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Project Management and Cost Optimization in QR Code-Based Parking Reservation System Development: A PERT, Monte Carlo and PMBOK Approach

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***Abstract*—This study investigates project cost optimization through a quantitative case study on the development of an in-house parking reservation system using QR code technology, utilizing a descriptive-quantitative method based on the PMBOK (Project Management Body of Knowledge) framework. Project activities were systematically organized using a Work Breakdown Structure (WBS) to enhance clarity and task accountability. To improve cost efficiency and support data-driven decision-making, PERT (Program Evaluation and Review Technique) cost analysis was applied to refine cost estimates based on optimistic, most likely, and pessimistic scenarios. Following this, Monte Carlo simulation was employed to assess cost uncertainty and variability, providing a probabilistic range of possible outcomes. The simulation results revealed a significant reduction in projected human resource costs from IDR 748 million to IDR 403 million, with a 95% probability that the actual total project cost would fall within this range. These findings offer a more realistic and risk-aware estimation for project budgeting and planning. Furthermore, robust risk management strategies and proactive stakeholder engagement contributed to informed decision-making, enhanced transparency, and overall project success.**

***Index Terms*—Project Management; Qr Code Technology; Parking Reservation System; PERT Cost Analysis; Monte Carlo Simulation**

I. INTRODUCTION

The rapid advancement of technology has significantly transformed various sectors, including urban infrastructure and management. The growing demand for efficient parking solutions in urban areas has led to the need for more sophisticated management systems. Traditional parking reservation methods, often characterized by manual processes and limited accessibility, are becoming inadequate to meet modern requirements. The adoption of QR code technology offers a streamlined approach to parking reservations, enabling users to book and manage their parking spaces with ease and precision. However, the successful implementation of such a system requires careful project management to address various challenges, including technical integration, resource allocation, risk management, and stakeholder coordination.

QR Code is a method that converts textual information into two-dimensional codes, which are then printed on a more compact medium. QR Code is a form of bar code that can be scanned and interpreted using a mobile phone camera [1].

As concluded by Farooq et al. “Many studies have indicated that insufficient skills, a lack of understanding in key knowledge areas, or the inability to effectively use modern tools by the project manager primarily cause project failures and delays. Consequently, these project managers struggle to effectively apply project management methods throughout the project life-cycle” [2].

To address these challenges effectively, it is crucial to implement robust project management practices that encompass all phases of the project life-cycle. This includes thorough planning, clear definition of project objectives, detailed scheduling, efficient resource management, and proactive risk management. In addition, ensuring that all stakeholders are engaged and their needs are addressed is vital for the successful deployment of the QR code-based parking reservation system.

Numerous strategies have been suggested to assist in human resource scheduling and allocation using models that incorporate triangular constraints. These approaches include optimizing project duration, reducing project costs, enhancing revenue, or improving efficiency [3]. In the human resource management, study says that “Strategic human resource planning is crucial for effective construction

project management. Proper planning and allocation of human resources significantly enhance overall project performance" [4]. Therefore, managers must focus more on how their team operates as a cohesive unit, while assessing collaboration and communication skills, as these factors directly affect teamwork performance.

In addition to human resource management, project cost management also plays a crucial role in the success of a project. Successful project cost management demands precise budget forecasts, continuous oversight, and the flexibility to modify plans as needed. Without adequate control, cost overruns and delays frequently impede the smooth execution of the project. Numerous study says that poor budget estimation can cause cost overrun. According to statistics, about 25% of all software projects that are started are completed on time, another 25% are cancelled, and about 50% of projects are completed over budget or late [5]. Another study says "Project success is described through three main factors: cost, quality, and project implementation time" [6]. Foroutan Mirhosseini et al. (2022) identified factors that influence cost increases in the planning phase, including: Inaccurate estimation, ineffective project management, technological advancements, and changes or variations in staffing [7]. But not all of the study says cost overrun makes project delayed or canceled. Ning Nan & Harter. (2009) says "development team get motivated and can catch up with the schedule when the project comes to get cost overrun" [8].

Effective project planning and scheduling can greatly enhance project performance in every industry. By dedicating more effort to planning, scheduling, and control, project performance can be significantly improved and also can avoid project become over budgeting.

In the context of this project, the application of QR code technology aims to simplify the reservation process and enhance user convenience by allowing real-time booking and management of parking spaces. The integration of this technology into an in-house system demands meticulous attention to technical details and coordination among various teams. Effective project management is not only essential for overcoming technical hurdles, but also for ensuring that the system meets the desired operational standards and delivers value to both users and stakeholders.

II. METHOD

A. Project Management Body Of Knowledge

The Project Management Institute (PMI) has significantly contributed to the establishment of standards and documentation of project management practices. Their widely accepted Project Management Body of Knowledge (PMBOK) is a comprehensive resource detailing standards, guidelines, and best practices for project management. The PMBOK, published by PMI, encompasses a range of globally recognized processes, tools, techniques, and methodologies designed to aid project managers in effectively overseeing projects. The guide is structured around several key knowledge areas, including scope, time, cost, quality, resource, communication, risk, procurement, and stakeholder management.

The PMBOK acts as an essential resource for achieving Project Management Professional (PMP) certification and is widely adopted by organizations to enhance project success and consistency in project management practices. The PMBOK is structured around several key knowledge areas essential for successful project management:

- Scope Management: Defines and controls what is included and excluded in the project.
- Time Management: Involves planning and controlling the schedule to ensure timely completion.
- Cost Management: Encompasses budgeting and controlling project costs to stay within financial constraints.
- Quality Management: Guarantees that the project deliverables meet the necessary standards and satisfy stakeholder expectations.
- Resource Management: Focuses on the efficient allocation and utilization of human and material resources.
- Communication Management: Involves the effective dissemination of information among project stakeholders.
- Risk Management: Recognizes, evaluates, and addresses risks that could affect the project.
- Procurement Management: Manages the acquisition of goods and services from external sources.
- Stakeholder Management: Involves engaging and managing relationships with all parties affected by the project.

In working on a project, it is important to follow a structured foundation. Figure 1 describes the project life cycle, which serves as the general framework for project execution.

This study focuses on optimizing project cost and improving efficiency during the development of an in-house parking reservation system using QR code technology. To guide the investigation, the following research questions are proposed:

- How can structured project management approaches improve project cost efficiency?

- How effective are PERT and Monte Carlo methods in estimating and controlling project costs?

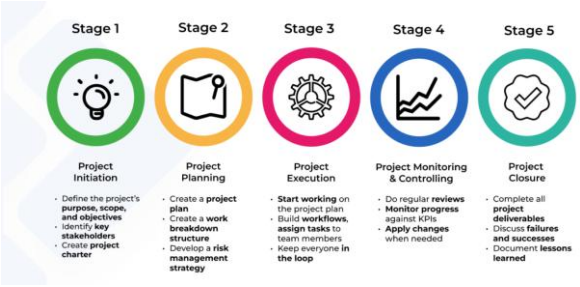

Fig. 1. Project Life Cycle

B. *Project Initiation*

Project initiation is the first phase in the project life-cycle, designed to lay a strong foundation for the project. This stage encompasses several crucial steps to ensure the project has a clear objective and receives support from all stakeholders. In a traditional organizational structure, project initiation involves the mobilization of resources across various organizational units to achieve objectives within a defined timeframe, under the supervision of a project manager [9]. The initial step in starting a project is to identify the problem or potential benefit that the project seeks to address. This involves a thorough examination of the problem or opportunity, coupled with consultations with stakeholders to gain a clear understanding of their requirements.

After identifying the need or opportunity, the next step is to create a business case. This document outlines the project's benefits, costs, risks, and objectives, providing a rationale for why the project should proceed and how it will benefit the organization. The business case is then evaluated through a feasibility study to assess whether the project is viable from technical, economic, and operational standpoints. This study ensures that risks can be managed and that necessary resources are available.

C. *Project Planning*

Project planning is the second stage in the project life-cycle, focusing on detailing how the project will be executed and managed. This stage is crucial as it ensures that all project aspects are thoroughly planned, thereby minimizing risks and enhancing the likelihood of success. A key component of project planning is developing a comprehensive project plan, which addresses various elements such as project objectives, timeline, funding, standards, assets, and potential issues, communication, and procurement.

The project scope is meticulously defined to identify and document all necessary tasks, including the development of a Work Breakdown Structure (WBS) that divides the project into more detailed, actionable tasks. WBS is a crucial tool and technique in scope management within project management [10]. Another essential element is project scheduling, which lists all tasks in chronological order and establishes their interrelationships, resulting in a project schedule that indicates when each task should start and finish, and identifies the risky path that determines the project's overall duration.

Communication is a vital tool in project management, and a project's success depends significantly on how effectively its communication system operates. As time goes by, communication becomes increasingly important and central to all management processes [11]. The project communication plan describes how information will be distributed to stakeholders and the project team, including the frequency and methods of communication to be used, ensuring that all parties receive timely and transparent information. Procurement planning identifies the need for purchases or contracts with third parties and outlines the process for acquiring and managing these goods or services.

By creating a thorough and structured project plan, the planning phase ensures that all project aspects are thoughtfully considered and planned. This approach not only facilitates more effective project management, but also provides clear guidance for the project team in executing their tasks. Effective planning is crucial for achieving successful project outcomes, as it helps identify potential issues early on and provides strategies to address them before they escalate. But it is also necessary to know the focus on project planning varies according to the project's size and the type of product being developed. However, regardless of the project type, short-term planning for sprints is consistently conducted [12].

D. *Project Execution*

Project Execution is the third stage in the project life-cycle, concentrating on implementing the project plan developed during the planning phase. During this phase, all planned activities are carried out to produce the project's deliverable. It is also the phase where most of the budget and resources are utilized, making effective management crucial to keep the project on track and achieve its objectives.

The execution phase involves coordinating between the project team and stakeholders to carry out the tasks outlined in the project schedule. The project manager has a vital role in leading the team, managing resource allocation, and overseeing the implementation of day-to-day activities. Effective communication is crucial at this stage to keep all team members and stakeholders updated on project progress, changes, and any emerging issues. Regular meetings, status reports, and online collaboration tools are commonly used to facilitate smooth communication.

The primary goal of the execution phase is to produce project outputs that meet the defined objectives and specifications. The success of this phase largely depends on the project team's collaboration, the project manager's ability to manage resources and resolve issues, and the adaptability of the project plan in response to changes and challenges. With effective management, the execution phase can ensure the project progresses smoothly and deliverable align with stakeholder expectations.

E. Project Monitoring And Controlling

Project Monitoring and Controlling is a stage in the project life-cycle that operates alongside the execution phase. This stage aims to ensure the project is proceeding as planned, meeting its objectives, and adhering to quality standards. It involves ongoing monitoring of project performance, evaluating work outcomes, and make the required adjustments to keep the project on track.

A key aspect of monitoring and controlling is measuring project performance. Project managers utilize various methods and strategies to collect performance information, such as earned value analysis (EVA), key performance metric (KPM), and status reports. The data is subsequently matched against the project plan to detect any discrepancies or variances.. For instance, if the project encounters delays or exceeds its budget, corrective actions can be implemented to resolve the issue.

Project control also encompasses change management. Changes in a project are often unavoidable, whether they pertain to scope, schedule, cost, or quality. The change control process ensures that we thoroughly evaluate all proposed changes, obtain approval from relevant stakeholders, and document them properly. This helps maintain project stability and prevents changes from negatively impacting the project's overall success.

Additionally, risk management is a crucial component of monitoring and controlling. Risks identified during the planning stage are continuously monitored, and mitigating actions are implemented if they occur. Risk monitoring also involves identifying new risks that may arise during project execution, and assessing their impact on the project. Effective risk management helps minimize potential obstacles and ensures the project's successful completion.

F. Project Closure

Project Closure is the final stage in the project life-cycle, signaling the formal completion of all project activities. The main goal of this stage is to confirm that all deliverable have been completed and delivered according to the specifications and that all project objectives have been met. Additionally, this phase aims to formally conclude all project activities and ensure that all resources utilized during the project are released and reassigned as necessary within the organization.

One of the initial steps in project closure is the verification and acceptance of deliverable. The project team collaborates with stakeholders to make sure that all project results meet the defined conditions and standards. This process often includes final testing, inspections, and obtaining approval signatures from relevant stakeholders. Once confirmation is received that deliverable have been accepted, the project is considered formally completed.

The next step involves preparing project closure documentation. This includes a final project report that summarizes the project's performance, results achieved, and lessons learned throughout the project. The report typically features variance analysis, highlighting differences between the initial plans and actual outcomes, and offers recommendations for future projects. Additionally, all project documents, such as contracts, financial statements, and correspondence, are archived for future reference.

Project evaluation is also a crucial component of project closure. This involves a final evaluation of the project's outcomes as well as the effectiveness of the project team. This evaluation is often conducted through a closing session where the project team and stakeholders review what went well and identify areas for improvement. This session helps to capture lessons learned that can be used to enhance performance and results in future projects.

The project closure phase occurs when the achieved requirements and goals align with the agreement between the product owner and the team. At this point, the final version of the product is prepared for release and distribution. Additionally, all necessary documentation and user manuals are completed and ready [13].

G. PERT

The PERT (Program Evaluation and Review Technique) method is a project management approach that utilizes statistical analysis to predict task completion times. It serves as a fundamental framework for scheduling and cost estimation. However, since construction projects are inherently uncertain, advanced modeling techniques are necessary to precisely estimate the Most Likely (M), Pessimistic (P), and Optimistic (O) values. These estimates are essential for effective resource allocation and project planning [14]. The most likely estimate represents a projection based on the assumption that both advantageous and disadvantageous conditions will occur in a balanced and realistic manner. A pessimistic estimate refers to a projection made under the assumption that all adverse conditions prevail, where every potential threat materializes and no opportunities are realized. An optimistic estimate refers to a projection made under the assumption that

all favorable conditions prevail, wherein every opportunity is realized and no adverse events or threats occur [15].

Although PERT is commonly applied in project time management to evaluate and review project durations, it can also be extended to project cost management. In this context, what is originally referred to as the optimistic estimate assuming all favorable conditions will occur translates into the lowest possible project cost. Similarly, the most likely and pessimistic estimates represent, respectively, the expected cost under balanced conditions and the highest potential cost when all unfavorable factors are assumed to take place.

PERT, also referred to as the Back Research Technique, utilizes time as a key variable in planning, scheduling, organizing, coordinating, and controlling uncertain activities, while also defining performance specifications [16]. A central aspect of PERT is its ability to account for uncertainties in the duration of activities during the analysis [17].

Using PERT in project management, project manager can identify potential risks, optimize workflow and improve decision-making for the project. The PERT method also promotes a more structured and analytical approach to project execution. By breaking down complex project into smaller and manageable tasks. Besides that, the method improve coordination between stakeholders with valuable insights into potential risks and uncertainties, ensuring the project are completed within the expected timeframe and budget.

The formula used for PERT-based cost estimation is as follows:

$$\text{PERT Cost Estimate} = \frac{O + 4M + P}{6} \quad (1)$$

Where:

- O = Optimistic cost which can be interpreted as the lowest possible cost
- M = Most likely which means normal cost
- P = Pesimistic cost which means highest possible cost

This formula enables project managers to obtain a weighted average of the estimated project cost, giving greater emphasis to the most likely cost while still accounting for best-case and worst-case scenarios. By incorporating uncertainty into the estimation process, the PERT method enhances the accuracy of budget forecasts and supports more effective cost planning and risk management throughout the project life-cycle.

H. Monte Carlo Simulation

The Monte Carlo method is a problem-solving approach that deals with stochastic characteristics by utilizing repeated statistical experiments. This method relies on a probabilistic model, aligning with the processes defined by the model, to generate simulation test results as an estimated solution to the problem [18]. Monte Carlo method is widely used in various field, including finance and engineering. As Abu Bakar and Rosbi did in their journal *Monte Carlo Simulation for Data Volatility Analysis of Stock Prices in Islamic Finance for Malaysia Composite Index* [19]. They use monte carlo simulation method to assess the fluctuation rate of Sharia-compliant companies in the Malaysia Stock Exchange.

Monte carlo used to analyze complex system, optimize decision-making and assess risk by simulating numerous possible outcomes. By running a large number of simulations, the monte carlo method allows project manager to understand uncertainties. Additionally, this method allows businesses, scientists, or anyone who used it to explore different scenarios, evaluate potential risks, and develop robust strategies based on probability distributions rather than fixed assumptions. As Tokdemir et al. state in their paper, Monte Carlo simulation generates a probability distribution of potential outcome values after multiple iterations and Monte Carlo simulation allows decision-makers to estimate the likelihood of meeting project objectives and to analyze the differences between the base case scenario and both the best- and worst-case outcomes [20]. As shown in [21], the Monte Carlo method can yield more accurate results than other uncertainty analysis models while using less sample data.

III. RESULT AND DISCUSSION

In this section, we examine the outcomes of implementing project management in the development of QR code-based parking reservation system.

A. Conceptual Framework

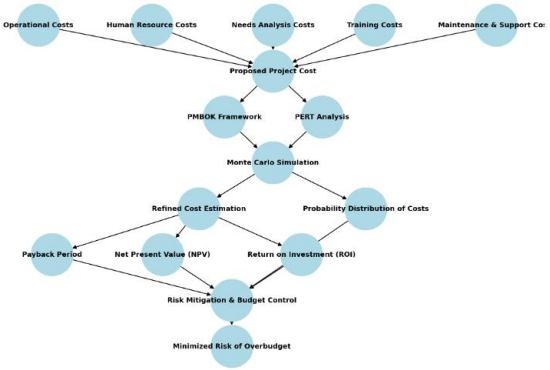

Fig. 2. Conceptual Framework

In the conceptual framework used describes how the risk of cost overrun in a project can be reduced

with the PMBOK Framework, PERT and Monte Carlo Simulation approach. Here is an explanation of each part:

- *Cost Factor*

There are several factors affect the Proposed Project Cost, including Operational Costs, Human Resource Costs, Needs Analysis Costs, Training Costs and Maintenance & Support Costs. This factors are the main elements that determine the initial cost of Proposed Project Costs. Precise of initial costs is crucial, as errors at this stage can cause to budget inconsistencies, potentially resulting in cost overrun or insufficient funding.

- *Cost Management Method*

Once a project has an initial cost estimate, the PMBOK framework and PERT Analysis methods are used to improve the accuracy of planning cost. PMBOK framework provides a systematic approach to project cost management and PERT Analysis is used for estimating project duration and cost by considering optimistic, pessimistic and realistic scenarios.

- *Monte Carlo Simulation*

The result of PERT Analysis are used in monte carlo simulation which will simulate possible cost distributions based on various scenarios, generated refined cost estimation and provide probability distribution of costs to understand cost risk statistically. And generate Payback Period, NPV and Return of Investment.

- *Risk Mitigation and Budget Control*

Based on monte carlo simulation result, we can implement risk mitigation and budget control to reduce uncertainty in project costs and improve the accuracy of budget control.

B. Project Charter

TABLE I. PROJECT CHARTER TABLE

Project Title	: :	Sistem Reservasi Parkir Inap
Project Information	: :	Start Date : February 20, 2020 Complete Date : February 20, 2021 Project Manager : Yostian Ari Sujarwo Key Stakeholders : PT. Sanggraha Daksamitra
Project Objective	:	Developing an overnight parking system using Qr Code
Project Scope	:	Building web and mobile based applications for end users Building desktop based applications for parking gate admin Integrating applications with parking gates
Project Limitation	:	This system is only built for PT. Sanggraha Daksamitra
Project Milestones	:	Web, mobile and desktop UI/UX design completed May 20, 2020 Backend development completed October 20, 2020 Backend integration with web, mobile and desktop UI completed December 2020 System testing completed February 14, 2021 Beta Release February 17, 2021 Final Release February 20, 2021
Project Budget	:	The total budget for this project is IDR 900,000,000 which includes the cost of application development and infrastructure development, testing, training, and also socialization.
Main Risks	:	Delay in project completion Integration issues with parking gates
Agreement	:	Yostian Ari Sujarwo (Jakarta, Februari 2020)

C. Project Planning

- *Requirement*

The project requirements document provides guidance on various aspects important for the implementation and success of the project. In this project it will be divided into 2 specifications, namely: a) Functional Specification; b) Non Functional Specification. Both spesification will be describe in table II and table III.

TABLE II. FUNCTIONAL SPESIFICATION

Function	Description	Requirement
Dashboard	Displaying parking lot statistics	Every user and admin in the system can see the availability of parking lots.
User Management	Displaying user information	Each user can change information about themselves. Admin can disable problematic users
Reservation	Displaying reservation information	Each user can see the reservation information that is ongoing or has occurred. Each staff can see the reservations that the user made
Shuttle Bus	Displays shuttle bus schedule information	Every user can see the shuttle bus schedule. Admin can change the shuttle bus schedule
Report	Displays information about financial reports	Each staff can view financial reports and print financial reports.

TABLE III. NON FUNCTIONAL SPESIFICATION

Category	Specification	Detail
Performance	Response Time	
	Home Page	< 1 second for standard internet
	Parking Reservation	< 3 seconds for parking reservation
Scalability	Horizontal Scaling	

	Infrastructure	Supports dynamic addition of additional servers
	Vertical Scaling	
	Server	Ability to increase CPU, RAM and storage capacity
Security	Authentication	
	Authentication Method	Token-based authentication and 2FA
	Session Management	User sessions expire automatically after 10 minutes of inactivity.
	Encryption	
	Data	Encryption of sensitive data in storage and transmission
	SSL Certificate	Use of SSL certificates for secure communications
Availability	Operational Hours	
	SLA	99.9% within one year; planned downtime < 1 hour per month
	Backup	
	Backup Frequency	Automatic backup every night
	Recovery	Data recovery within < 1 hour after failure
Maintenance	Updates	
	Update Frequency	Automatic software and security update
	Compatibility	Updates are compatible with supported hardware and software.
	Monitoring	
	System Log	Activity and error logging
	Monitoring Tools	Real-time performance and availability monitoring

- *Work Breakdown Structure*

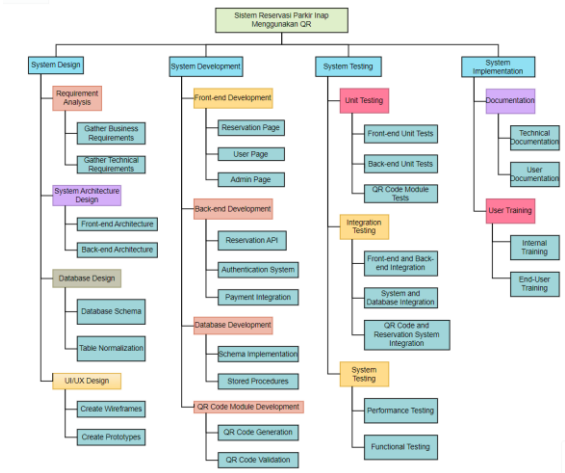

Fig. 3. Work Breakdown Structure

Fig 3 shows the work breakdown structure developed by the author based on the actual project tasks. The tasks are divided into four main categories: system design, system development, system testing, and system implementation.

D. Project Schedule Management

- *Management Approach*

A management approach is a systematic framework designed to help organizations manage projects, processes, or daily operations effectively and efficiently. It starts with establishing SMART (specific, measurable, achievable, relevant, and time-bound) targets and aims. Following goal-setting, strategic and operational planning is conducted to develop both long-term and short-term plans that include a vision, mission, strategy, and resource allocation. This phase also involves risk management to identify, analyze, and plan for potential risks during implementation.

Next, the approach focuses on organizing and allocating resources by setting up an effective organizational structure and managing assets such as personnel, funds, equipment, and technology. During the implementation phase, project management techniques are used to lead the team, manage activities according to the schedule, budget, and quality standards, and ensure effective communication with stakeholders.

The management approach also emphasizes full documentation and reporting, including performance reports and lessons learned. It supports continuous improvement through the Kaizen principle, where feedback from evaluations is used to refine future processes and approaches. By following this structured and systematic approach, organizations can efficiently achieve their goals, manage resources effectively, and mitigate risks during project or operational execution.

- *Scheduling Methodology*

Scheduling methodology is a structured approach for planning, organizing, and managing time and resources needed to complete a project efficiently. The process begins with determining the tasks and activities required to accomplish the project's objectives. Each task is detailed, including its duration, order, and dependencies.

Next, the project schedule is developed using tools like Gantt charts or network diagrams, along with methods like the Critical Path Method (CPM) or the Program Evaluation and Review Technique (PERT). Gantt charts offer a visual overview of the project timeline, detailing the tasks to be completed and the time assigned to each. CPM and PERT assist in identifying the critical path—the series of tasks that influence the project's total duration and cannot be postponed without impacting the project's completion.

- *Critical Path Method (CPM)*

Critical Path Method (CPM) is a project management method used for plan, schedule, and control project activities. According to [22], CPM is a method of analyzing project networks that focuses on optimizing the cost or budget of a project by reducing or accelerating the project's completion time. CPM identifies the longest sequence of dependent tasks in a project, referred to as the critical path, which governs

the overall duration of the project. Tasks on this critical path must be finished on time to ensure that the project meets its deadline.

By pinpointing these critical activities, the project manager can allocate resources and focus appropriately to keep the project on schedule. CPM involves constructing a network diagram to illustrate the sequence and dependencies of tasks, and determining the start and finish times for each activity. It also helps identify float or slack time, which is the allowable delay in non-critical tasks without affecting the entire project timeline. Consequently, CPM is a valuable tool for effective project planning and management, assisting in achieving project goals within the planned schedule. The following is a CPM table for a parking reservation system.

TABLE IV. CRITICAL PATH METHOD

Task	Duration(week)	Dependency(week)
Needs Analysis	1	-
System Design	3	1
Frontend Development	9	2
Backend Development	24	4
QR Code Integration	5	1
System Testing	8	1
User Training	1	2
System Launch	1	1

- *Program Evaluation and Review Technique (PERT)*

PERT (Program Evaluation and Review Technique) is akin to CPM (Critical Path Method) but focuses more on addressing uncertainties in estimating activity durations. PERT uses three different duration estimates: (a) -optimistic duration (b) -pessimistic duration, and most probable duration. This method creates a network model that incorporates these uncertainties and enables probability analysis of project completion times.

Fig. 4 presents the PERT diagram created based on project tasks, illustrating the sequence of activities and the estimated duration range for each. This diagram supported better planning and risk mitigation, especially in identifying activities on the critical path.

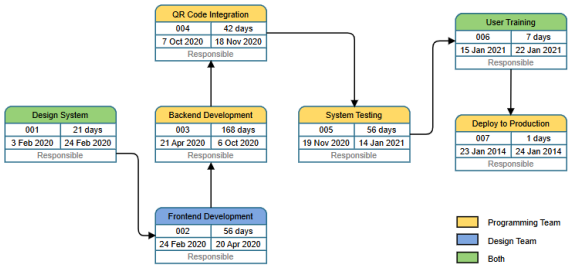

Fig. 4. PERT Diagram

E. Project Cost Management

- *Project Cost*

Project cost refers to the total amount of expenditure needed to finish a project. This comprises several components like personnel, supplies, tools, and other operational costs. Additionally, it accounts for unforeseen costs, including risk and contingency expenses. Effective cost management requires meticulous planning, continuous monitoring, and required modifications to keep the project on budget while maintaining quality and achieving the desired outcomes.

TABLE V. PROPOSED PROJECT COST

No	Cost	Year 0	Year 1	Year 2	Year 3
1	***Operational Cost***				
	Promotion	Rp. 10,000,000	Rp. 5,000,000	Rp. 3,000,000	-
	Server	Rp. 100,000,000	Rp. 100,000,000	Rp. 100,000,000	Rp. 100,000,000
	Total Operating Costs	Rp. 110,000,000	Rp. 105,000,000	Rp. 103,000,000	Rp. 100,000,000
2	***HR Costs***				
	Project Manager	Rp. 180,000,000	-	-	-
	Programmer	Rp. 324,000,000	-	-	-
	System Analyst	Rp. 120,000,000	-	-	-
	Business Analyst	Rp. 100,000,000	-	-	-
	Tester	Rp. 24,000,000	-	-	-
	Total HR Cost	Rp. 748,000,000	-	-	-
3	***Needs Analysis Cost***				
	Analysis of user and stakeholder needs	Rp. 5,000,000	-	-	-
	Total Cost of Needs Analysis	Rp. 5,000,000	-	-	-
4	***Training Cost***				
	User training	Rp. 5,000,000	-	-	-
	Total Training Cost	Rp. 5,000,000	-	-	-
5	***Maintenance and support cost***				
	System maintenance and support	-	Rp. 10,000,000	Rp. 15,000,000	Rp. 20,000,000
	Parking gate maintenance	-	Rp. 6,000,000	Rp. 6,000,000	Rp. 8,000,000
	Total Cost of Maintenance and Support	-	Rp. 16,000,000	Rp. 21,000,000	Rp. 28,000,000

	Total cost	Rp. 868,000 ,000	Rp. 121,000 ,000	Rp. 124,000 ,000	Rp. 128,000 ,000

- *Pert Analysis*

After we have activity pert diagram and proposed project cost, the next step is to perform a detailed breakdown of tasks and resources. This involves estimating the cost of each activity, allocating necessary resources, and aligning the cost estimates with the project schedule to ensure efficient planning and execution. First of all, we need to breakdown the HR costs.

TABLE VI. HR COSTS

No	Position	Salary(million)	Period(month)
1	Project Manager	15	12
2	System Analyst	12	10
3	Business Analyst	10	10
4	Frontend Programmer	13	12
5	Backend Programmer	14	12
6	Tester	8	3

The table above explains the component of human resource costs required in this project. Each row represents one position involved in the project, along with the estimated monthly salary and period of involvement of the personel. It is also important to note that not all roles are engaged for the entire duration of the project. Key positions such as the Project Manager, Frontend Programmer, and Backend Programmer are involved throughout the full implementation period (12 months), ensuring continuous oversight and development. In contrast, roles such as the Tester are only required for specific phases particularly in the final stages of the project resulting in a shorter engagement period of only 3 months.

The next step is to conduct a PERT analysis to ensure that the planned costs correspond accurately with the project's scheduled activities and overall duration.

TABLE VII. MAPPING COST TABLE

No	Activity	Optimistic (Million)	Most Likely (Million)	Pesimistic (Million)	Position
1	Design System	21	31.08	50.4	System Analyst, Business Analyst, Project Manager
2	Frontend Development	38.08	62.72	94.08	Frontend Developer, Project Manager
3	Backend Development	117.6	194.88	288.96	Backend Developer, Project Manager
4	QR Code Integration	29.4	48.72	72.24	Backend Developer, Project Manager
5	System Testing	33.6	51.52	82.88	Tester, Project Manager
6	User Training	2.8	4.2	7	Project Manager
7	Live Production	0.98	1.68	2.4	Frontend Developer, Backend Developer, Project Manager
	Total	**243.96**	**394.80**	**597.96**	

The table above explains optimistic, most likely and pesimistic cost from activity pert diagram, Right now some, key position like frontend programmer and backend programmer are not involved the full implementation period, only project manager that involved the full implementation period. It's because when divided into several acitivities, only project manager that involved in the full implementation period. The table also explains about salary that given to each position has been change, from salary that pay per month to salary pay per day. The next step is to implement pert to every aspect in mapping cost table.

TABLE VIII. PERT ESTIMATION COST

No	Activity	Estimation Cost(Million)
1	Design System	32.94
2	Frontend Development	63.61
3	Backend Development	199.68
4	QR Code Integration	49.26
5	System Testing	53.10
6	User Training	4.48
7	Live Production	1.68
	Total	404.75

The table above shows the estimated cost of each project activity based on PERT method. PERT is used to calculate the cost estimate by considering three possible scenarios. Through this approach, a weighted average cost estimate is obtained for each activity, which provides more realistic cost planning result than using only one estimated value.

- *Monte Carlo Simulation*

Monte Carlo simulation is used to simulate various possible total project cost based on PERT cost estimates of each activity. The result of this simulation

provide a probabilistic distribution of total project cost.

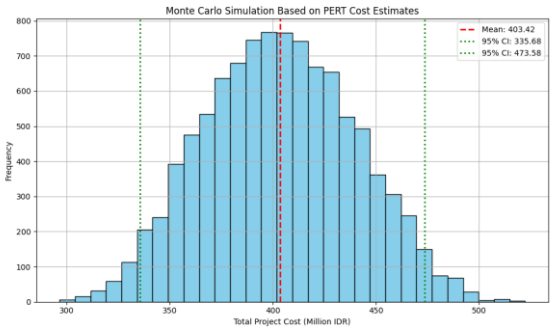

Fig. 5. Monte Carlo Simulation For Total Cost

After performing 10,000 simulations, the Monte Carlo simulation resulted in a mean estimated project cost of 403.42 million IDR, with a 95% confidence interval ranging from 335.68 to 473.58 million IDR. This indicates that there is a 95% probability that the actual total project cost will fall within this range, providing a more realistic and risk-aware cost estimation for project planning. Fig 6 will show cost for every activity in pert cost estimates.

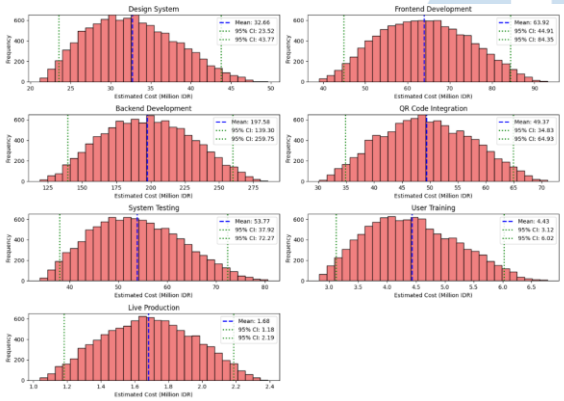

Fig. 6. Monte Carlo Simulation For Every Activity

Fig 6 illustrates the cost distribution for each individual project activity based on 10,000 Monte Carlo simulations using PERT estimates. Each histogram shows the variability and uncertainty of the cost for a specific activity, along with the mean (blue dashed line) and the 95% confidence interval (green dotted lines). The visual representation highlights which activities have higher cost uncertainties and can help identify components with the greatest impact on overall project risk and budget planning.

- *Refined Cost Estimation*

Refined cost estimation is performed to obtain more realistic and accurate cost of the development of the qr parking system. In this process, the PERT approach and monte carlo simulation are used specifically of the hr cost component. Other cost, such as operational costs, need analysis, training, and system maintenance and support are still referred to the initial plan because they have a lower level of uncertainty and have a fixed cost.

TABLE IX. REFINED PROJECT COST

No	Cost	Year 0	Year 1	Year 2	Year 3
1	***Operational Cost***				
	Promotion	Rp. 10,000,000	Rp. 5,000,000	Rp. 3,000,000	-
	Server	Rp. 100,000,000	Rp. 100,000,000	Rp. 100,000,000	Rp. 100,000,000
	Total Operating Costs	Rp. 110,000,000	Rp. 105,000,000	Rp. 103,000,000	Rp. 100,000,000
2	***HR Costs***				
	Project Manager	Rp. 199,990,000	-	-	-
	Programmer	Rp. 157,800,000	-	-	-
	System Analyst	Rp. 10,590,000	-	-	-
	Business Analyst	Rp. 10,590,000	-	-	-
	Tester	Rp. 26,450,000	-	-	-
	Total HR Cost	Rp. 403,420,000	-	-	-
3	***Needs Analysis Cost***				
	Analysis of user and stakeholder needs	Rp. 5,000,000	-	-	-
	Total Cost of Needs Analysis	Rp. 5,000,000	-	-	-
4	***Training Cost***				
	User training	Rp. 5,000,000	-	-	-
	Total Training Cost	Rp. 5,000,000	-	-	-
5	***Maintenance and support cost***				
	System maintenance and support	-	Rp. 10,000,000	Rp. 15,000,000	Rp. 20,000,000
	Parking gate maintenance	-	Rp. 6,000,000	Rp. 6,000,000	Rp. 8,000,000
	Total Cost of Maintenance and Support	-	Rp. 16,000,000	Rp. 21,000,000	Rp. 28,000,000
	Total cost	Rp. 523,420,000	Rp. 121,000,000	Rp. 124,000,000	Rp. 128,000,000

- *S-Curve*

A S-curve is a graphical tool commonly applied in project management to illustrate the progress of work or the usage of resources over time. It is named for its characteristic "S" shape, which reflects the typical progression pattern of a project. Initially, progress is slow as the project starts with planning and setup. As core tasks are executed and resources are heavily engaged, the rate of progress accelerates. Finally, as the project approaches completion, the rate of progress

decelerates, with the focus shifting to finishing touches and final inspections.

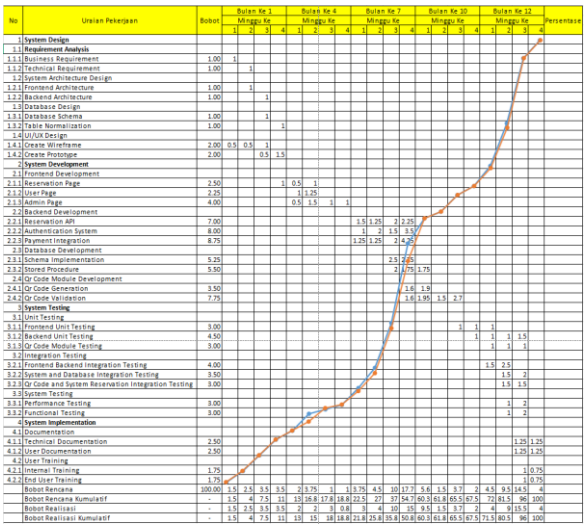

Fig. 7. S-Curve

- *Payback Period*

The payback period is the duration needed to recoup the initial investment in a project or investment through the generated cash inflows. It is determined by summing the annual cash inflows until the cumulative amount matches or surpasses the initial investment. A shorter payback period indicates a quicker recovery of the investment, which is typically preferred due to reduced risk and uncertainty.

TABLE X. PAYBACK PERIOD

Year	Cash Inflow(million)	Cash Outflow(million)
0	0	523.42
1	200	121
2	275	124
3	340	128
4	500	133

From the table above, we can see that the initial investment of 523.42 million will be returned between Year 2 and Year 3. The detailed calculation for Year 2 is as follows:

a) Cumulative total after Year 2 = 475 million.

b) The remaining amount needed to recover the initial investment of 523.42 million after Year 2 is 523.42 million - 475 million = 48.42 million.

c) The payback period occurs in Year 3, with an estimate of 2 years and 1.7 months.

- *Net Present Value (NPV)*

Net Present Value (NPV) is a financial analysis method used to determine the present value of a project's, investment's or accounting future cash flows for the initial investment cost and the discount rate. NPV helps assess whether a project or investment will yield a positive return after considering the cost of capital and associated risks. Below is the NPV table for a parking system.

TABLE XI. NPV

Year	Cas Inflow(million)	Discount Factor(10%)	Discounted Cash Flow(million)
0	0	1.00	-523.420
1	200	0.909	71.71
2	275	0.826	124.68
3	340	0.751	159.47
4	500	0.683	250.75
Total			618.54
NPV			95.12

With NPV value > 0, which is Rp. Rp 95,120,000 the investment for the parking reservation system project is declared feasible.

- *Return Of Investment (ROI)*

Return on Investment (ROI) is a metric that evaluates the performance of an investment or compares the efficiency of different investments. It calculates net profit in relation to the initial investment cost.

Description	Amount(million)
Total Cash Inflow	815
Initial Investment Cost	523.42
Net profit	291.58
ROI	55.7%

F. Project Human Resource Management

Project Human Resource Management is an important aspect of project management that focuses on managing human resources in an effective manner to ensure the project team works efficiently and achieves its goals. The main aim is to guarantee that every team member possesses the essential skills, knowledge, and motivation to execute the project as planned. For the parking reservation system project, the following considerations are essential:

a) Team Organization: The project requires a team comprising at least 1 Project Manager, 1 System Analyst, 3 Backend Developers, and 1 Frontend Developer.

b) Selection: Choosing the best candidates based on their skills, experience, and fit with the project's needs.

c) Motivation: Identifying what motivates team members and fostering a supportive work environment.

d) Effective Communication: Ensuring clear and open communication channels among all team members and stakeholders.

e) Conflict Management: Addressing and resolving any conflicts within the team in a constructive way.

G. Project Communication Management

Project Communication Management is a vital aspect of project management that focuses on planning, executing, and controlling effective communication among all parties involved in the project. The primary aim is to ensure that crucial

information is conveyed clearly, timely, and to the appropriate recipients. Effective communication enhances collaboration, minimizes the risk of misinformation, and ensures that all stakeholders have a consistent understanding of the project's status and objectives. For this project, the communication methods utilized by the team include WhatsApp, Google Meet, and offline meetings, with all communications occurring within a single chat group that includes 6 team members and 1 stakeholder.

H. Project Risk Management

Project Risk Management in a parking reservation system using QR includes the process of identifying, analyzing, and responding to risks that can affect the success of the implementation and operation of the system. With effective risk management, the project can minimize negative impacts and maximize the chances of success. Here are some stages in the parking reservation system:

- *Risk Identification*
  a) Technology: Risks associated with the QR system, including potential failures in QR scanning, connectivity issues, or device malfunctions.
  b) Security: Risks concerning data security, such as potential breaches of user information, cyberattacks, or misuse of data.
  c) Operational: Risks in daily operations, including reservation errors, irregular queues, or system failure under high user volumes.
  d) Stakeholders: Risks affecting user satisfaction, whether drivers using the parking service or parking management personnel.
  e) Finance: Financial risks, such as exceeding budgeted implementation costs, generating lower-than-expected revenue, or failing to meet financial targets.
  f) Regulatory: Risks related to compliance with relevant regulations and standards, including traffic laws, data protection, and information security.
- *Risk Analysis*
  a) Qualitative: Evaluating and ranking risks according to their possible impact and probability of happening. For instance, a data security risk might be categorized as high if user data is extremely sensitive.
  b) Quantitative: Evaluating the financial or operational consequences of specific risks, such as estimating the potential financial loss from a data breach.
- *Risk Response Planning*
  a) Avoid: Eliminating the risk, such as by strengthening security measures to prevent data breaches.
  b) Reduce: Minimizing the impact or probability of the risk, for example, by performing thorough system testing before deployment to reduce the chance of technical failures.
  c) Accept: Accepting the risk if its impact is minor or the cost of mitigating it outweighs the potential impact.
  d) Transfer: Shifting the risk to another party, such as through insurance or a contract with a dependable technology provider.
- *Risk Monitoring And Control*
  a) Continuous Monitoring: Keeping track of identified risks and staying alert for any new risks that may arise during the project.
  b) Corrective Action: Taking immediate steps to address the risk if it materializes, including adjusting the project plan or applying pre-established mitigation strategies.
  c) Risk Reporting: Providing regular updates on risk status to project management and stakeholders.
- *Implementation of Project Risk Management in QR Parking Reservation System:*

TABLE XII. PROJECT RISK MANAGEMENT

Risk Type	Identification	Analysis	Response	Monitoring
Technology Risk	Qr Scanning failure	High impact, medium likelihood	Implementing redundancy systems and extensive testing on various devices	Regularly checking system performance and ensuring technical support availability
Security Risk	Leakage of user data	Very high impact, medium probability	Employing data encryption, firewalls, and performing regular security audits	Monitoring system activities for suspicious behavior and providing regular reports
Operational Risk	Errors in reservation processes	Medium impact, high probability	Designing an intuitive user interface and training staff to manage errors effectively	Conducting user surveys to identify and resolve operational issues
Financial	Cost	High	Use	Revalidate

Risk	overruns	impact, medium probability	PERT Cost Analysis and Monte Carlo Simulation to develop a refined cost plan and estimate uncertainties	cost assumptions regularly and review simulation outputs to adjust financial plans

I. Project Stakeholder Management

Project Stakeholder Management involves identifying, analyzing, and managing interactions with all individuals and groups affected by or involved in a project. For a QR parking reservation system, this process aims to ensure that the needs and expectations of all stakeholders are clearly understood and addressed to achieve the project's success. Implementation of Project Stakeholder Management in a QR Parking Reservation System:

a) Project Owner: PT. Sanggraha Daksamitra.

b) Project Manager: Yostian Ari Sujarwo

c) End User: (Driver)

d) Parking Manager: PT. Sanggraha Daksamitra.

e) Technology Vendor: PT. Gama Solusi Internasional.

J. Project Closure

Project closure is the concluding phase of the project management cycle, ensuring that every aspect of the project is finalized, deliverable are approved by stakeholders, and all documentation is completed and archived appropriately. The detailed steps for closing a QR reservation system project are as follows:

- *Project Work Finalization*

a) Task Completion Verification: Confirm that all project tasks and deliverable have been completed as outlined in the project plan.

b) Final System Test: Perform final testing to ensure the QR parking reservation system meets all specified requirements.

- *Project Acceptance*

a) Stakeholder Approval: Secure final approval from all key stakeholders, confirming that the project has achieved the established success criteria.

b) Final Documentation: Prepare and finalize documentation, including the test report, user manual, and technical documentation.

- *Project Handover*

a) Training and Knowledge Transfer: Provide training to end users, such as parking operators and users, ensuring they understand how to use the system effectively.

b) System Handover: Officially transfer the QR parking reservation system to the responsible operational department or parking operator.

- *Project Evaluation*

a) Project Performance Review: Assess the project's performance by making comparisons achieved results with the original plan and objectives.

b) Lessons Learned: Document lessons learned from the project, including both successes and areas for improvement, for future reference.

- *Documentation and Filing*

a) Documentation Completion: Ensure that all project documents, such as contracts, progress reports, and meeting minutes, are complete and properly filed.

b) Final Project Report: Compile a final report summarizing project activities, results, and evaluations.

- *Project Team Disbandment*

a) Rewards and Recognition: Acknowledge and reward project team members for their contributions to the project.

b) Team Member Transitions: Facilitate the transition of project team members to new roles or back to their previous positions.

- *Closure Communication*

a) Project Closure Announcement: Officially announce the completion of the project to all stakeholders.

b) Final Report Distribution: Distribute the final project report to relevant stakeholders.

IV. CONCLUSION

This study showed that using a structured project management approach based on the PMBOK framework improved cost efficiency by providing clear task definitions, scheduling, and proactive risk control. These elements helped the project stay on track and reduced resource waste.

PERT and Monte Carlo Simulation effectively handled cost uncertainty by offering probabilistic estimates rather than fixed values. Their application led to a significant reduction in projected human resource costs from Rp748 million to Rp403 million with 95% confidence. These findings align with recent research [23], [24], which demonstrated that

simulation-based methods enhance cost estimation and risk management in complex projects.

As a recommendation for future researchers or project managers, it would be beneficial to apply PERT Cost Analysis and Monte Carlo Simulation to the entire project cost, not just human resource expenses. This broader application could offer even more accurate financial planning and reduce the risk of budget overruns across all project components.

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