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Analysis of Project Management Optimization Using CPM and PERT in a Dynamic Business Environment

Dr. Manishkumar Jaiswal[1*], Dr. Vishwajeet S. Goswami[2]

[1]*Assistant Professor, Department of Mathematics Shri Chinai College of Commerce & Economics, Mumbai, Maharashtra*

[2]*Assistant Professor, School of Engineering, Ajeenkya DY Patil University, Pune Maharashtra, India*

manish.jaiswal544@gmail.com

Abstract

In the current fast-changing business environment, organizations must remain agile and strategically responsive to unpredictable challenges such as supply chain disruptions, shifting consumer demands, and evolving market trends. Project management techniques like the Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT) serve as valuable tools in helping businesses manage these complexities effectively. CPM is a time-focused method that identifies the longest sequence of dependent tasks in a project, enabling timely completion through better scheduling. In contrast, PERT uses a probabilistic approach, incorporating multiple time estimates to address uncertainty and evaluate project risks more accurately. This study investigates the practical use of CPM and PERT within the context of the electric vehicle (EV) industry, particularly focusing on manufacturing processes and infrastructure expansion. The EV sector is experiencing rapid growth but is also confronted with numerous hurdles, including logistical constraints, regulatory pressures, and competitive market entry. By applying both CPM and PERT to a structured project framework, including a detailed activity network and timeline analysis, this research highlights how these tools aid in minimizing delays, optimizing resource use, and managing risks effectively. The analysis reveals that combining CPM and PERT allows project managers to identify critical tasks, foresee potential delays, and allocate resources more efficiently. This strategic application is especially useful in time-sensitive and innovation-driven industries like EV manufacturing. The

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study further suggests that leveraging modern technologies such as artificial intelligence (AI) and data analytics can significantly enhance project planning and execution. In conclusion, CPM and PERT continue to be instrumental in improving project outcomes and enabling organizations to adapt swiftly in a competitive landscape.

***Key-words**:* Strategic adaptation, CPM, PERT, project management, business environment, risk management, electric vehicle industry.

1.Introduction

In today's rapidly changing global economy, businesses are facing increasing complexity due to technological innovation, regulatory changes, and external disruptions such as supply chain breakdowns and geopolitical tensions. To maintain a competitive edge and ensure long-term sustainability, organizations must adopt effective and adaptable project management techniques. Among the most prominent tools available are the Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT). These methodologies provide structured and flexible frameworks for planning, executing, and monitoring projects, particularly in industries characterized by high uncertainty and innovation. CPM is known for its effectiveness in optimizing project timelines by pinpointing the critical tasks that directly impact the total project duration. By concentrating on these key activities, project managers can manage resources effectively and minimize the risk of delays. In contrast, PERT is especially beneficial when there is uncertainty in estimating task durations. It uses three different time estimates—optimistic, most likely, and pessimistic—to determine the expected time required for each activity. This probabilistic method enables project managers to evaluate risks more precisely and prepare for possible fluctuations in the project schedule[1-3].

The electric vehicle (EV) industry presents a compelling case for applying CPM and PERT. As the sector experiences rapid growth, it also faces unique challenges such as fluctuating availability of raw materials like lithium and cobalt, evolving emissions regulations, and the urgent need to develop supporting infrastructure, including charging stations. These challenges require precise planning and agile execution, making CPM and PERT valuable tools for ensuring project success. For instance, in EV manufacturing, CPM can help identify production bottlenecks, while PERT can provide insights into delays caused by supplier uncertainties or regulatory changes[5-8].

This paper investigates how CPM and PERT contribute to strategic adaptation in the EV industry. Through a detailed case study, we explore how these tools have been used to improve efficiency, manage operational risks, and support timely market entry. The analysis

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demonstrates that organizations implementing these techniques are better positioned to handle dynamic project requirements and respond to disruptions without significant delays[1-3].

Moreover, the findings suggest that integrating advanced technologies, particularly artificial intelligence (AI), can further enhance the application of CPM and PERT. AI can support predictive analytics, automate scheduling, and offer real-time insights for decision-making, thereby increasing the accuracy and responsiveness of project management. For instance, artificial intelligence algorithms can examine past project data to predict potential risks and suggest proactive measures to address them. By integrating traditional project management methods with advanced technologies, organizations can handle complex projects with increased agility and clearer foresight. In summary, CPM and PERT continue to be vital components of contemporary project management practices. Their systematic yet flexible approach makes them particularly valuable in dynamic and high-risk sectors such as the electric vehicle industry.. As global emphasis shifts toward sustainable mobility and carbon neutrality, EV manufacturers must adopt strategic project management practices to stay competitive. By leveraging CPM and PERT—augmented by AI-driven solutions—organizations can enhance their ability to plan effectively, respond to uncertainty, and ensure the successful delivery of critical projects[4-5].

Objectives of the Research

1. To analyse the effectiveness of CPM and PERT in strategic adaptation within the EV industry.
2. To evaluate the impact of these methodologies on project risk management and resource optimization.

2. Literature Review

this study explores how CPM and PERT facilitate efficient project execution in volatile markets. The findings highlight the strengths of CPM in structured scheduling and the value of PERT in uncertainty management.

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this research examines how PERT helps organizations manage risks in complex projects. The probabilistic approach of PERT allows for better contingency planning and decision-making.

the major supply chain challenges faced by EV manufacturers and highlights the importance of project management tools in addressing production and logistics issues.this paper presents case studies on how CPM has improved efficiency in manufacturing processes, reducing lead times and optimizing resources.the study discusses how PERT can be used in fast-changing industries, ensuring timely execution of technology-driven projects with multiple dependencies. this paper highlights the relevance of CPM and PERT in sustainable project management, particularly in industries focusing on eco-friendly innovations[9-11].

3. Research Methodology

This study employs a mixed-method approach, integrating both qualitative and quantitative research methods to assess the effectiveness of CPM and PERT in strategic adaptation within the electric vehicle (EV) industry.

3.1 Research Design

The research is designed as a case study analysis, focusing on real-world applications of CPM and PERT in EV manufacturing and infrastructure development. The study evaluates how these methodologies help optimize resource allocation, manage risks, and improve project execution efficiency.

3.2 Data Collection Methods

The study utilizes secondary data sources, including:

- Industry reports from Tesla Inc., International Energy Agency, and World Economic Forum
- Academic literature from peer-reviewed journals and project management studies
- Case studies of EV manufacturers implementing CPM and PERT

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- Expert interviews from industry professionals in project management and EV production

3.3 Data Analysis Techniques

- Critical Path Method (CPM) Analysis – A network diagram is developed to identify the longest sequence of dependent activities, ensuring efficient project scheduling.
- Program Evaluation and Review Technique (PERT) Analysis – Probabilistic time estimation is applied to assess project uncertainties and risk factors.
- Comparative Analysis – The effectiveness of CPM and PERT is compared using key performance indicators (KPIs) such as project completion time, cost efficiency, and risk mitigation.

3.4 Scope and Limitations

- Scope: The study focuses on EV manufacturing and charging infrastructure projects, offering insights applicable to the broader automotive sector.
- Limitations: The findings are based on secondary data, and primary data collection from active project implementations is limited.

4. Results & Discussion

Case Study: A leading automobile manufacturer, EcoDrive Motors is launching a new electric SUV with a nationwide charging infrastructure rollout. The company faces challenges in battery production, supply chain logistics, regulatory compliance, and market adoption. To ensure a timely and cost-effective launch, EcoDrive Motors implements CPM and PERT techniques for strategic project planning table 1 and fig 1 and 2.

Table 1: Project Breakdown and Activities

Task ID	Activity	Duration (Days)	Dependencies
A	Research & Development (R&D)	180	None

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B	Battery Production Setup	150	A
C	Manufacturing Facility Construction	120	A
D	Regulatory Approvals	90	A
E	Supplier & Logistics Coordination	100	B, C
F	Vehicle Production	180	E
G	Charging Infrastructure Setup	120	D, F
H	Market Launch & Distribution	60	G

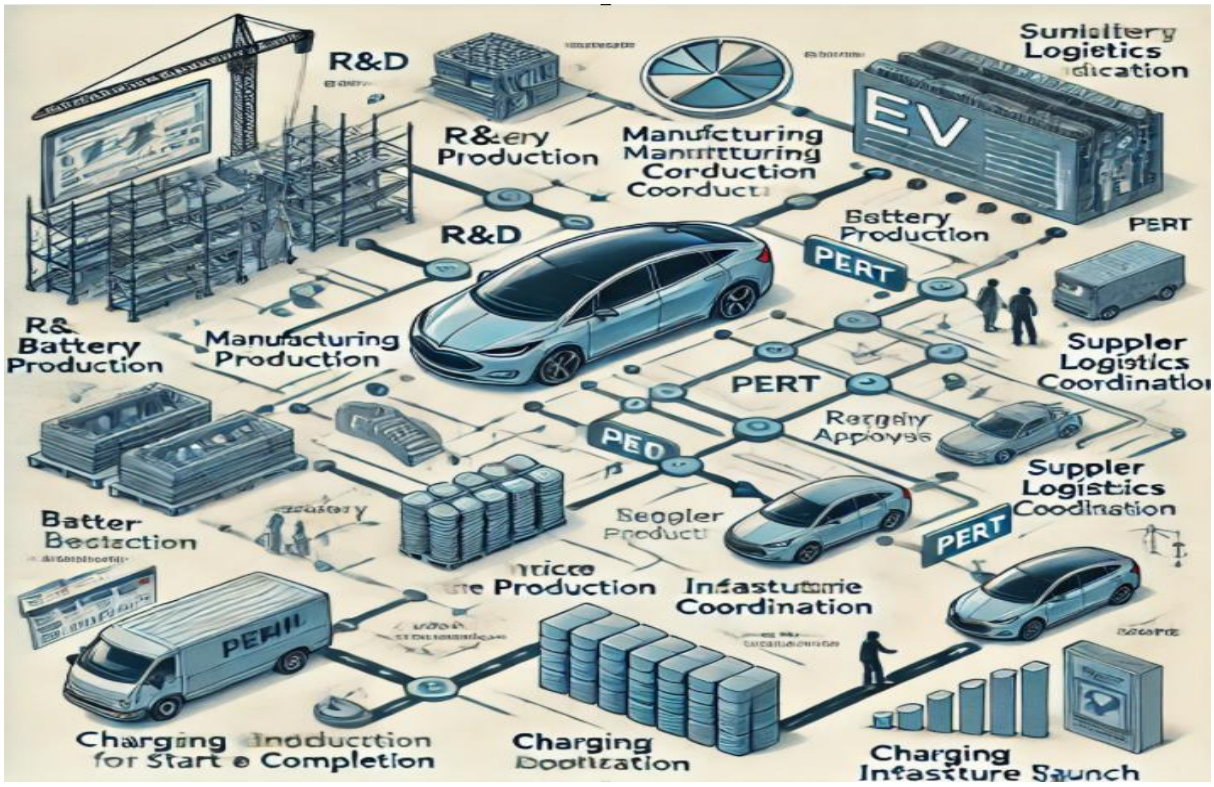

Fig 1: **Project Breakdown image**

Fig 2: Network Diagram for EV Project

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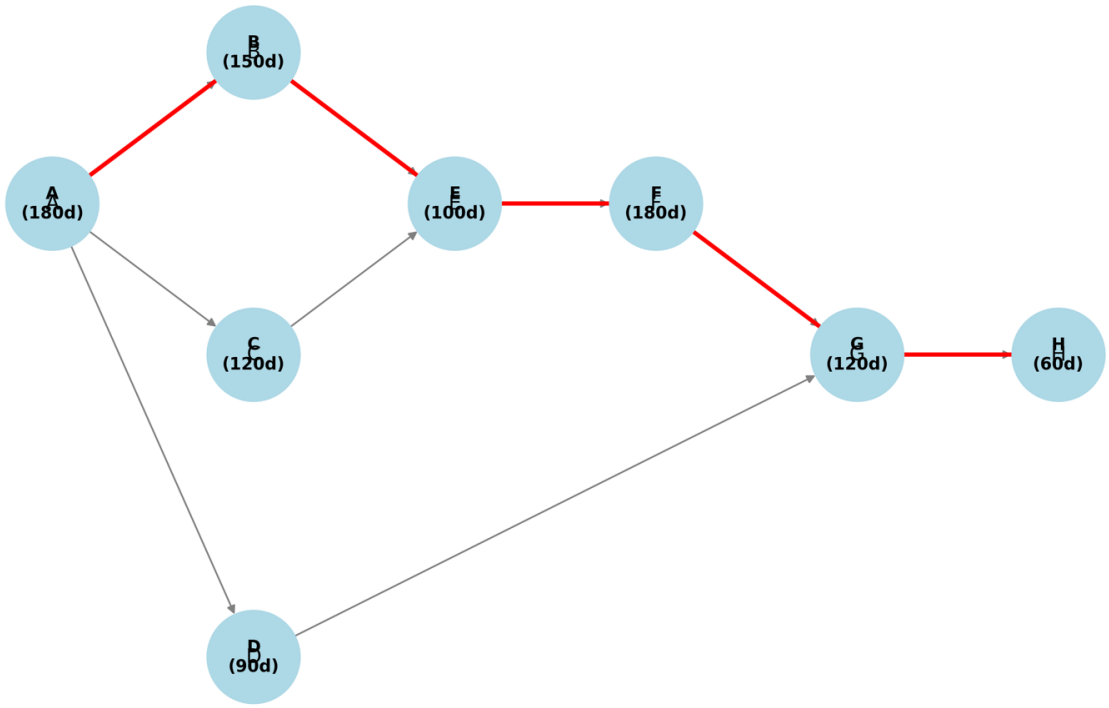

4.3 CPM Analysis

- List All Possible Paths in the Project:
  - Path 1: A → B → E → F → G → H (690 Days) ← Critical Path
  - Path 2: A → C → E → F → G → H (660 Days)
  - Path 3: A → D → G → H (450 Days)
- Determining the Critical Path:
  - The longest path (690 days) determines the minimum project completion time.
  - Any delays in tasks on the critical path will directly impact the project's deadline.

The Critical Path Method (CPM) was applied to the EV manufacturing and infrastructure development project.

The critical path identified was:

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Path 1: A → B → E → F → G → H (690 Days)

- The longest path determines the minimum project completion time (690 days).
- Any delays in tasks along this path will directly impact the overall project deadline.
- Other paths were shorter, meaning delays in those would not necessarily delay the project unless they affected a critical task.

4.3 PERT Analysis for Risk Management

Example: Charging Infrastructure Setup (Task G)

- Optimistic Time (O): 100 days
- Most Likely Time (M): 120 days
- Pessimistic Time (P): 160 days

Step 1: Calculate Expected Time (TE)

T.E = (O+4M+P)/6 = (100+4(120)+160)/6

=123.3 days

Step 2: Calculate Variance & Standard Deviation

Variance = (P−O/6)2 = (160−100/6)2 =10

Standard Deviation = Variance=10≈3.16

Insights from PERT:

- If Task G gets delayed by more than 6 days, there is a high risk of affecting the market launch timeline.
- The company should have a contingency plan such as partnering with multiple energy providers to mitigate the risk of delays.

Discussion

- **Efficiency in Project Execution:**

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    - CPM ensured precise scheduling and helped determine the most time-sensitive tasks.
    - PERT provided a probabilistic view to anticipate possible delays in infrastructure development.
- **Risk Management & Adaptation:**
    - The EV sector faces supply chain issues, particularly in battery production.
    - Using PERT estimates, companies can buffer resources to manage unexpected delays.
- **Market Readiness & Strategic Decision-Making:**
    - The timely establishment of charging stations (Task G) is critical for consumer adoption.
    - By optimizing production & logistics (E and F), manufacturers can reduce time-to-market.
- **Future Considerations:**
    - Integration of AI-driven project management tools can improve real-time monitoring.
    - Further studies can explore how supply chain disruptions affect project timelines.

5. Findings and Conclusion

Findings

This research highlights the effectiveness of CPM (Critical Path Method) and PERT (Program Evaluation and Review Technique) in optimizing project execution in the Electric Vehicle (EV) industry. The study identifies key challenges and strategic insights that impact EV manufacturing, infrastructure development, and market adoption. The major findings are as follows:

- **Identification of Critical Path for EV Project Execution:**

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- The longest path in the project is A → B → E → F → G → H (690 days), making it the Critical Path.
- Any delays in these tasks will directly impact the project's overall completion time.
- Efficient scheduling, resource allocation, and risk management are crucial to ensuring timely project completion.

- **Risk Management through PERT Analysis:**
  - Task G (Charging Infrastructure Setup) was analysed using optimistic, most likely, and pessimistic time estimates, leading to an expected duration of 123.3 days with a standard deviation of 3.16 days.
  - The findings indicate that a delay of more than six days in this activity may significantly impact the market launch timeline.
  - Contingency planning, such as partnering with multiple energy providers, is essential to mitigate risks.
- **Challenges in EV Industry Project Execution:**
  - Battery Production: Lithium supply chain disruptions create uncertainties in meeting production schedules.
  - Charging Infrastructure Development: Delays in partnerships with energy providers slow down infrastructure growth.
  - Regulatory Compliance: Meeting emission and safety standards adds complexity to project execution.
  - Consumer Adoption: Ensuring affordability and widespread availability of EVs is essential for market penetration.
- **Strategic Adaptation in a Changing Business Environment:**
  - CPM enables structured planning to optimize project efficiency, reducing unnecessary delays and improving coordination.
  - PERT helps in uncertainty management, allowing businesses to prepare for worst-case scenarios while optimizing project timelines.
  - Collaboration with multiple suppliers, use of AI-driven project management, and block chain-based tracking systems enhances adaptability.
- **Sustainability and Cost-Effectiveness:**

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- Optimized project scheduling reduces costs by preventing resource wastage and delays.
- Strategic supply chain management and infrastructure planning ensure long-term growth and sustainability in the EV sector.

Conclusion

This study highlights the importance of CPM and PERT in optimizing project management for the electric vehicle (EV) industry. CPM ensures efficient scheduling, while PERT helps manage uncertainties, enabling smoother execution of complex projects. By implementing these techniques, EV manufacturers can reduce delays, improve resource allocation, and enhance market readiness. Strategic project management is crucial for overcoming supply chain, regulatory, and infrastructure challenges. Future advancements, including AI-driven project planning, can further refine these methodologies, ensuring sustainable growth in the EV sector.

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