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To Link this Article: http://dx.doi.org/10.6007/IJARBSS/v12-i10/15142 DOI:10.6007/IJARBSS/v12-i10/15142

Received: *18* August 2022*, **Revised:** 21* September 2022*, **Accepted:** 31* September 2022

Published Online: *24* October 2022

In-Text Citation: (Amran et al., 2022)

To Cite this Article: Amran, N., Bahry, F. D. S., Razak, A. H. A., Muksin, M. S., & Rahaman, N. A. A. (2022). Database Conceptual Diagram Using ERD and Data Dictionary Metadata for SME Construction Business. *International Journal of Academic Research in Business and Social Sciences*, *12*(10), 2985 – 2999.

Vol. 12, No. 10, 2022, Pg. 2985 – 2999

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Database Conceptual Diagram Using ERD and Data Dictionary Metadata for SME Construction Business

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Abstract

The data of construction business such as customers, projects, payments, workers, materials, and suppliers are very essential to the contractors especially to the Small and Medium-sized Enterprises (SME) construction companies. The customers' request and confirmation for constructions projects, which workers involves in which project and what are the materials selected for the project are important to handle but still been manage manual. Some of the information requested, discussed or ordered are missing, misplaced or overlooked, especially when there are many concurrent constructions projects which to be completed at the same time. Therefore, the project aims to design a database of construction business for accelerating the information flow and transaction between each construction phase. The conceptual diagram has been designed and constructed using Entity relationship modelling and continue referred to the Database Life Cycle (DBLC) as methodology approach. The SME Construction management of Entity Relationship Diagrams (ERD), consist of the Customer, Project, Payment, Supplier and Material entities which constructed based on SME Construction Business rules and process validation. The findings can assist the researchers, students, system designers and developers to understand more on designing the database conceptual diagram and identify the data elements in the data dictionary which required for construction business database. Furthermore, the findings from this research project can be used to develop a SME construction management system database and SME information system in the future.

Keyword: Database Design, Entity Relationship Diagram (ERD), Data Dictionary Metadata, Construction Business, Small and Medium-sized Enterprises (SME)

Introduction

The small and medium-sized enterprises (SMEs) in construction business provides many projects works such as painting, renovation, ironwork, plumbing and wiring. Contractors

frequent communicate with customers who want to do any construction works or projects either by discussion face to face (F2F), through phone discussion
or other various digital platforms such as WhatsApp, Telegram and short message systems. They also use social media platforms like Facebook to advertise their business services. The construction business activities include the process of customers request and confirm for constructions projects, the payments which being made by the customers for the projects, the workers who are working for each project, the materials which being used in the project and the material which being purchased from the suppliers. Figure 1 shows the Diagram of Constructions Business Activities.

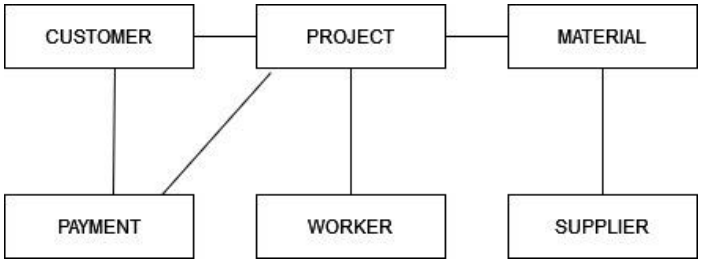

Figure 1: Diagram of Constructions Business Activities

The construction business activities mostly are being done manually. While the contractors communicate with their customers either by F2F discussions, by phone or using digital/social media, it regularly happened some of the information requested, discussed or ordered are missing, misplaced or overlooked, especially when there are many concurrent construction projects which to be completed at the same time. It also takes longer time to search specific data or information especially on the project and workers schedule, payment, materials used and purchased.

Therefore, to assist them in managing the data/information of their construction business especially the customers, projects, payments, workers, materials, supplier and other business transactions information, a database of construction business is suggested to be developed. The specific data/ information stored in the database can be easily search, retrieve and generate. Addition of that, the data/information can also be analyzed and used for wise decision making and strategic planning. Database Life Cycle (DBLC) which contains six phases namely database initial study, database design, implementation and loading, testing and evaluation, operation, and maintenance and evolution defines the stages involved for developing and implementing a database (Coronel & Morris, 2019). Database design as defined by Peterson (2022), is a collection of process that facilitate the designing, development, implementation and maintenance of enterprise data management systems. Proper database design is important for easy maintenance, improves data consistency and cost effective in terms of disk storage space. It decides how the data elements correlate and what data must be stored. A good database design starts with a list of data which to be included in the database and which to be used with the database later on (Datanamic, 2022).

In DBLC (Coronel & Morris, 2019), database design actions consist of creating the conceptual design, DBMS software selection, create the logical design and create the physical design. For conceptual design, the steps involved are (1) data analysis and requirements (2) entity relationship modelling and normalization, (3) data model verification and (4) distributed

database design. To develop the conceptual model using ER diagrams, it contains 8 steps which are:

1) Identify, analyze and refine the business rules
2) Identify the main entities
3) Define the relationships among the entities
4) Define the attributes, primary key and foreign keys for each entity
5) Normalizes the entities
6) Complete the initial ERD
7) Validate the ER model against the end user's information and processing requirements
8) Modify the ER model

This article mainly describes on database design: developing the database conceptual model using Entity Relationship Diagrams (ERD), which describes the business rules, entities, attributes and relationships of SME Construction Business and the Data Dictionary.

Business Rules (BR)

Business rules (BR) is a description of a policy, procedure, or principle within an organization. Identify, analyze and refine the BR is the first activity in developing the conceptual model using ERD. Detail description of construction operational business at one SME local construction company has been studied to identify the BR.

BR1: One CUSTOMER has many PROJECTs (1:M)

A customer has one construction project (1:1) or a customer has many construction projects (1:M). However, one construction project is for one customer only (1:1).

BR2: One CUSTOMER makes many PAYMENTs (1:M)

A customer makes one payment (1:1) or a customer makes many payments (1:M). However, one payment can be made by one customer only (1:1)

BR3: One PROJECT receive many PAYMENTs (1:M)

One project receives one payment (1:1) or one project receives many payments (1:M). However, one payment is for one project only (1:1)

BR4: Many PROJECTs have many WORKERs (M:N)

One project has one worker (1:1) or one project has many workers (1:M). One worker can also work at many projects (1:M)

BR5: Many PROJECTs use many MATERIALs (M:N)

One project uses one material (1:1), or one project uses many materials (1:M). One material can also be used at many projects (1:M)

BR6: Many MATERIALs supplies by many SUPPLIERs (M:N)

One material can be supplied by one supplier (1:1), or one material can be supplied by many suppliers (1:M). One supplier can also supply many materials (1:M) for the construction project.

ENTITY RELATIONSHIP DIAGRAM (ERD)

ER Models are presented using entity relationship diagram (ERD), which use graphical representations to model the database components. This study used Crow's Foot notation (concept.Draw, 2022) to present the ERD components of entities, attributes and the relations. Diagrams.net software has being used to draw the ERD.

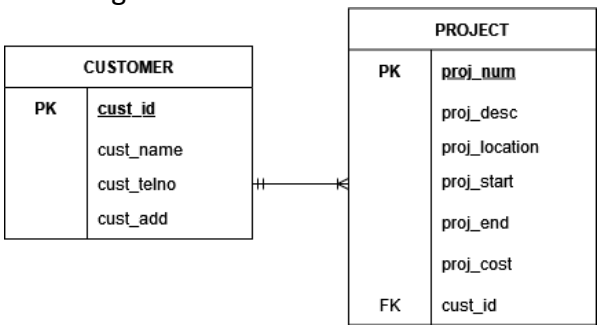

Figure 2: ERD1 for BR1

Figure 2 shows the ERD1 for BR1, one-to-many (1:M) relationship between CUSTOMER and PROJECT entities. The attributes related to CUSTOMER entity are customer identification number (cust_id) as Primary Key (PK), customer name (cust_name), customer telephone number (cust_telno) and customer address (cust_add), while the attributes for PROJECT entity are project number (proj_num) as PK, project description (proj_desc), project location (proj_location), project start date (proj_start), project end date (proj_end), project cost (proj_cost) and customer identification number (cust_id) as Foreign Key (FK).

Table 1
CUSTOMER table

cust_id	cust_name	cust_telno	cust_add
C001	ALI ABU	12344578	LOT12, JALAN 12A, 41200 KLANG
C002	AMINAH	14778778	10, JALAN SIPUT, 42000 PKLANG

Table 2
PROJECT table with cust_id (FK)

proj_num	proj_desc	proj_location	proj_start	proj_end	proj_cost	cust_id
P001	HOUSE RENOVATION	LOT12, JALAN 12A, 41200 KLANG	1/01/2022	30/03/2022	50000	C001
P002	WIRING	NO 3, JALAN UGANDA, 42000 P.KLANG	1/02/2022	14/02/2022	2000	C002
P003	HOUSE RENOVATION	LOT20, JALAN 12A, 41200 KLANG	1/5/2022	30/6/2022	10000	C001

Table 1 and Table 2 are the CUSTOMER and PROJECT tables which being transformed from CUSTOMER and PROJECT entities. The sample data shows one-to-many (1:M) relationship, where one customer (cust_id C001) has many projects (proj_num P001 and P003).

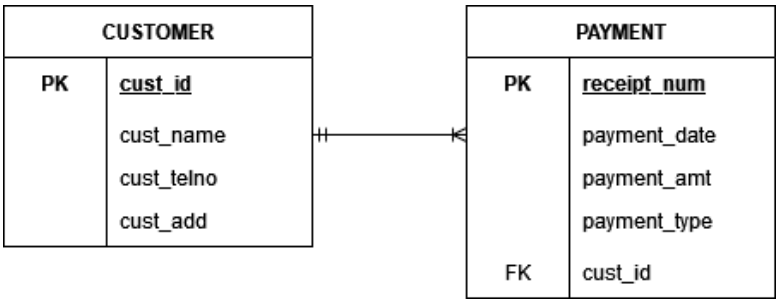

Figure 3: ERD2 for BR2

Figure 3 shows the ERD2 for BR2, one-to-many (1:M) relationship between CUSTOMER and PAYMENT entities. The attributes related to CUSTOMER entity are customer identification number (cust_id) as PK, customer name (cust_name), customer telephone number (cust_telno) and customer address (cust_add), while the attributes for PAYMENT entity are receipt number (receipt_num) as PK, payment date (payment_date), payment amount (payment_amt), payment type (payment_type) and customer identification number (cust_id) as FK.

Table 3
CUSTOMER table

cust_id	cust_name	cust_telno	cust_add
C001	ALI ABU	12344578	LOT12, JALAN 12A, 41200 KLANG
C002	AMINAH	14778778	10, JALAN SIPUT, 42000 PKLANG

Table 4
PAYMENT table with cust_id (FK)

receipt_num	payment_date	payment_amt	payment_type	cust_id
R001	1/01/2022	10000	E-BANKING	C001
R002	2/01/2022	10000	E-BANKING	C001
R003	1/02/2022	500	CASH	C002

Table 3 and Table 4 are the CUSTOMER and PAYMENT tables which being transformed from CUSTOMER and PAYMENT entities. The sample data shows one-to-many (1:M) relationship, where there is one customer (cust_id CI01) has made many payments (receipt_num R001 and R002).

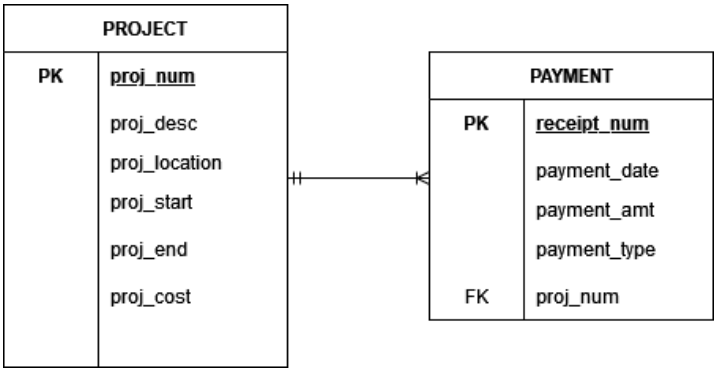

Figure 4: ERD3 for BR3

Figure 4 shows the ERD3 for BR3, one-to-many (1:M) relationship between PROJECT and PAYMENT entities. The attributes for PROJECT entity are project number (proj_num) as PK, project description (proj_desc), project location (proj_location), project start date (proj_start), project end date (proj_end) and project cost (proj_cost). While the attributes for PAYMENT entity are receipt number (receipt_num) as PK, payment date (payment_date), payment amount (payment_amt), payment type (payment_type) and project number (proj_num) as FK.

Table 5
PROJECT table

proj_num	proj_desc	proj_location	proj_start	proj_end	proj_cost
P001	HOUSE RENOVATION	LOT12, JALAN 12A, 41200 KLANG	1/01/2022	30/03/2022	50000
P002	WIRING	NO 3, JALAN UGANDA, 42000 P.KLANG	1/02/2022	14/02/2022	2000
P003	HOUSE RENOVATION	LOT20, JALAN 12A, 41200 KLANG	1/5/2022	30/6/2022	10000

Table 6
PAYMENT table with proj_num (FK)

receipt_num	payment_date	payment_amt	payment_type	proj_num
R001	1/01/2022	10000	E-BANKING	P001
R002	2/01/2022	10000	E-BANKING	P001
R003	1/02/2022	500	CASH	P002

Table 5 and Table 6 are the PROJECT and PAYMENT tables which being transformed from PROJECT and PAYMENT entities. The sample data shows one-to-many (1:M) relationship, where one same project (proj_num P001) has received many payments (receipt_num R001 and R002).

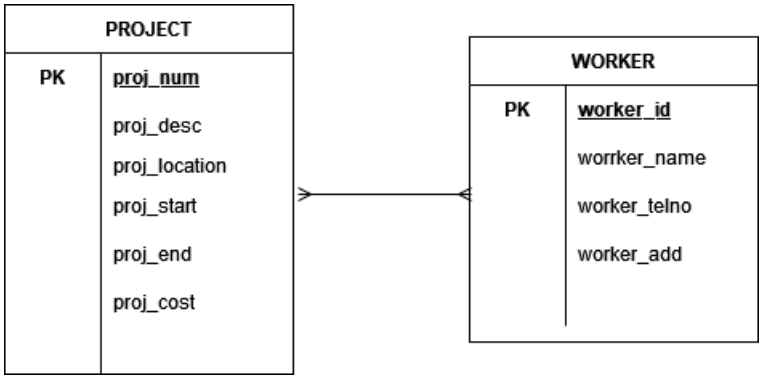

Figure 5: ERD4 for BR4

Figure 5 shows the ERD4 for BR4, many-to-many (M:N) relationship between PROJECT and WORKER entities. The attributes related to PROJECT entity are project number (proj_num) as PK, project description (proj_desc), project location (proj_location), project start date (proj_start), project end date (proj_end) and project cost (proj_cost). While the attributes for WORKER entity are worker identification number (worker_id) as PK, worker name (worker_name), worker telephone number (worker_telno) and worker address (worker_add).

Table 7
PROJECT table

proj_num	proj_desc	proj_location	proj_start	proj_end	proj_cost
P001	HOUSE RENOVATION	LOT12, JALAN 12A, 41200 KLANG	1/01/2022	30/03/2022	50000
P002	WIRING	NO 3, JALAN UGANDA, 42000 P.KLANG	1/02/2022	14/02/2022	2000
P003	HOUSE RENOVATION	LOT20, JALAN 12A, 41200 KLANG	1/5/2022	30/6/2022	10000

Table 8
WORKER table

worker_id	worker_name	worker_telno	worker_add
W001	SUWARNO	1244455578	KG TUALANG
W002	JAMAL	121112222	KG JUARA

Table 7 and Table 8 are the PROJECT and WORKER tables wwhich being transformed from PROJECT and WORKER entities and contained some sample data.

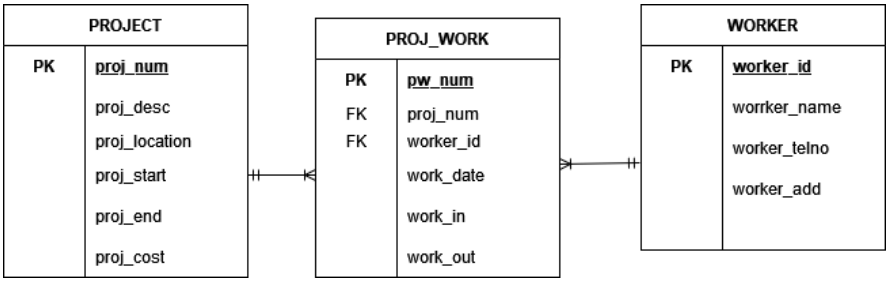

Figure 6: ERD4 for BR4 with bridge entity

Figure 6 shows a bridge entity has been created to implement the many-to-many (M:N) relationship in the relational model between PROJECT entity and WORKER entity, namely as PROJ_WORK entity. The PK of PROJECT entity (proj_num) and PK of WORKER entity (worker_id) will be the FK in PROJ_WORK entity. The other attributes for PROJ_WORK entity is project work number (pw_num) as PK, working date (work_date), worker time in (work_in) and worker time out (work_out).

Table 9
PROJ_WORK table with proj_num (FK) and worker_id (FK)

pw_num	proj_num	worker_id	work_date	work_timein	work_timout
1	P001	W001	1/01/2022	9:00	17:00
2	P001	W001	2/01/2022	9:00	17:00
3	P001	W002	2/01/2022	9:00	12:00
4	P002	W002	20/3/2022	9:00	12:00

Table 9 shows PROJ_WORK table which being transformed from PROJ_WORK entity. The sample data shows many-to-many (M:N) relationship, where one same project (proj_num P001) has many workers (worker_id W001 and W002) and one worker (worker W002) works in many projects (proj_num P001 and P002).

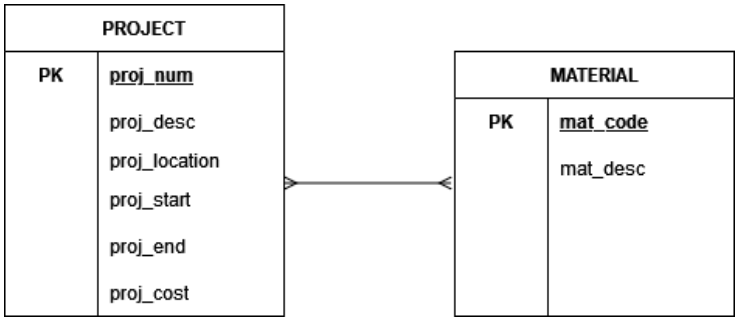

Figure 7: ERD5 for BR5

Figure 7 shows the ERD5 for BR5, many-to-many (M:N) relationship between PROJECT and MATERIAL entities. The attributes for PROJECT entity are project number (proj_num) as PK, project description (proj_desc), project location (proj_location), project start date (proj_start), project end date (proj_end) and project cost (proj_cost). While the attributes for MATERIAL entity are material code (mat_code) as PK and material description (mat_desc).

Table 10
PROJECT table

proj_num	proj_desc	proj_location	proj_start	proj_end	proj_cost
P001	HOUSE RENOVATION	LOT12, JALAN 12A, 41200 KLANG	1/01/2022	30/03/2022	50000
P002	WIRING	NO 3, JALAN UGANDA, 42000 P.KLANG	1/02/2022	14/02/2022	2000
P003	HOUSE RENOVATION	LOT20, JALAN 12A, 41200 KLANG	1/5/2022	30/6/2022	10000

Table 11
MATERIAL table

mat_code	mat_desc
MC001	CEMENT
MC002	WIRE CABLE CAT5E
MC003	SAND

Table 10 and Table 11 are the PROJECT and MATERIAL tables which being transformed from PROJECT and MATERIAL entities, and contained some sample data.

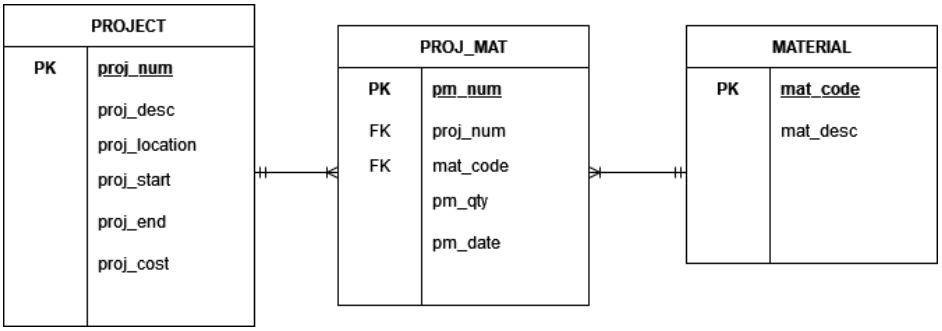

Figure 8: ERD5 for BR5 with bridge entity

The bridge entity is created to implement the many-to-many (M:N) relationship in the relational model between PROJECT entity and MATERIAL entity, namely as PROJ_MAT entity as shows in Figure 8. The PK of PROJECT entity (proj_num) and PK of MATERIAL entity (mat_code) will be the FK in PROJ_MAT entity, while new attribute for project use material number (pm_num) being created as PK in PROJ_MAT entity. Other attributes for PROJ_MAT entity are project material quantity (pm_qty) and project material used date (pm_date).

Table 12
PROJ_MAT table with proj_num(FK) and mat_code(FK)

pm_num	proj_num	mat_code	pm_date	pm_qty
1	P001	MC001	1/01/2022	100
2	P001	MC003	10/01/2022	500
3	P003	MC001	1/02/2022	20

Table 12 shows PROJ_MAT table which being transformed from PROJ_MAT entity. The sample data shows many-to-many (M:N) relationship, where one same project (proj_num P001) has used many materials (mat_code MC001 and MC003), and one material (mat_code MC001) used in many projects (proj_num P001 and P003).

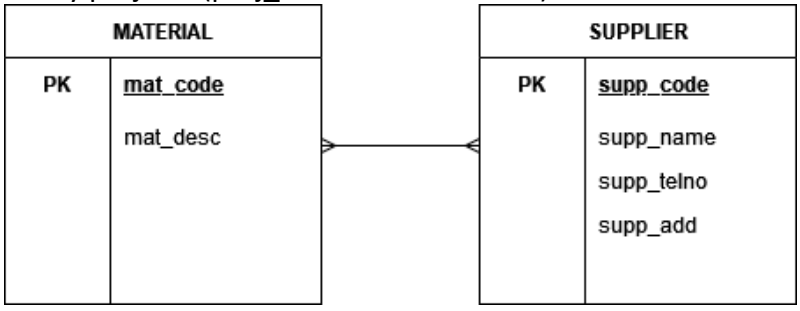

Figure 9: ERD6 for BR6

Figure 9 shows the ERD6 for BR6, many-to-many (M:N) relationship between MATERIAL and SUPPLIER entities. The attributes for MATERIAL entity are material code (mat_code) as PK and material description (mat_desc). While the attributes for SUPPLIER entity are supplier code (supp_code), supplier name (supp_name), supplier telephone number (supp_telno) and supplier address (supp_add).

Table 13
SUPPLIER table

supp_code	supp_name	supp_telno	supp_add
S001	AH SENG HARDWARE	12444777	JLN SG JATI
S002	RAJU TECH ENT	3444555	JLN UGANDA

Table 13 is the SUPPLIER table which being transformed from SUPPLIER entity and contained some sample data.

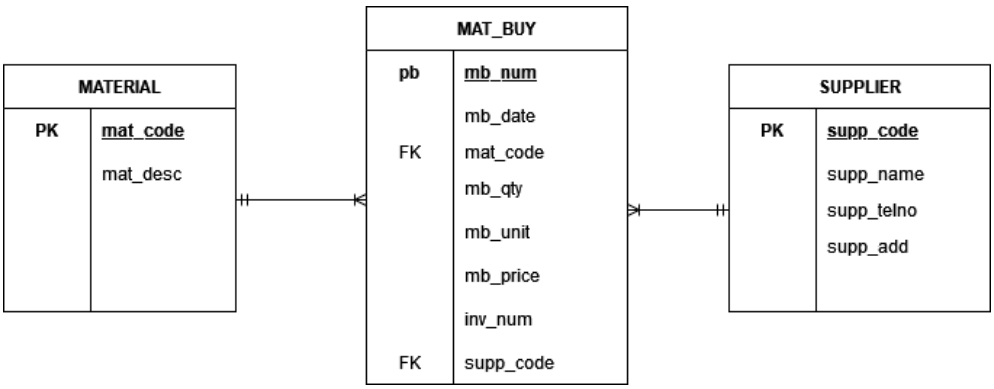

Figure 10: ERD6 for BR6 with bridge entity

The bridge entity is created to implement the many-to-many (M:N) relationship in the relational model between MATERIAL entity and SUPPLIER entity, namely as MAT_BUY entity as shows in Figure 10. The PK of MATERIAL entity (mat_code) and PK of SUPPLIER entity (supp_code) will be the FK in MAT_BUY entity, while new attribute material buy number (mb_num) is being created as PK in MAT_BUY entity. Other attributes for MAT_BUY entity are material buy date (mb_date), material buy quantity (mb_qty), material buy unit (mb_unit), material buy price (mb_price) and invoice number (inv_num).

Table 14
MAT_BUY table with mat_code (FK) and supp_code (FK)

mb_num	mb_date	mat_code	mb_qty	mb_unit	mb_price	inv_num	supp_code
1	1/01/2022	MC001	200	Kg	2000	R001	S001
2	1/01/2022	MC002	50	meter	50	A001	S001
3	2/01/2022	MC001	100	Kg	1000	A1001	S002

Table 14 shows MAT_BUY table which being transformed from MAT_BUY entity. The sample data shows many-to-many (M:N) relationship, where one same material (mat_code MC001) has being supplied by many suppliers (supp_code S001 and S002) and one supplier (supp_code S001) supply many materials (MC001 and MC002).

Database Conceptual Diagram Using Erd

The database conceptual model provides a global view of an entire database and describes the main data objects. Figure 11 shows the SME Construction Business database conceptual model which integrates all ERDs (ERD1- ERD6) which have been developed during the database design in earlier stages. Hence this is an implementation-ready model, which shows the bridge entities.

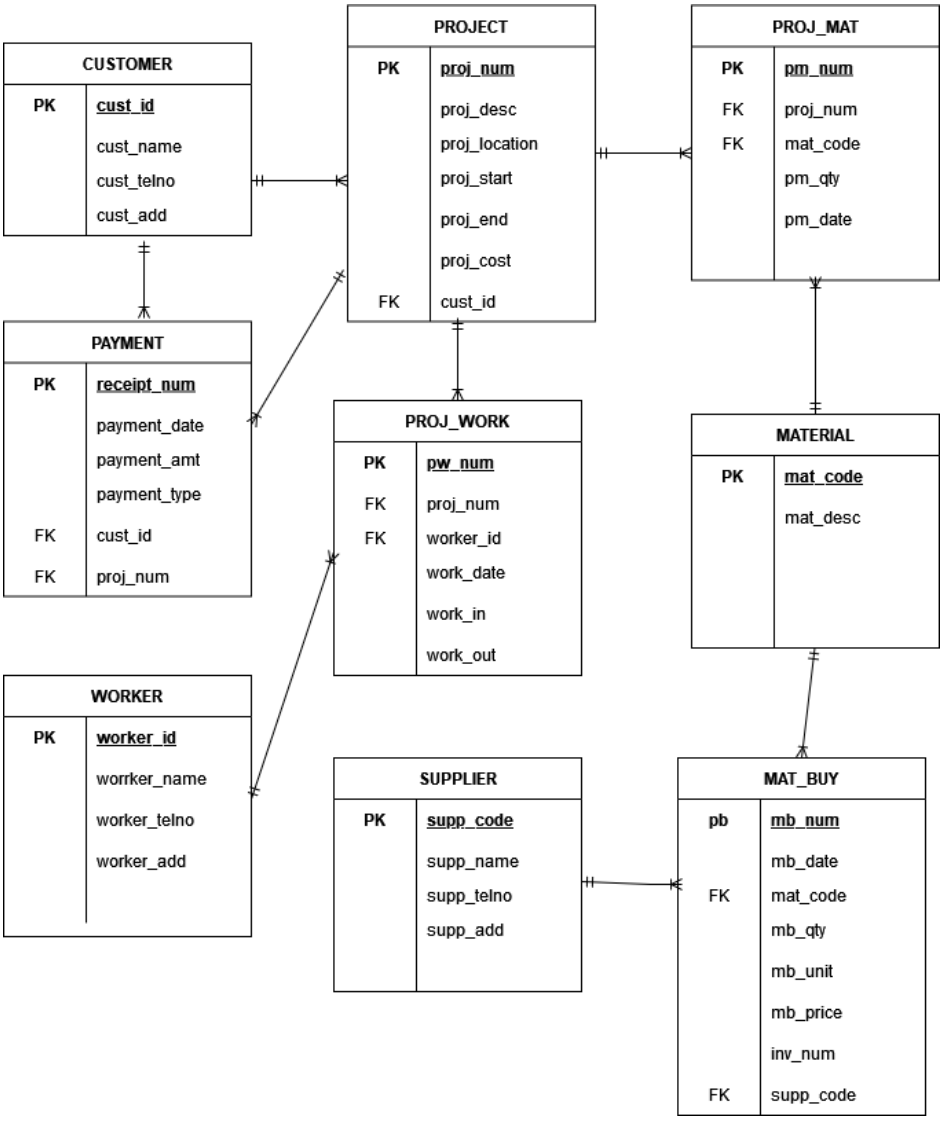

Figure 11: Database conceptual diagram for SME Construction Business

Data Dictionary

A data dictionary is a collection of descriptions of the data objects or items in a data model for the benefit of programmers and others who need to refer to them. Often a data dictionary is a centralized metadata repository (Wesley, 2020). The data dictionary or technical metadata which describes data about data, contains the definition as well as its characteristics

and relationships. Base on the revised ERD above which presents the global view of entire database, the data dictionary for SME Construction Business database has designed as in Figure 12.

ENTITY/ TABLE	ATTRIBUTE / FIELD	CONTENTS/ DESCRIPTION	TYPE	FORMAT	REQUIRED	PK or FK	PK AND FK REFERENCED TABLE
CUSTOMER	Cust_Id	Customer Identification Number	CHAR(4)	X999	Y	PK	
	Cust_Name	Customer Name	VARCHAR(30)	Xxxxxxxxx	Y		
	Cust_Telno	Customer Telephone Number	CHAR(10)	9999999999	Y		
	Cust_add	Customer Address	VARCHAR(80)	Xxxxxxxxx	Y		
PROJECT	Proj_num	Project number	CHAR(4)	X999	Y	PK	
	Proj_desc	Project description	VARCHAR(30)	XXXXX	Y		
	Proj_location	Project location	VARCHAR(50)	XXXXX	Y		
	Proj_start	Project start date	DATE	DD/MM/YYYY	Y		
	Proj_end	Project end date	DATE	DD/MM/YYYY	Y		
	Proj_cost	Project cost	DECIMAL(9,2)	9,999,999.99	Y		
	Cust_Id	Customer identification number	CHAR(4)	X999	Y	FK	CUSTOMER
PAYMENT	Receipt_num	Receipt number	CHAR(4)	XXXX	Y	PK	
	Payment_date	Payment date	DATE	DD/MM/YYYY	Y		
	Payment_amt	Payment amount	DECIMAL(9,2)	9,999,999.99	Y		
	Payment_type	Payment type	CHAR(10)	XXXXX	Y		
	Cust_id	Customer identification number	CHAR(4)	X999	Y	FK	CUSTOMER
	Proj_num	Project number	CHAR(4)	X999	Y	FK	PROJECT

WORKER	Worker_id	Worker identification number	CHAR(4)	X999	Y	PK	
	Worker_name	Worker name	VARCHAR(30)	XXXXX	Y		
	Worker_telno	Worker telephone number	CHAR(10)	9999999999	Y		
	Worker_add	Worker address	VARCHAR(80)	XXXXX	Y		
PROJ_WORK	Pw_num	Project work number	CHAR(3)	999	Y	PK	
	Proj_num	Project number	CHAR(4)	X999	Y	FK	PROJECT
	Worker_id	Worker identification number	CHAR(4)	X999	Y	FK	WORKER
	Work_Date	Working date	DATE	DD/MM/YYYY	Y		
	Work_in	Working time in	TIME	HH:MM	Y		
	Work_out	Working time out	TIME	HH:MM	Y		
MATERIAL	Mat_code	Material code	CHAR(5)	XX999	Y	PK	
	Mat_desc	Material description	VARCHAR(50)	XXXXX	Y		
PROJ_MAT	Pm_num	Project material number	CHAR(3)	999	Y	PK	
	Proj_num	Project number	CHAR(4)	X999	Y	FK	PROJECT
	Mat_code	Material code	CHAR(5)	XX999	Y	FK	MATERIAL
	Pm_qty	Project material quantity	INT	9999	Y		
	Pm_date	Project material used date	DATE	DD/MM/YYYY	Y		
SUPPLIER	Supp_code	Supplier code	CHAR(4)	X999	Y	PK	
	Supp_name	Supplier name	VARCHAR(50)	XXXXX	Y		
	Supp_telno	Supplier telephone number	CHAR(10)	9999999999	Y		
	Supp_add	Supplier address	VARCHAR(80)	XXXXX	Y		

MAT_BUY	Mb_num	Material buy number	CHAR(3)	999	Y	PK	
	Mb_date	Material buy date	DATE	DD/MM/YYYY	Y		
	Mat_code	Material code	CHAR(5)	XX999	Y	FK	MATERIAL
	Mb_qty	Material buy quantity	INT	9999	Y		
	Mb_unit	Material buy unit	CHAR(10)	XXXXX	Y		
	Mb_price	Material buy total price	DECIMAL(9,2)	RM9,999,999.99	Y		
	Inv_num	Invoice number	CHAR(10)	XXXXX	Y		
	Supp_code	Supplier code	CHAR(4)	X999	Y	FK	SUPPLIER

Figure 12: Data Dictionary Metadata

Conclusion and Future Enhancement

Databases are critical to a company's success because it stored the valuable company and business transactions data and information. It will assist them to achieve their goals, develop business strategy and expand their profit potential. This study has produced a database conceptual diagram which represent real-world objects of SME constructions business, from the business rules, entities, attributes, relationship, relational table with sample data and developing the conceptual diagram. All data elements metadata required by the database transactions also have been discovered and presented as in the Data Dictionary metadata.

The next step in database design process is to determine the DBMS software selection to be installed and, create the logical design where mapping the conceptual model to logical model components base on the Data Dictionary. This study may assist the researchers, students, system designers and developers to understand more on database design focusing on database conceptual diagram, data dictionary and developing database, and developing information system of SME construction business in future.

Limitation

This study is based on a construction business activities at one SME local construction company. The business rules may differ with other construction companies and cannot be generalized.

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