Proc. [1st] Intl. Conf. on Very Large Data Bases, ACM, Sept. 1975, pp. 535-537.

"The problem of data base access via different data models has been investigated for the network model and the relational model. The network model is based on ... Codasyl. ... For a given network model of the data base a coexistent relational model is proposed. The proposal is based on an extension of the usual relational model ... by an incorporation of appropriate network parameters".