Implementing a Relational Database in Processing Construction Project Documents

Mik Wanul Khosiin and Ardian Umam

Abstract Construction project documents are extensive and complex, and most of those are still carried out with traditional systems. Consequently, it takes much time to process, low accuracy, cannot be stored for long periods, and make it difficult for future engineers to access historical data project for the next project planning. The current researchers have responded to this situation by implementing database management. However, it has not had a significant impact on the industrial field. Thus, the study of the application of relational databases through SQL with a different approach, namely integrating project tables such as resource tables, cost items, work items, and project drawings, which are currently being worked on separately. As the output, it would be demonstrated into a supply chain management table (table_3), construction cash flow (table_4), and the quantity take-off management table (table_5). The total project price from the result of the SQL program shown in supply chain and project cash flow tables is IDR 1.42 billion, with a project duration of 109 days. The SCM table describes the types of resources used in the project, including the quantity and price values. Then, the table of CSF contains a list of cost items and the volume and price of work for the budget plan and cash flow plan. Moreover, the QTO table describes the association between cost items and project drawings intended to project surveyors for the quantity take-off management process. Project managers are always required to make decisions for project control appropriately, such as cost estimation, resource planning, and project schedule effectively. Therefore, through those three tables, the authors hope they can help construction practitioners to improve their construction projects efficiently in the future.

Keywords Relational database · Construction · SQL

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1 Introduction

The construction industry has a large market and will be stable for the next few years because all countries are competing to build monumental buildings as the identity of the nation's progress [1]. Therefore, all construction companies also compete in the use of information technology as part of project management [2]. Most of the current construction projects have implemented building information modelling (BIM), artificial intelligence (AI), virtual reality (VR), as well as data science [3]. Scientists and practitioners agree that in the future, the construction sector will be dominated by the automation system in construction by answering various problems and challenges currently faced by project managers [4].

During the construction phase, the project will be faced with various kinds of documents with a large amount of data [5]. These data are interrelated, which are always reviewed, revised and controlled during the project. However, in practice, in the construction field today, they still use conventional methods so that the project database process is very long and the level of accuracy is quite low. Thus, the project manager is difficult to make decisions in real time, and then it will have an impact on project implementation performance [6].

This study was carried out to solve problems regarding complexity of project databases, by totally using SQL programming, all project documents will be integrated and simplified to make it easier for engineers in creating supply chain management table, cash flow construction, and quantity take-off management table.

2 Database Management System (DBMS)

Today databases are very important for every industry, including the construction sector. There is always a database behind the scenes on every data or document we request, because all companies always maintain all important data for future use. The database management system is a powerful tool for creating and managing large areas of data efficiently and can maintain it for very long periods in a secure manner. Basically a database is nothing more than a collection of information that has existed for a very long time, then users can create a new database with a different scheme, dig up the desired data, be able to accommodate a very large amount of data, and can be done with access control for a sufficient period of time long. The DBMS can be designed through several programming languages such as structured query language (SQL), R language, python, unified modelling language (UML), object definition language (ODL), Application Programming Interface (JDBC), hypertext pre-processor (PHP), and etc. [7, 8].

Several previous studies on the role and application of relational databases in the construction industry have been carried out by many researchers, starting from simple management in the form of table management in MS. Excel to involve building information modelling (BIM) and the internet in data management. In addition, the

programming language that used in the current studies are different according to the their research objectives.

Database in Construction Project

Project database management in Indonesia has not been well managed. The hundreds or even thousands of cost items and work items which are the core of all project documents are still done traditionally and have not been integrated. Through the use of data analytics (Pivot Table) the correlation between the cost breakdown structure (CBS) and the work breakdown structure (WBS) can be done better, thus helping contractors to estimate costs and schedule better and more efficiently [9]. Project documents that require integration between CBS and WBS are very diverse, including S-curve, bill of quantity, budget plan, resources plan, project scheduling, progress reports, payment progress, and others. Research collaborations between countries such as Indonesia and Taiwan have been carried out to develop the best scheme for integrating CBS and WBS and demonstrated in the form of a construction progress curve [14].

Internet-Based Database Management

The advanced database management system can be generated by the internet, all work packages, data history, and formulas are integrated to develop the project database stores. Therefore, this system can help the fund contractor to track and control their construction projects in real time and accurately [10].

Building Information Modelling and DBMS

Information about historical project data is very difficult to trace, because it is developed separately, so that the engineers worked hard to estimate the project costs. The application of a relational database that contains tables of project history connected to BIM models is proven to be able to carry out costs tracking to determine the final costs required for future projects [11]. The BIM system can also be used to maintain the sustainability of project procurement by considering life-cycle cost analysis (LCCA) through a database management system, this is very helpful for project managers to manage supply chains in construction projects [12].

DBMS for Current Construction Issues

Construction projects have a high risk of delays due to natural conditions or mismanagement. Through the use of historical data for certain project types, database management is carried out which can identify what jobs are often affected by delays, as well as the costs and duration of work due to delays. By using a relational database, contractors can anticipate delays or can submit claims supported by accurate data through the results of studies that have been conducted [13]. In another study, the application of the DB2 database management system as a database design can also improve management and information levels. By using UML class diagrams to find a logical structure in order to accelerate the development of project costs to make it faster and more accurate [14].

The review that has been carried out from previous studies (Table 1) can be concluded that DBMS is proven to be able to help the construction sector to manage

Table 1 Comparison model of the previous studies

Year	Researchers	Model	Brief concept	Output
2006	Ji Li et al.	Internet-based	A relational database in storing all project data through internet based	Developed system to track an control the construction project in real time
2016	Nannan Zhang et al.	UML, DB2	Integrating the database management system to accelerate the construction cost system	Index design on construction project cost system
2015	Gozde Bilgin et al.	MS. Access	Relational database in processing previous projects data to predict construction delay	Delayed activities and response party
2020	Hang Thu Thi Le et al.	BIM, MS. Access	BIM integrated with database management to compute building cycle	Building life-cycle costs for sustainable procurement
2020	Wijatmiko et al.	MS. Excel	Using pivot table and unique code to integrate WBS and CBS	The association table of cost item and work item
2021	Khosiin et al.	SQL	Assigning entity relationship on complex project data through SQL script	Supply chain, cash flow and take-off tables
2021	Khosiin et al.	SQL	Assigning entity relationship on complex project data through SQL script	Supply chain, cash flow and take-off tables

data efficiently. An advanced scheme using the internet and a combination with project controlling software such as BIM is also able to overcome the latest problems in the construction industry such as mitigating the risk of delay, cost estimation, data mining, etc. However, due to the complexity of the problem, and the scope of the data to be faced, there are still many challenges that must be resolved immediately. Therefore, this indicates that there is a need for further study on project database management through one of the programming languages like SQL to correlate data so that it can be realized in a simpler and more accurate table form to help project managers make real-time and efficient decisions (Table 1).

3 Case Study

A simple one-story residential building and all its construction data are plotted to demonstrate the function of a relational database. The project document is formed in several stages, starting with a detailed engineering design (DED) which contains a project drawing, then the contractor will list the work items and their work order and end with the creation of a project schedule. At the same time the engineer will also compile a cost item for making a project budget plan. Each of those has a unit item, quantity, and unit price that previously analysed according to the price of the resources used (labour, material, equipment and subcontractor). All of these data categories are interrelated, project drawings are used as a reference for making project schedules and budgets, while cost items are integrated with work items with one to many or one to one relationship model as in Fig. 1. These project documents will always be reviewed by engineers during the project.

Step One, Relationship Design

To implement a relational database begins with creating an entity relationship diagram (ERD) through the MySQL programming language such as Fig. 2, this diagram consists of several tables that represent the project database that has been mentioned earlier. Then, the tables are integrated through the ID numbers that have been assigned to each database category, the details of the table used as an ERD compiler are,

1. Drawing table, contains drawing_id, description and number of drawing pages
2. The cost_item table has a cost_id, cost breakdown structure (CBS), units, work volume, and project overhead
3. Table work_item, contains the work_id, work breakdown structure (WBS), project schedule
4. The resource table, consisting of the resource_id, resource name, unit, and resource unit price

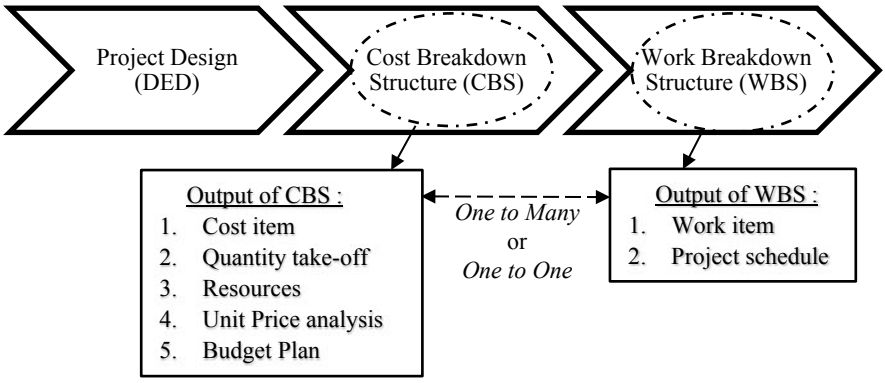

Fig. 1 The overview of construction database

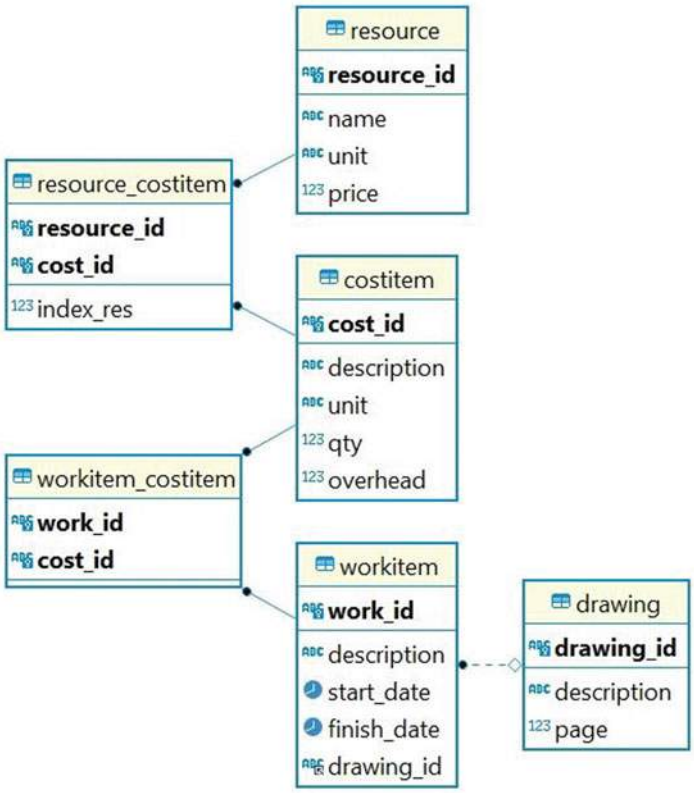

Fig. 2 ER diagram for construction database

5. Table workitem_costitem, describes the relationship between work_id and cost_id
6. Table resource_costitem, is the relation between resource_id (along with index_resource) and cost id

Step Two, SQL Script

The process of joining between tables is the second step in the project database management process. SQL scripts are arranged according to the required output table form. This study will present three project management tables as a demonstration of the application of a database management system, namely the supply chain management table, project financial plans, and quantity take-off management. Table 2 SQL script to prove that a relational database can help project managers in processing construction documents better through the three tables previously mentioned.

To obtain the Table_3 with columns of resources name, unit, quantity (qty), start_date, finish_date, duration, price and cost, we can join the tables of resource, resource_costitem, costitem, workitem_costitem and workitem using attributes of

Table 2 SQL script for construction database

```
#Table 1
WITH temp(name, cost_id, unit, qty, start_date, finish_date, duration, price, cost) as
    (SELECT r.name, c.cost_id, r.unit, c.qty, MIN(w.start_date), MAX(w.finish_date),
DATEDIFF(MAX(w.finish_date), MIN(w.start_date)) as duration, r.price,
CAST(((rc.index_res*c.qty*r.price)) AS DECIMAL(14,2)) as cost
      FROM (((resource r JOIN resource_costitem rc USING(resource_id)) JOIN costitem c
USING(cost_id)) JOIN workitem_costitem wc USING(cost_id)) JOIN workitem w USING(work_id)
      GROUP BY r.name, c.cost_id, rc.index_res, r.price, r.unit)
      SELECT name, cost_id, unit, qty, start_date, finish_date, duration, price, cost
      FROM temp
        UNION
      SELECT "~TOTAL", "-", "-", "-", MIN(start_date), MAX(finish_date),
DATEDIFF(MAX(finish_date),MIN(start_date)), "-", SUM(cost)
      FROM temp
      ORDER BY name
#Table 2
WITH temp1(cost_id, cost_item, unit, qty, price, total_price, start_date, finish_date, duration) as
(WITH temp2(cost_id, cost_item, resource, unit, qty, price, start_date, finish_date) as
   (SELECT c.cost_id, c.description, r.name, c.unit, c.qty, (rc.index_res*r.price), MIN(w.start_date),
MAX(w.finish_date)
    FROM (((costitem c JOIN resource_costitem rc USING (cost_id)) JOIN resource r USING (re-
source_id)) JOIN workitem_costitem wc USING(cost_id)) JOIN workitem w USING(work_id)
   GROUP BY c.cost_id, r.name, rc.index_res, r.price
   ORDER BY c.cost_id)
     SELECT cost_id, cost_item, unit, qty, CAST(SUM(price) AS DECIMAL(14,2)) as price,
CAST((qty*SUM(price)) AS DECIMAL(14,2)) as total_price, MIN(start_date) as start_date,
MAX(finish_date) as finish_date, DATEDIFF(MAX(finish_date), MIN(start_date)) AS duration
     FROM temp2
     GROUP BY cost_id)
   SELECT cost_id, cost_item, unit, qty, price, total_price, CAST((total_price/(SELECT
SUM(total_price) FROM temp1)*100) AS DECIMAL(3,2)) as "weight (%)", start_date, finish_date, dura-
tion
   FROM temp1
     UNION
   SELECT "TOTAL", "-", "-", "-", "-", SUM(total_price), "100", MIN(start_date), MAX(finish_date),
DATEDIFF(MAX(finish_date),MIN(start_date))
   FROM temp1
#Tabel 3
SELECT DISTINCT c.cost_id, c.description as cost_item, c.unit, c.qty, w.drawing_id, d.description
FROM (costitem c JOIN workitem_costitem wc ON (c.cost_id = wc.cost_id)) JOIN workitem w ON
(wc.work_id = w.work_id) JOIN drawing d ON(w.drawing_id = d.drawing_id)
ORDER BY c.cost_id, w.drawing_id
```

resource_id, cost_id, cost_id and work_id, respectively. The price is calculated by multiplying qty with price in 'SELECT' clause, meanwhile for total cost is aggregated using 'sum function' toward the 'cost column', and in order to do that, we implement a temporary table called 'temp' using 'WITH' clause. Table_4 is composed of several columns, namely cost_id, cost_item, unit, qty, price, start_date, and finish_date. Thus, it is necessary to combine the resource_costitem, resource, workitem_costitem, and workitem tables through the attribute id of each table. To retrieve the unit price for each cost item, it is necessary to analyse the resources consisting of human resources, equipment, and material as detailed items for unit price compilers through SELECT clause, DATEIFF, and WITH clause as the formula in Table_2. In the last table is quantity take-off management, the column cost_id, cost_item, column unit, qty, drawing_id and drawing description column are presented. This is to show

Table 3 Supply chain management

Resources	Cost ID	Unit	Qty.	Start	Finish	Dur.	Unit price	Cost
Bar bender & Cutter	CS001	Ls	2 K	21-01-13	21-02-23	41	5 K	10 M
Bared steel	CS009	Kg	250	21-03-14	21-03-23	9	70 K	14.9 M
Baseplate & stiffener	CS008	Kg	200	21-03-14	21-03-23	9	14 K	3 M
Wooden glue	CA004	Kg	4.2	21-03-10	21-03-13	3	13 K	55 K
Wooden rafters	CS004	M3	500	21-02-02	21-02-23	3	3.6 M	72.5 M
Etc.	..	..	..	..	..	..	..	..
Total				21-01-01	21-04-20	109		1.42B

the relationship between each volume of work on the cost item having an association with a particular project drawing, so that the quantity surveyors can more easily calculate the quantity of buildings. Table_5 is obtained from the merging of the workitem_costitem, workitem, and drawing tables by using ORDER BY and SELECT clause.

Step Three, SQL Statement Execution

The rendering process of the SQL script for the three demo tables cannot be generated at same time, but must be executed one by one script, so that there is no failure in the execution process. Table 3 contains the types of resources used in the project along with detailed data including the volume of work, resource usage schedules and cost analysis to determine the total project value. Based on the results of the analysis in Table 3, it is also obtained 36 types of resources involved or 146 resource items after the repetition process, this shows that the construction project has a large enough order for material, equipment, and labour, so it's no wonder this will be a huge data when the project is scaled up. The next table is the project cash flow, which explains the project cost budget plan through a cost breakdown structure along with a time schedule to estimate the project cost flow during the construction process. Table 4 can also be transformed into an S-curve, which is the correlation between the accumulated costs and the project implementation time (weeks or months). Therefore, the project manager can easily control the amount of costs that must be spent within a certain time and can find out what kind of jobs and resources involved in it, [9]. Table 4 shows that of the 23 cost items, the total project value is IDR 1,420,522,875.06 with a project duration of 109 days starting from January 1 to April 20, 2021. Table 5 provides information that those cost items whose work volume is calculated based on the particular project drawing as its association. This process is part of the quantity take-off management that is usually managed by an engineer or quantity surveyor in a construction project.

Table 4 Project cash flow

Cost ID	Cost item	Unit	Qty.	Price	Total price	%	Start	Finish	Dur.
CA001	Brick laying	M2	500	149 K	74 M	5	21-03-02	2103-09	7
CA002	Stucco work	M2	500	90 K	44 M	3	21-03-10	21-03-09	7
CA003	Wooden Door and windows	M2	14.4	1 M	14 M	1	21-03-14	21-03-13	3
CS009	Steel bracing	Kg	250	630 K	15 M	1	21-03-14	21-03-23	9
CS010	Metal roof	M2	750	167 K	125 M	9	21-01-01	21-03-23	9
Etc.	..	..	..	..	..	..	..	..	
Total					1.42B	100	21-01-01	21-04-20	109

Table 5 Quantity take-off management

Cost ID	Cost item	Unit	Qty.	Drawing ID	Description
CA001	Brick laying	M2	500	AR001	Walls and stucco
CA002	Stucco work	M2	500	AR001	Walls and stucco
CA003	Wooden Door and windows	M2	14,4	AR002	Doors and window
CS009	Steel bracing	Kg	250	ST005	Roof plan
CS010	Metal roof	M2	750	ST005	Roof plan
Etc.	..	..	..	..	..

4 Conclusion

A large market in the construction industry sector must be accompanied by professional project database management. Project data including project design tables, work items, cost items, and resource lists are interrelated and generated separately. The database management system (DBMS) is a tool for managing a broad set of information effectively so that it can be accessed easily and can last a long time. Previous researchers have initiated the application of relational databases to address construction issues but their role is not significant yet, so a new approach is needed in this case. A case study through a simple residential project database was fully demonstrated in SQL language in the form of three strategic tables in the construction industry including supply chain table, the table of construction cash flow, and quantity take-off management table.

There are three stages that must be made in designing a database in SQL language. The first step is integration design, by compiling the project tables such as cost_item, work_item, resource, etc. through entity relationship diagram (ERD) with the unique

ID in each data. The next step is arranging the data analytical script to combine, classify, and analyze all of tables automatically and obtain the purposed tables. Finally, the tables in question are obtained by running the script (final step) shows that the total project price is IDR 1.42 billion with a project duration of 109 days. Furthermore, resource types and project scheduling can also be identified properly.

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References

1. T. B. Research Comp (2020) Global construction market, the business research company, Philadelphia, USA
2. Halpin DW, Senior BA (2011) Construction management fourth edition, Colorado. Wiley, USA
3. Haynes ME (2002) Project management practical tools for success. Axzo Press, Arkansas
4. Fryer B (1996) The practice of construction management, 3rd edn. Blackwell Science, London
5. Institute PM (2013) A guide to the project management body of knowledge (PMBOK Guide)-fifth edition. Project Management Institute Inc., Pennsylvania
6. Oxley R, Poskitt J (1971) Management techniques applied to the construction industry, 2nd edn. Crosby Lockwood Staples, London
7. Molina HG, Ulman JD, Widom J (2009) Database systems the complete book, 2nd edn. Pearson Prentice Hall, New Jersey
8. Sumanthi S, Esakkirajan S (2007) Fundamentals of relational database management systems. Springer, Tamil Nadu
9. Khosiin MW, Wang KC, Wijatmiko I, Wang HH, Wang WC (2019) S-Curve development model by integrating Taiwanese and Indonesia Practices. In: The 23rd Symposium on construction engineering and management, Taichung, Taiwan
10. Li J, Moselhi O, Alkass S (2006) Internet-based database management system for project control. Eng Constr Archit Manag 13(3):242–253
11. He X, Liu R (2020) A relational database scheme of construction cost tracking from BIM model to final costs. In: American association of civil engineering, Florida, USA
12. Thi Le HT, Likhitruangsilp V, Yabuki N (2020) A BIM-Integrated relational database management system for evaluating building life-cycle costs. Eng J 75–86
13. Bilgin G, Eken G, Dikmen I, Birgonul MT (2015) A relational database for construction delay. In: Eighth international conference in the 21st Century, Thessaloniki, Greece
14. Zhang N, Song W (2016) Database design on construction project cost system. In: 3rd International conference on materials engineering, manufacturing technology and control (ICMEMTC), Jinzhou, China