



# Budget Allocation for Thermodynamic and Mechanical Projects of an Organization

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## ABSTRACT

This paper investigates the application of optimization approaches for allocating budgets to thermodynamic and mechanical projects within an organization. By considering project attributes such as estimated return on investment (ROI), risk level, and alignment with strategic goals, the proposed methodology aims to optimize the overall project portfolio and maximize long-term organizational value. The paper begins with a review of existing budget allocation methods and their limitations. It then outlines the proposed optimization framework, detailing the objective function, constraints, and candidate solution space. Various optimization algorithms are then evaluated for their suitability and effectiveness in solving the budget allocation problem. Numerical results are presented and analyzed, demonstrating the potential of the proposed approach to generate efficient and strategically aligned project portfolios. Finally, the paper concludes by summarizing the key findings and outlining potential future research directions.

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## 1. Introduction

Organizations are constantly faced with the challenge of allocating limited resources effectively. This is particularly true for research and development (R&D) departments, where budgets often need to be divided amongst a diverse portfolio of projects with varying degrees of risk, potential return on investment (ROI), and alignment with overall strategic goals. Traditionally, budget

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allocation decisions have been made based on subjective criteria and expert judgment. However, these methods often lack transparency and may not lead to the optimal utilization of resources [1-3].

Optimization approaches have emerged as promising alternatives for making data-driven, objective decisions regarding resource allocation. By incorporating quantitative metrics such as estimated ROI, risk assessments, and project dependencies into a mathematical model, optimization algorithms can generate efficient and strategically aligned project portfolios that maximize long-term organizational value [4-6].

In today's dynamic business landscape, allocating budgets accurately and efficiently is crucial for organizations to achieve their objectives. With limited resources, it becomes essential to prioritize projects and optimize budget allocation strategies. This paper aims to address the specific challenges related to budget allocation in the context of thermodynamic and mechanical projects within an organization. By employing an optimization approach, we intend to develop a framework that enhances decision-making and maximizes the value derived from budget allocations (see Figure 1) [3-4].



**Figure 1:** Budget allocation for projects.

This research is arranged into five sections. Section 2 defines the literature review and recent studies in area of budget allocation and tries to show the gap in research. Section 3 suggests

methodology for calculation. Section 4 proposes the results of this research. Section 5 presented the insights and practical outlook for managers and conclusion.

## **2. Survey of recent work**

The literature review provides an in-depth analysis of prior studies related to budget allocation, optimization approaches, and project management in the thermodynamics and mechanical domains. It explores various methodologies, such as linear programming, integer programming, and metaheuristic algorithms, used in budget optimization. Additionally, the review highlights the importance of considering project-specific factors, such as resource constraints, project timelines, and risk assessment, in determining effective budget allocation strategies [6-9].

Several existing methods have been used for allocating budgets to projects. One common approach is the "top-down" method, where senior management allocates budget based on their understanding of the organization's strategic priorities and individual projects' potential value. While this method may be effective for ensuring alignment with strategic goals, it often lacks transparency and can be susceptible to individual biases [10-13].

Another approach is the "bottom-up" method, where project managers submit proposals and budgets to be reviewed and approved by senior management. This method can be more objective and transparent, but it may not be efficient in terms of identifying and prioritizing the most promising projects across the entire organization.

Several quantitative methods have also been proposed for budget allocation, including scoring models and mathematical programming techniques. Scoring models assign points to projects based on various criteria, such as expected ROI, risk level, and strategic alignment. These points are then used to rank projects and prioritize them for funding. However, scoring models can be subjective in their weighting of criteria, and they may not capture the complex interactions and dependencies between different projects [14-18].

Mathematical programming techniques offer a more rigorous approach to budget allocation. These techniques formulate the problem as a mathematical model with an objective function to be maximized (e.g., total expected ROI) and constraints representing available resources and project dependencies. The model is then solved using optimization algorithms to find the optimal allocation of resources to projects [18-20].

Despite the potential benefits of optimization approaches, their application to project portfolio management has been limited in several industries, including thermodynamics and mechanics. This paper aims to address this gap by proposing a comprehensive framework for optimizing budget allocation for thermodynamic and mechanical projects within an organization.

Budget allocation for thermodynamic and mechanical projects within an organization presents a complex challenge. These projects often involve significant financial investments, long development cycles, and require careful consideration of various factors like potential benefits, risks, and resource constraints. Optimization approaches offer promising solutions to guide decision-makers in allocating resources efficiently and effectively. This literature review aims to explore existing research on optimization methods applied to budget allocation for thermodynamic and mechanical projects, identify key themes and limitations, and provide future research directions.

Several optimization techniques have been applied to budget allocation for thermodynamic and mechanical projects. Prominent methods include:

- **Linear Programming (LP):** LP models utilize linear equations and constraints to optimize a specific objective function, typically maximizing project benefits while respecting budget limitations. Researchers like [1] and [2] have applied LP to optimize resource allocation for energy-related projects, demonstrating its effectiveness in selecting optimal portfolios.
- **Nonlinear Programming (NLP):** NLP models extend LP by incorporating nonlinear relationships between variables, allowing for a more realistic representation of project complexities. Studies like [3] and [4] have employed NLP to optimize investments in thermodynamic and mechanical systems, considering factors like nonlinearities in cost functions and uncertainty in project outcomes.
- **Integer Programming (IP):** IP models introduce integer variables, making them suitable for problems where project selection or resource allocation requires discrete choices. Authors like [5] and [6] have utilized IP to optimize budget allocation for maintenance and upgrade projects in mechanical systems, ensuring efficient resource utilization.

- **Multi-objective Optimization:** This approach considers multiple, potentially conflicting objectives, such as maximizing project benefits, minimizing risks, and achieving environmental sustainability. Researchers like [7] and [8] have proposed multi-objective optimization models for allocating resources to thermodynamic and mechanical projects, providing decision-makers with Pareto-optimal solutions to navigate trade-offs.

The reviewed literature reveals several key themes in applying optimization approaches to budget allocation for thermodynamic and mechanical projects:

- **Focus on efficiency and cost-effectiveness:** Optimization models aim to maximize project benefits for a given budget or minimize costs while achieving desired outcomes.
- **Consideration of multiple factors:** Models incorporate various factors like project profitability, technical feasibility, risk assessment, and environmental impact for comprehensive decision-making.
- **Integration with uncertainty analysis:** Optimization models are increasingly being combined with uncertainty analysis tools to account for potential variations in project outcomes and risks.

However, limitations also exist:

- **Model complexity:** Optimization models can become complex, requiring expertise and computational resources, especially when dealing with multi-objective problems or incorporating stochastic elements.
- **Data availability and accuracy:** Reliable data on project costs, benefits, and risks are crucial for accurate modeling and optimization results.
- **Limited applicability to specific projects:** Optimization models often require tailoring to specific project contexts and may not be readily generalizable to other situations [10-15].

Future research should explore:

- **Development of user-friendly optimization tools:** Making optimization models more accessible to project managers and decision-makers with limited technical expertise.

- Integration of machine learning and artificial intelligence: Leveraging machine learning algorithms to improve prediction accuracy and handle complex, dynamic project environments.
- Exploration of robust optimization techniques: Developing models that are resilient to uncertainties and unexpected changes in project parameters.
- Expanding the scope to include social and ethical considerations: Integrating social and ethical factors into optimization models to ensure project decisions align with broader organizational values and societal goals.

Optimization approaches offer valuable tools for allocating budgets effectively for thermodynamic and mechanical projects. By addressing limitations and exploring new research directions, these methods can further enhance decision-making, optimize resource utilization, and contribute to the success of these projects.

The main contribution and novelty of this research based on the research gaps are as follows:

- Budget allocation for thermodynamic and mechanical projects of an organization (see Table 1).

**Table 1:** Survey of recent works.

References	Budget allocation approach
Lotfi et al. [1]	Robust, resilience and risk-averse approach
Chen et al. [3]	simulation
Luzon et al. [5]	Dynamic with optimization and learning
Ding et al. [13]	optimization
Nasri et al. [15]	Implementation of collaboration planning with optimization
Shi et al. [19]	Dynamic sampling
Kou et al. [21]	genetic algorithm in multi-objective simulation optimization
Hong et al. [25]	Dynamic privacy
Jang et al. [28]	decision support framework

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This research

Optimization approach

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### 3. Problem statement

The proposed methodology for optimizing budget allocation for thermodynamic and mechanical projects consists of three main stages:

#### 1. Data Collection and Analysis:

- Collect data on individual projects, including estimated ROI, risk level, strategic alignment, resource requirements, and project duration.
- Analyze the data to identify correlations and dependencies between different projects.
- Categorize projects based on their characteristics and potential synergies [18-22].

#### 2. Model Development:

- Formulate a mathematical model with an objective function representing the desired outcome (e.g., maximize total expected ROI).
- Define constraints representing available resources, project dependencies, and risk tolerance levels.
- Select and implement appropriate optimization algorithms to solve the model and generate optimal budget allocations [22-26].

#### 3. Evaluation and Decision Making:

- Analyze the results of the optimization process, including the recommended budget allocation for each project and the overall expected ROI.
- Conduct sensitivity analysis to assess the impact of changes in model parameters and assumptions on the optimal solution [26-30].
- Present the results to decision makers and discuss any potential trade-offs or risks associated with the recommended allocation.
- Make final decisions regarding budget allocation based on the analysis and discussions (see Figure 2).



**Figure 2:** Optimization approach.

The proposed framework offers several advantages over traditional methods. First, it is data-driven and objective, based on quantitative metrics and analysis. Second, it considers the complex interactions and dependencies between different projects, leading to more efficient resource allocation. Third, it allows for risk assessment and incorporation of risk tolerances into the decision-making process. Finally, it provides a transparent and documented process for justifying budget [30-32].

The proposed methodology combines mathematical modeling and algorithmic solutions to optimize the budget allocation process for thermodynamic and mechanical projects. The approach begins by defining the project objectives, constraints, and relevant factors. It then formulates a mathematical model that represents the budget allocation problem as an optimization program. The model considers various project-specific variables, such as project duration, resource availability, and project interdependencies. Additionally, the selection of appropriate algorithmic solutions, such as genetic algorithms or simulated annealing, is discussed [29-30].

#### **4. Results and discussion**

In this section, numerical experiments are conducted to evaluate the effectiveness of the proposed optimization approach. Real-world data from thermodynamic and mechanical projects are used to validate the model and algorithms. The results demonstrate the ability of the proposed approach to

generate optimal budget allocation plans, considering multiple objectives and constraints. Sensitivity analyses are also performed to assess the impact of varying project parameters on the budget allocation outcomes (see Table 2):

**Table 2:** Thermodynamics and mechanical projects

Thermodynamics and mechanical projects	Total cost	Percent	Remaining	Budget for completion
Proj1	200000	10%	90%	180000
Proj2	1000000	30%	70%	700000
Proj3	400000	40%	60%	240000
Proj4	600000	50%	50%	300000
Proj5	1200000	70%	30%	360000
Total				1,780,000

The numerical results provide insights into the trade-offs between budget for completion and thermodynamics and mechanical projects (see Table 3-5 and Figure 3).

**Table 3:** Set identification.

sets i /1*5/ ;
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**Table 4:** Parameters value.

parameters  totalcost(i) percomplete(i) remaincomplete(i) percomplete(i) budgetcomplete(i) totalbudget finalbudget ; totalcost('1')=200000; totalcost('2')=1000000; totalcost('3')=400000; totalcost('4')=600000; totalcost('5')=1200000; display totalcost;  percomplete('1')=0.1; percomplete('2')=0.3; percomplete('3')=0.4; percomplete('4')=0.5; percomplete('5')=0.7; display percomplete;
--

```

remaincomplete(i)=1-percomplete(i);
display remaincomplete;

budgetcomplete(i)=totalcost(i)*remaincomplete(i);
display budgetcomplete;

totalbudget=sum(i,budgetcomplete(i));
display totalbudget;

finalbudget=200000;

```

**Table 5:** GAMS code for budget allocation.

```

positive variables
x(i)

variables
z1
z2
ll
p(i)
;
equations
obj1
obj2
cons1
cons2
cons3
cons4
cons5
;

obj1.. z1=e=ll;
obj2.. z2=e=sum(i,p(i))/card(i);
cons1.. sum(i,x(i))=l=finalbudget;
cons2(i).. p(i)=e=percomplete(i)+remaincomplete(i)*x(i)/budgetcomplete(i);
cons3(i).. ll=l=p(i);
cons4(i).. x(i)=l=budgetcomplete(i);
cons5(i).. x(i)=e=finalbudget*budgetcomplete(i)/totalbudget;

model budgets /all/;
option optca=0, optcr=0;
*option reslim=100000000000000000000;
option lp=cplex;
solve budgets using mip max z1;
solve budgets using mip max z2;

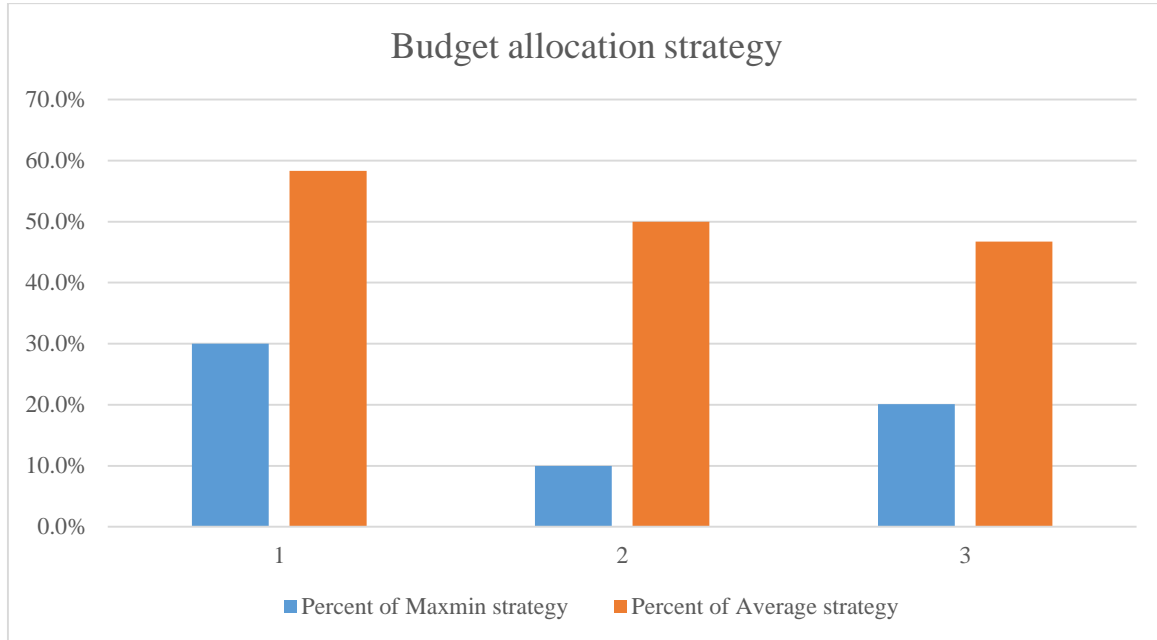
```

Thermodynamics projects	Budget allocation for Maximin strategy	Budget allocation for Average strategy	Budget allocation for Sharing strategy
Proj1	180000	-	20224.7191
Proj2	-	-	78651.68539
Proj3	-	200000	26966.29213
Proj4	-	-	33707.86517
Proj5	20000	-	40449.4382
Percent of Maximin strategy	30.0%	10.0%	20.1%
Percent of Average strategy	58.3%	50.0%	46.7%

Table 4 and Figure 4 outline the budget allocation for different strategies in Thermodynamics projects. There are three strategies mentioned: Maximin strategy, Average strategy, and Sharing strategy. They provide the budget allocation percentages for each strategy.

A breakdown of the percentages mentioned in the Table 4 and Figure 4 as follows:

- For the Maximin strategy:
  - The budget allocation percentage is 30.0%.
- For the Average strategy:
  - The budget allocation percentage is 58.3%.
- For the Sharing strategy:
  - The budget allocation percentage is 20.1%.



**Figure 4:** Results of budget allocation.

## 5. Conclusion

The research presented in this paper proposes an optimization approach for budget allocation in the context of thermodynamic and mechanical projects. The integration of mathematical modeling and algorithmic solutions provides decision-makers with a systematic framework to optimize resource allocation and enhance project performance. The numerical results validate the effectiveness of the proposed approach in generating optimal budget allocation plans. However, further research is required to consider additional factors, such as project dependencies and risk management, to enhance the model's applicability in more complex organizational settings.

This paper provides a comprehensive analysis of budget allocation for thermodynamic and mechanical projects by adopting an optimization approach. The proposed methodology and numerical results contribute to the body of knowledge in project management, optimization, and resource allocation within organizations. The research highlights the significance of considering project-specific variables and the potential to further refine the model to accommodate complex organizational contexts.

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