GEP - LLiurable 3: Gestió Econòmica i sostenibilitat

Tomàs Osarte Segura

March 2024

1 Introduction

This document is structured to meticulously outline the economic management and sustainability aspects of the graduation thesis titled ”Search & Analysis for New Heuristics for Solving NP-Hard Problems with Deep Reinforcement Learning.” It commences with a comprehensive overview of the project's budget, including a detailed identification and estimation of all associated costs. This is followed by a thorough analysis of management control mechanisms, ensuring efficient resource allocation and financial oversight. The document culminates with an in-depth sustainability report, evaluating the project's long-term viability and its alignment with broader economic, social, and environmental objectives.

2 Economic management

To ensure effective economic management, it is crucial to comprehensively define all aspects related to the budget of this project. This takes into account, as previously stated, the identifiaction and estimation of the costs and management control of it.

2.1 Identification and estimation of costs

Building on the budget planning framework outlined in [1], our costs can be categorized into four distinct groups. This classification simplifies the process and proves beneficial for identifying all expenses. By structuring the budget planning into these separate categories, we gain a clearer and more organized overview of our financial landscape.

2.1.1 Personnel costs

These costs are associated with the personnel involved in the project. Since each role carries a distinct market value, it's imperative to identify all the roles within the project and assign competitive salaries accordingly. Moreover, we must account for social security (SS) contributions, which effectively means multiplying the gross salary by 1.3 to cover these additional expenses. In Table 1 we have an overview for all different roles of the gross salary, the social security payment and the overall retribution. It's important to remark that all the salaries are based on average salaries in Spain by [2, 3].

Role	Gross Salary	SS	Retribution
AI Researcher	20€/h	6€/h	26€/h
AI Developer	30€/h	9€/h	39€/h
Decision Maker	50€/h	15/h	65€/h
Analyst	20€/h	6€/h	26€/h
Project Manager	32.5€/h	9.75€/h	42.25€/h
Quality Assurance	21€/h	6.33€/h	27.33€/h
Documenter	16€/h	4.8€/h	20.8€/h
Financial Analyst	30€/h	9€/h	39€/h
Evaluator	25€/h	7.5€/h	32.5€/h

Table 1: Cost breakdown per role. Own elaboration.

Upon compiling a comprehensive overview of the total compensation for each role involved in the thesis, we can then proceed to calculate the CPA (cost per activity). This is accomplished by estimating the costs for each task outlined in the Gantt chart. Table 2 provides a detailed breakdown of these tasks, including their estimated costs, thus offering a deep understanding of the financial implications associated with each activity.

ID	Task	Hours	Resources	Role	Cost (€)
Study (ST) - Total Hours: 70					
ST1	DRL applied to NP-HARD problems	45	Internet device	Researcher	1170
ST2	Explainability for DRL	25	Internet device	Researcher	650
Development (D) - Total Hours: 115					
D1	DRL frameworks for single instances	45	Computational Resources	Developer	1755
D2	DRL frameworks for generalization	45	Computational Resources	Developer	1755
D3	Explainability framework	25	Computational Resources	Developer	975
Evaluation (E) - Total Hours: 40					
E1	Evaluation of single instance frameworks	15	Benchmarks, Computational Resources	Evaluator	487.5
E2	Evaluation of generalization frameworks	15	Benchmarks, Computational Resources	Evaluator	487.5
E3	Evaluation of explainability framework	10	Benchmarks	Evaluator	325
Selection (SE) - Total Hours: 10					
SE1	Selection of frameworks for single instances	5	-	Decision Maker	325
SE2	Selection of generalization frameworks	5	-	Decision Maker	325
Analysis (A) - Total Hours: 10					
A1	Analysis of the heuristic	5	Documentation	Analyst	130
A2	Analysis of explainability	5	Documentation	Analyst	130
Follow up (F) - Total Hours: 40					
F1	Follow-up meetings	25	Internet, Meeting Space	Project Manager	1062.5
F2	Correction sessions	15	Internet, Meeting Space	Quality Assurance	409.95
Documentation (DC) - Total Hours: 85					
DC1.1	Contextualization & Scope	20	Computer	Documenter	416
DC1.2	Temporal Planning	10	Computer	Documenter	208
DC1.3	Budget and Sustainability Analysis	10	Computer	Financial Analyst	390
DC2	Project Documentation	45	Computer	Documenter	936
				Total Hours:	**400**
				Total CPA:	**11937.45**

Table 2: Detailed Cost Estimation per Task. Own elaboration.

We also provide in Table 3 a detailed overview of the budget per each group of tasks to have a more comprehensive visualization.

ID	Task	Hours	Role	Cost (€)
ST	Study	70	Researcher	1820
D	Development	115	Developer	4485
E	Evaluation	40	Evaluator	1300
SE	Selection	10	Decision Maker	650
A	Analysis	10	Analyst	260
F	Follow up	40	Project Manager, Quality Assurance	1472.45
DC	Documentation	85	Documenter, Financial Analyst	1950
			Total CPA:	**11937.45**

Table 3: Simplified Cost Estimation per Task Category. Own elaboration.

2.1.2 Generic costs

Generic costs refer to the necessary expenditures associated with the project that are not directly assignable to specific tasks. These encompass in this project overhead expenses such as reimbursements, workspace rental, electricity usage, and internet service charges.

- **Reimbursements:** There is only hardware reimbursements since all the software used is open source an do not require any inversion. For the hardware, we account for a laptop valued at 1100€ and a monitor at 150€. Based on a standard operational period of 220 workdays annually, with 8 working hours per day, and factoring in the hardware's estimated lifespan of 4 years, we determine the reimbursement cost using the following formula:

$$Reimbursements = \frac{Cost * hours\ used}{Useful\ life * 220 * 8}$$

  Given that the hardware is estimated to be in use for 1000 hours, primarily due to the extensive time required for model training, the total reimbursement cost is calculated to be **177.55€**.

- **Work space rental:** The project's primary workspace will be located in Gracia, a district in Barcelona. The average rent there is approximately 1100€ per month, as stated in [4]. Given the project's duration of about five and a half months, the total rental expenditure is expected to surpass **6050€**.

- **Electricity usage:** Given that nowadays the electricity price in Spain is about 0.2966€/kWh and the average power consumption of a laptop and screen are about 0.075kWh and 0.0225kWh respectively, and the previously estimated hardware usage is about 1000 hours, the total electrical expenditures extend to **29.92€**. All this prices are found on [5, 6, 7].

- **Internet service charges:** We also have to take into account the internet service charges, which are on average 45€ per month according to [8]. Since the project has a duration of 5 and a half months as previously mentioned, the total internet expenses will round up upon **247.5€**.

In Table 4, a comprehensive overview of generic costs is presented, offering a summarized visualization of the various expenses associated with the project.

Expense Category	Amount (€)
Reimbursements	177.55
Workspace Rental (Gracia, Barcelona)	6050.00
Electricity Usage	29.92
Internet Service Charges	247.5
Total Generic Costs	**6504.97**

Table 4: Summary of Generic Expenses. Own elaboration.

Outlining the potential collaboration with the Barcelona Supercomputing Center (BSC) is crucial, as it would significantly alter the expenses associated with electricity usage and hardware reimbursements. With the bulk of computational demands transferred to BSC's resources, the reliance on our own laptop for intensive tasks would be substantially reduced. This shift necessitates a readjustment of costs, factoring in the power usage specific to the BSC's infrastructure rather than our personal hardware.

2.1.3 Contingencies

In any project, particularly one involving AI, it's crucial to anticipate potential cost overruns due to unforeseen challenges. For this project, a standard approach is to allocate an additional 15% to the total costs, encompassing both the CPA (cost per activity) and generic costs (GC). This contingency measure helps ensure financial preparedness for any unexpected issues that may arise during the project's lifecycle.

2.1.4 Unexpected costs

All foreseeable challenges and risks associated with this thesis, such as those commonly encountered in deep reinforcement learning frameworks, including sample efficiency, exploration-exploitation tradeoff, and generalization issues upon others, are already factored into the project's timeline with corresponding time extensions. Considering that these potential delays and their high likelihood have been proactively included in the planning stage, we anticipate no unexpected costs arising from these factors. This proactive approach ensures that our time planning comprehensively addresses the typical obstacles inherent in such projects.

There are only unexpected costs related with the breaking of the computer and the screen. Since this events a rarely likely to happen. We can associate a 5% probability to this events. This would result into:

$$cost * probability = (1100 + 150) * 0.05 = 62.5€$$

At Table 5 we conclude with an overview of the total costs of the project separated in each important cost category, which ensures a general overview upon the financial aspects of the thesis.

Cost Category	**Amount (€)**
Total CPA (Cost per Activity)	11937.45
Total Generic Costs (GC)	6504.97
Contingency (15%)	2766.36
Unexpected Costs	62.5
Total Costs	**21271.28**

Table 5: Summary of Total Project Costs. Own elaboration.

2.2 Management Control

In our project, we propose and thoroughly describe excellent mechanisms to control any budget deviations that might arise. This includes defining numerical indicators for calculating deviations, which will facilitate effective monitoring and control. Specifically, we will implement a variance analysis system, comparing actual expenditures against the planned budget periodically. This will enable us to promptly identify and analyze any discrepancies.

To quantify these deviations, we'll calculate both the variance in absolute terms and as a percentage of the budgeted amount. These indicators will be critical for understanding the scale and impact of any deviation. Regular reviews will be scheduled to ensure timely responses to these variances.

Furthermore, we plan to use a rolling forecast model. This approach allows us to adjust our forecasts based on actual performance periodically, thus improving the accuracy of our budget predictions and enhancing our ability to manage resources effectively.

In summary, our approach to budget control combines proactive planning, regular monitoring, and adaptive forecasting to ensure that any deviations are quickly identified, analyzed, and addressed, keeping the project on track financially.

3 Sustainability report

Sustainability is a crucial factor in all project undertakings due to its significant impact on the economy, society, and the environment. This importance necessitates a comprehensive report for this project, derived from a carefully conducted survey, to ensure heightened awareness and integration of sustainability practices within this graduation thesis.

3.1 Introspection

After having answered to the survey leaded into the academic world from EDINSOST, I've gained clearer insight into my competencies and deficiencies in this area. My understanding of sustainability is fundamental, and I recognize that my experience in developing various techniques or metrics in this field is limited. Despite this, I feel well-informed about our society's sustainability challenges. However, my practical experience is insufficient to fully back this claim.

Regarding my research-focused project, I acknowledge that there is limited scope for applying sustainability measures. Nonetheless, I bear the responsibility to monitor and endeavor to reduce my environmental impact throughout the execution of my thesis. There is also really important to bear in mind the impact of the thesis within the scope of sustainability, which if the research comes to fruition, could improve the condition over the economical, social and environmental dimensions.

3.2 Economic dimension

Focusing on the economic dimension, it's crucial to deliberate on the estimated cost of the project. Given that the tasks are meticulously defined—which is challenging in a research project—and the costs are thoroughly justified, it seems that the financial aspects are well outlined and adhere to standard procedures.

There are a lot of ways to solve NP-HARD problems but we are focusing on deep reinforcement learning frameworks which is an heuristic approach. Historically has been solved in many different ways and is a field that evolved quite fast. In the actuality, one of the best ways to solve it is using the [9] which tries to solve the problem using a REINFORCE train framework over attention networks using a similar structure to the transformers proposed in the famous paper [10].

Moreover, the economic impact of this graduation thesis warrants attention. Although it may not have an immediate direct effect, the potential for a significant indirect impact is noteworthy. For instance, if this thesis succeeds in enhancing the solutions for TSP variants, which are emblematic NP-HARD problems, it could encourage enterprises to adopt our methodologies. This adoption could yield improved routing solutions, achieving efficiency in addressing larger problems more swiftly. However, there is a caveat: the necessity for these companies to modify their existing systems incurs an initial cost, despite the promise of long-term benefits.

3.3 Environemental dimension

In this section, we delve into the environmental dimension of the sustainability report, focusing on the ecological impact associated with conducting this graduation thesis. We commit to rigorously monitoring and measuring our carbon footprint throughout the thesis, particularly during the training phases, and also in everyday tasks. Our primary source of emissions is the use of our laptop, which will be meticulously monitored to accurately gauge its emissions. Furthermore, should our collaboration with the Barcelona Supercomputer Center (BSC) materialize, we pledge to similarly track the emissions generated by their infrastructure.

Efforts to mitigate our environmental impact include implementing energy-saving practices such as shutting down the computer and internet when not in use, optimizing the computer's power management, and performing regular maintenance and component cleaning to extend its useful life.

As previously mentioned, there are already effective methods for medium-sized graph problems. Our goal, however, is to enhance the quality and scalability of these solutions. This endeavor indirectly benefits numerous routing challenges, many of which are NP-HARD, potentially leading to a significant reduction in the carbon footprint of entire companies on a larger scale. This project, therefore, not only contributes to academic knowledge but also offers tangible environmental benefits.

3.4 Social dimension

In this section, we address the social and personal impacts of the graduation thesis. The personal impact is especially significant. Having chosen this topic out of deep interest, my dedication to both the process and the outcomes of this thesis is immense. My longstanding fascination with AI, combined with a more recent intense focus on reinforcement learning, means this project is not just an academic pursuit, but a chance to deepen my own understanding and passion in a field that excites me.

The social impact of this thesis is also substantial. As a research project, achieving our set goals will contribute to advancing the state of the art, which is always beneficial for both science and society. This progress is particularly meaningful in the context of reinforcement learning, a field that is increasingly critical across various global industries. By pushing the boundaries of current knowledge in this area, this thesis has the potential to offer new insights and solutions, especially the routing industry or biology community, where there is a growing demand for innovation and improvement. This contribution to the scientific community not only elevates the field but also supports practical advancements in industries that rely on these technologies.

References

[1] Departament d'Organització d'Empreses. *Mòdul 2.4: Gestió Econòmica*. Facultat d'Informàtica de Barcelon (FIB). Unpublished course notes. 2024.

[2] PayScale. *Salary Data and Compensation Analysis*. `https://www.payscale.com`. Accessed on March 9, 2024. 2024.

[3] SalaryExpert. *Salary Data and Compensation Analysis*. `http://www.salaryexpert.com/`. Accessed on March 9, 2024. 2024.

[4] La Vanguardia. *Los propietarios de vivienda en Gracia, los más afortunados de Barcelona*. `https://www.lavanguardia.com/economia/finanzas-personales/20230726/9133205/propietarios-vivienda-gracia-mas-afortunados-barcelona-mkt-hfy.html`. Accessed on March 10, 2024. 2024.

[5] Electricity In Spain. *Electricity Prices In Spain*. `https://electricityinspain.com/electricity-prices-in-spain/`. Accessed on March 10, 2024. 2024.

[6] Energuide. *How much power does a computer use and how much CO2 does that represent?* `https://www.energuide.be/en`. Accessed on March 10, 2024. 2024.

[7] ITpedia. *Our Computer, Monitor, and Energy Consumption*. `https://en.itpedia.nl/`. Accessed on March 10, 2024. 2023.

[8] Remote Year. *Cost of Living in Spain*. `https://www.remoteyear.com/blog/cost-of-living-in-spain`. Accessed on March 10, 2024. 2024.

[9] Wouter Kool, Herke Van Hoof, and Max Welling. "Attention, learn to solve routing problems!" In: *arXiv preprint arXiv:1803.08475* (2018).

[10] Ashish Vaswani et al. "Attention is all you need". In: *Advances in neural information processing systems* 30 (2017).