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Monte Carlo simulation in an elementary school building

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A B S T R A C T

Education is the future. Education is the only way for a country to start developing and reducing poverty. In countries with medium incomes like Peru, the resources to spend on education is not unlimited. Therefore, it is necessary to have quality in investment. However, risks and uncertainty can make a project surpass its initial budget. Therefore, statistic based methods like Monte Carlo simulation is a powerful tool to forecast possible events that might endanger the profitability and sustainability of a project. Although there is not plenty of academic literature about Monte Carlo empirical usage, many projects employ this method to manage the possible risks the project could have. In consequence, the current research analyzed both risk and sensitivity of an elementary school building project. Both analyses showed that this project had huge probabilities to surpass the current profit and return estimations. However, the sensitivity analysis portrayed that the project could be endangered because of infrastructure overspending. Moreover, it indicated that students' attendance is also a critical factor to ensure the sustainability of the project.

1. Introduction

Nowadays, there are many public constructions that cannot cover the population needs. In developing countries, like Perú the bureaucracy makes public investment projects unnecessarily long in terms of requirements which do not fill with reality (Morin, 2017). states that if public investment projects overestimate the demand, the project is not sustainable in the long term. Hence, a waste of resources and inefficiency of public expenditure is generated (Ávila, 2019). Consequently, the people's needs belonging to estate intervention are not fulfilled. One of the most sensitive targets of social public investment is education (Teles & Andrade, 2008). In most countries, the state guarantees the right of free basic education for its people. Hence, public resources go for paying salaries of education personnel, building and maintenance of education infrastructure as schools, food for poor children, material, assets among other necessary stuff to give quality education to people. The importance of education investment is that it enables development to the country and helps people to run out of poverty (Braun, et al. 2006). Obviously, the education provided must meet quality criteria. One direct way to ensure quality is increasing public investment (Schultz, 1987). Moreover, there have been studies like Boissiere (2004) and Aturupane (2017) which remarks the importance of efficient public investment as an enabler of quality education. Hence, it is not uncommon that richer countries with big budgets can afford quality education, while poor countries cannot. However, public expenditure is not everything to get a better education. Then, it is also necessary to have quality in expenditure. Developing countries

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must face obstacles to reach quality in expenditure. As described before, bureaucracy is a waste machine of time and money. Also, these countries must deal with high levels of corruption, political instability, natural disasters, low-skilled workers, and other circumstantial factors that endanger the efficiency and quality of expenditure (Kasatuka & Minnitt, 2006). Hence, what can be done to ensure quality public expenditure in education projects? Project management academics have created tools based on social profitability. Moreover, the risk analysis aims to study and identify the actual and potential dangers of a project. The risk analysis performs such a task by trying to know the variability of the net present value, the factors that can affect it and their probability of occurrence (Sánchez, 2014). Moreover, in the sensitivity analysis, variables with the capability to modify the finance information are analyzed to estimate many possible scenarios (Pérez, et al. 2011). Every country has its own standards to evaluate public investment projects. In Peru, the estate guide compels project management firms and people to analyze both risk and sensitivity (Pérez, et al. 2011). Indeed, risk analysis is considered part of sensitivity analysis. Moreover, the guide recommends including the probability of natural disasters in the project analysis as well as other occurrences that can make the project budget. Besides the typical risk estimation and sensitive analysis, an alternative to estimate probabilities and critical variables is Monte Carlo analysis as suggested by (Azofeifa, 2004). Therefore, the current paper is going to perform this analysis in the project of the building of a public school in Peru. That project aims to build a school in an impoverished zone of the city of Chiclayo taking into consideration not only the infrastructure building but also the sustainability of the project in the long term.

2. Literature review

2.1 Previous studies

Inquilla and Rodríguez (2019) has developed a direct previous study regarding sensitivity and risk analysis of education projects in Peru. In their study, they applied the Monte Carlo simulation in a school project in a school located in the highlands of Puno. They considered the investment costs, operations and social benefits as input variables, while net present value and intern return rate as output ones. Applying a rate of discount of 8%, as mandatory according to Peruvian project guides, they have found that the project was socially profitable. Moreover, they have found that the project had a probability of 67% to be profitable under certain conditions. Furthermore, they pointed out the importance of students' assistance in the social profitability of the project. Serrano and Muñoz (2020) evaluated the risk of profitability in an energy project placed in Spain. First, they identified the possible risks with the capability to influence the project outcome. In total they identified more than sixty potential risks. After, by triangular distribution sets and Monte Carlo simulation they could estimate the impact of the identified risk in the net present values, internal rate or return and payback. They encountered that the most important risks were: revenue estimation change due to climate change, errors in estimating the effective solar radiation energy, technological climate change adequacy, performance losses and earthworks. In Colombia, Sastoque et al. (2016) aimed to identify the risk allocation of a public-school development. The context of the analysis is the public-private-partnership where both firms and government develop projects. They have found that the private sector assumes natural, financial, macroeconomic, construction and political risks.

Table 1
Previous studies

Author	Title	Results
Inquilla and Rodriguez, 2019	Análisis de riesgo mediante el método de simulación de Montecarlo aplicado a la inversión pública en el sector educativo peruano: el caso del departamento de Puno.	A highland school building project had the probability of 67% to be socially profitable. Moreover, it was crucial the students' attendance for the project´s sustainability.
Serrano and Muñoz, 2020	Risk influence analysis assessing the profitability of large photovoltaic plant construction projects	The research found that the most important risks were: revenue estimation change due to climate change, errors in estimating the effective solar radiation energy, technological climate change adequacy, performance losses and earthworks.
Arboleda and Ponz, 2016	A proposal for risk allocation in social infrastructure projects applying PPP in Colombia	The study found the private sector has to deal with economic, political and legal risks; while, the public sector is most vulnerable to legal circumstances. Also, the most important risks found were delays in permits, demand change, and natural disasters
Girardi, et al., 2018	Characterization of risk factor management in infrastructure projects	The analysis found that risk factor impact relies more on risk managers than in the project itself. Besides, they have stated that the most important risks were procrastination, planning, safety, social, legal and non-controllable forces.
Namazian, et al., 2019	Combining Monte Carlo simulation and Bayesian networks methods for assessing completion time of projects under risk	They have encountered that the most significant risk factors were the shortage of resources, company financial problems, delay in technical drawings systems, exchange rate changes and increase in the time and financial claims by contractors.
Bonato, et al., 2019	An application of Earned Value Management (EVM) with Monte Carlo simulation in engineering project management	They performed a mix of Monte Carlo and Bayesian methods to tackle overspending risk. Hence, they employed factors like process, civil, piping, mechanics, instrumental and electrical costs for the projects. In the end, they have proved that applying its methodology reduced the probability of overspending.

While both of them assumed legal and political risks. They have found that the most important risks were delays in permits, demand change, and natural disasters. Girardi, et al. (2018) analyzed how the risk factor management is handled in infrastructure projects. By applying surveys, interviews, and project data, they have found that the most important risk factors were due to procrastination, planning, safety, social, legal and non-controllable forces. Hence, they stated based on evidence that the risk factor impact in the project performance relies on risk managers not on the complexity of the project. The importance of getting projects in time is crucial; hence Namazian, et al. (2019) employed both Monte Carlo and Bayesian methods to assess the effect of completion time risk in an infrastructure project. After collecting possible risks of time completion, they employed both Monte Carlos and Bayes. In consequence, they have encountered that the shortage of resources, company financial problems, delay in technical drawings systems, exchange rate changes and increase in the time and financial claims by contractors were the most significant risks affecting time completion. Bonato, et al. (2019) applied a tool called earned value management along with Monte Carlo to assess a forecast of three project´s final costs. The factors employed were process, civil, piping, mechanics, instrumental and electrical costs for the projects. After performing the process, they have shown that applying both methods reduced the probability of overspending in the three projects. A brief summary of the studies is shown in Table 1.

2.2 Theoretical basis

2.2.1 Risk analysis

Risk analysis is a crucial element in many projects (Leroy & Singell, 1987). It is important to identify them and forecast the possible scenarios with those risks. Some authors believe that risk encloses events with known effects due to empirical evidence (Leroy & Singell 1987). Hence, it is impossible to avoid all risk, even with the risk presence it is possible to get profits (Bock, 2011). Therefore, project managers should know how to deal with risk uncertainty and keep the project profitability even with the risk presence. Gonzáles and García (2015) claims that risk analysis should identify both risks and its effects on the outcome. Hence, risk should be avoided under their point of view. In consequence, risk managers need to collect adequate information to minimize risk and uncertainty since both factors are believed to restrains wages. After that, it is necessary to classify and provide a degree of occurrence. The degree of occurrence determination is suggested to be optimistic, pessimistic, and conservative scenarios (Virine and Trumper, 2019). Obviously, in the risk process it is necessary to get experts' advice which might bias the information. Also, since uncertainty is present in both future and risk, it is almost impossible to identify and tackle all risks properly. Nonetheless, risk managers pursue to anticipate the future changes with capability to hurt the profitability of the project (Cornejo, 2018). The way they deal with uncertain events is via probabilities. Probabilities attempt to provide an answer to both occurrence uncertainty and impact. According to Peruvian project management guide, sensitivity analysis is part of risk study (DGPMIMEF, 2019). Sensitivity analysis is the subpart of risk assessment in which variables are deliberately manipulated to see how the changing impacts on the target. The target will depend on what is desired of the project. Not all risk analysis analyzes the project revenue, but they scrutinize other outcomes like time, sustainability, costs, environment impact among others as seen in the literature review. Here comes the controversy. Is it accurate to stick only in expert advice regarding the probability of occurrence of an event? Statistical-based methods like Monte Carlo provide an alternative answer.

2.2.1 Monte Carlo

Monte Carlo simulation is a statistical based model that provides random numbers of the selected variables (Virine and Trumper, 2019). It simulates the randomness of the well-known Monte Carlo casinos. Hence, through random numbers it is obtained a set of probable results (Cornejo, 2018). This tool is helpful in analyzing the probability of occurrence of an event which also helps with the project´s risk assessing (Wali and Othman, 2019). Only when it is not possible to make more simulations, the model stops and becomes stable (Inquilla and Rodríguez, 2019) After that, Monte Carlo provides the probability distribution of the objective as well as additional helpful statistical information (Kmak and Ingall, 2009). Due to the boundaries of Monte Carlo simulations, project managers around the world have harnessed this tool to assess risk analysis in all sizes of projects around the world (Bock and Truck, 2011). However, public agencies like the Peruvian ones still do not commit to use this tool, despite the evidence of the Monte Carlo robustness. Therefore, the current analysis will employ the Monte Carlo method to assess and evaluate the risk of a school building project in a Peruvian city. The analysis also aims to cover the gap in the Peruvian literature regarding school project risk management employing the Monte Carlo method.

3. Method

As seen in the literature preview, it is necessary to identify and handle the possible risk of the project. Hence, the current analysis found very helpful the academic approach of (Rodriguez, 2018), in this process. Moreover, it was necessary to review the project record which was possible thanks to the authority. Therefore, the analysis considered the following inputs: infrastructure cost, assets cost, project profile, supervision, wages and salary of teachers and auxiliary workers, and maintenance works. The maintenance works considered the risk of natural disasters like earthquakes and rains like “El Niño”. Hence, it is an expenditure intended to keep the building in optimal conditions to resist the natural fatalities. Of course, the analysis considered the benefits of the project. However, since it is a public school, it is not possible to establish an income because of student tuitions like private institutions. Therefore, the current analysis employed the methodology of (Rodriguez, 2018). This methodology has the following steps:

- First, establish a possible future income that a possible graduate of basic school gets. The income selected was S/. 695.5 or US$ 174.00. That information is available in the Peruvian statistical authority (INEI, 2019).
- Second, the age when a student enters a regular school is plenty of time at six years-old.
- Third, the legal age to work without parent permission is eighteen years-old according to Peruvian law.
-Fourth, the retirement age is sixty-five-year-old which is the recommendation of Peruvian law.
-Five, the rate of education return was 10.43% following (Arpi, 2016) suggestion.
-Sixth, the actual value of future incomes, VFI, was estimated following Eq. (1).

$$VFI = A/(1+r)^\wedge((C-B))\ * [(1-((1+r)^{-(D-C)}))/r] \tag{1}$$

where:

A: future incomes, i.e. S/. 695.5
B: age of a new school student, i.e. six years-old
C: legal age to work, i.e. eighteen years-old
D: retirement age, i.e. sixty-five years-old
r: rate of schooling return, i.e. 10.43%

- Seventh, the number of additional education years, E, relies on the number of years the student is going to get. The Peruvian elementary school lasts 6 years. Hence, a new elementary school student will get six years, while a student in the third year will get three years extra.
- Eight, net benefits per student, NBS, or additional incomes because of education will be estimated in the following way:
NBS = VFI*r*E
-Ninth, the analysis employed the students' quantity, Q, according to the project record effective demand.
-Tenth, the estimation of benefits, B, was:
B=NBS*Q

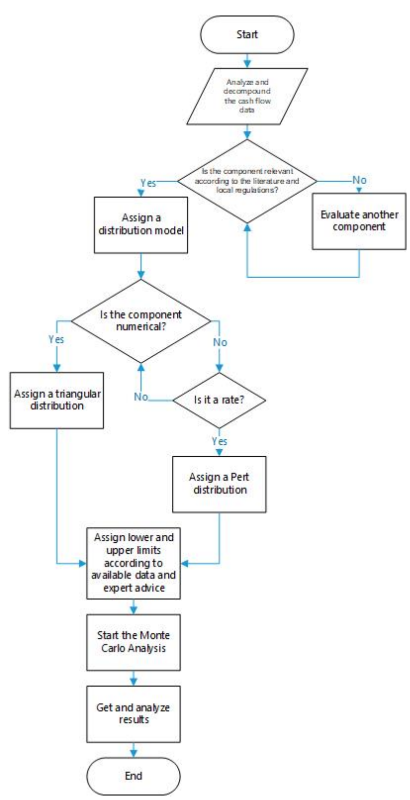

Fig. 1. Monte Carlo simulation flow chart

Furthermore, the variable benefits, which included the students' quantity, had its growth rate. According to (Espinoza, et al. 2021), this rate was 1.71%. Moreover, all financial variables were subject to inflation. Because of the expert advisory, the analysis employed PERT distribution to both inflation and growth rate. While the other variables had triangular distribution. Also, the number of iterations was 7, 000. The outcomes for the analysis were the project Net Present Value and Internal Rate of Return. For the entire process, the current analysis employed the Crystal Ball software. The process is shown in Fig. 1.

4. Results

The following figures and tables display both results of Net Present Value, NPV, and Internal Rate of Return, IRR. The Figure displays the scenarios distribution of the NPV analysis. The analysis had a 99.92% certainty that the current project will have a NPV between 2, 143 and 10, 322 thousand of dollars. Table 2 complements that information by showing the probability distribution of the project's NPV. It is almost 52% of probability that the project's NPV will be bigger than the estimated one. Although there exists near 48% of odds that the current NPV would be lower, it is almost unfeasible that it becomes lower than zero. The reason is that Fig. 2 shows that there is less than 0.64% of probabilities that NPV will be lower than zero. Finally, for the project's NPV, it is highly probable that the current NPV will move between 5, 000 and 6, 000 thousand of American dollars. Moreover, Fig. 2 shows the scenarios that considered the project's NPV as the output variable. Moreover, it shows a certainty of 99.46% that the project's NPV will be bigger than 3 292 and lower than 5 443 million dollars. Descriptive statistics are presented in Table 2. Table 3 depicts the project's NPV probability of occurrence. Hence, the project's NPV will be between 4 000 and 4 500 million dollars. Moreover, there is a low probability that the project's NPV will be less than 3 299 million dollars. Fig. 4 shows the project's NPV sensitivity analysis, where it is noticeable the high importance of incomes or benefits. The Methodology part explained the way the current study obtained this variable. Hence, there is evidence that the number of students attending the school is critical for the social profitability of the project. On the other hand, the sensitivity analysis showed that the infrastructure cost had a negative impact on the project's NPV. Therefore, project managers should take actions to avoid unnecessary delays and over expending the initial budget. Of course, there is also the probability that a natural event like "El Niño" might delay and make the project more expensive. Fig. 4 portrays the Internal Rate Return, IRR, analysis. That figure shows with a certainty of 99.94% that the current project will have an IRR between 13% and 35%. Those percentages are bigger than the required minimum rate, i.e. 8%. Therefore, there is a huge probability that the project will have a social benefit. Moreover, Table 4 complements the given information by providing the odds of several IRR placed between 13% and 35%. There is a probability of about 33% that the project´s value surpasses the estimated IRR, i.e. 24%. Although there is a probability of 67% that the current IRR would be lower than the estimated one, there is a huge probability that it does not even reach the minimum required rate. Indeed, the probability of getting a project's IRR lower than 13% is only 13%. Fig. 5 also shows the sensitivity analysis. Again, the sensitivity analysis warns about the negative impact that infrastructure costs could have on the project's IRR. Unlike the project's NPV, the variance contribution of that variable was near 53%. Also, even though Table 5 found that the benefits had a positive impact on the project´s IRR, it was only 25%.

Table 2
Descriptive statistics

Statistic	Values
Iteration	7 000
Base Case *	5,830.11
Mean*	6,169.67
Median*	6,032.99
Standard Deviation*	1,484.26
Bias	0.27
Kurtosis	2.63
Coefficient of variation	0.24
Min*	1,962.47
Max*	10,655.83
Statistic	Values

*in thousands of United States dollars

Table 3
Distribution of the project´s NPV odds

Rank*	Probability	Accumulated
< 3,000	0.64%	0.64%
[3,000-4,000>	5.66%	6.30%
[4,000-5,000>	15.69%	21.99%
[5,000-6,000>	26.47%	48.46%
[6,000-7,000>	23.01%	71.47%
[7,000-8,000>	15.34%	86.81%
[8,000-9,000>	9.11%	95.92%
[9,000-10,000>	3.69%	99.61%
>10,000	0.27%	99.92%

*in thousands of United States dollars

Table 4
Distribution of the project´s IRR odds

Rank	Probability	Accumulated
<13%	0.02%	0.02%
[13%-16%>	2.92%	2.94%
[16%-19%>	12.16%	15.10%
[19%-22%>	23.04%	38.14%
[22%-25%>	29.14%	67.28%
[25%-28%>	19.49%	86.77%
[28%-31%>	9.54%	96.31%
>31%	3.58%	99.94%

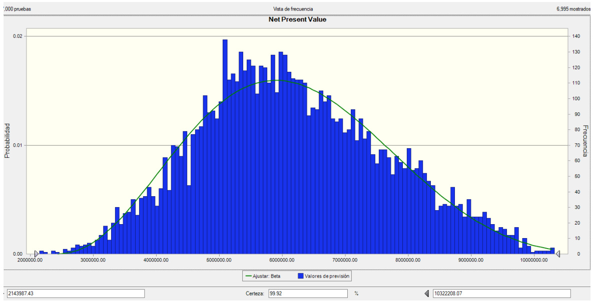

Fig. 2. Monte Carlo simulation for project NPV

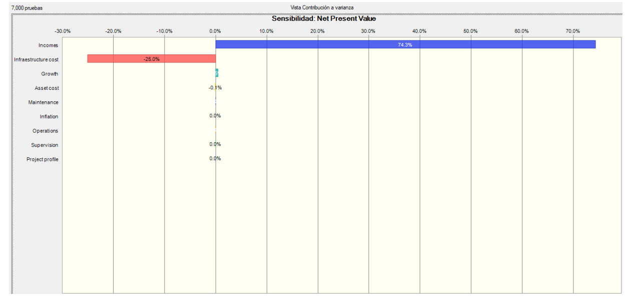

Fig. 3. Project NPV sensitivity analysis

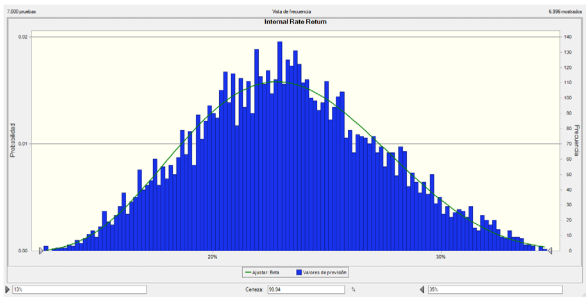

Fig. 4. Monte Carlo simulation for project IRR

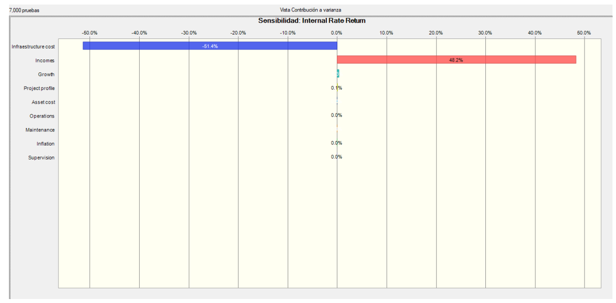

Fig. 5. Project IRR sensitivity analysis

5. Discussion

The current analysis studied the risk analysis for a school building project in a Peruvian city. Then, the research with the help of Monte Carlo simulation has arrived at several results. The study found that students had a huge impact on the sensitivity of the project's NPV; while, infrastructure had a several effect on project´s IRR. The finding of the importance of the number of students to keep the social profitability of a school building project matches with the findings of (Inquilla and Rodriguez, 2019). Since the demand in this project is the students' attendance, this result matches with the findings of (Sastoque, et al. 2016). That research discovered that the demand of education infrastructure was an issue for every school building project no matter who led the project. Besides, the current study encountered the possible impact of natural events on the revenue of the project. The variable that seemed more vulnerable to that risk was the project's IRR. (Serrano, et al. 2020) also found that climate change and natural events are risky enough to harm the project's NPV and IRR. Although natural disasters are a factor that might endanger the profitability of the project, it is necessary to remember that overspending is also because of delays in the project execution as stated by (Girardi, et al. 2018) and (Namazian, et al. 2019) Therefore, project managers should take actions to avoid the unnecessary delays in the project execution. Finally, it is expected that when the project is finished, there would not exist overspending. In consequence, it is necessary for project managers to develop an accurate cost structure for every single part of the project. Only when the project is totally materialized, the research would be able to state if it matched with the results of (Bonato, et al. 2019).

7. Conclusion

It is undebatable the importance of public investing in education. Education is the only way for people to get out of poverty and for the nation to develop. However, it is important to control the public expenditure to avoid overspending and resource embezzlement. People should be able to supervise that every cent coming from the national treasure is well employed. Besides corruption, there are factors that can endanger the project planned budget and even its sustainability. Those risks should be detected and tackled appropriately to avoid undesired situations. Although it is not feasible to forecast with a total certainty, it is possible to estimate probabilities of events. Monte Carlo meets that function by providing a unique way to analyze risks with strong statistical and empirical background. After applying the Monte Carlo method for assessing an education infrastructure project, the research found that assistance is the most important factor for the project´s sustainability. Therefore, measures like providing food to children, also called Qaliwarma program, is a valid method to avoid both malnutrition and evasion. Nonetheless, education with technical purposes for higher grades should also be taken into consideration. Many undereducated parents think that education is not useful. Then, if poverty is present they would persuade their children to start working prematurely. In the long term, the children might drop school. Therefore, education with job technical education might be a solution to prevent it.

Furthermore, infrastructure overspending is a huge risk for the project social profit rate. Therefore, efforts are necessary to establish an efficient way to destine the public resources. Of course, it does not mean to put at risk the entire structure for saving unnecessarily in materials. It means to avoid situations where overspending is present. For instance, the estate should write meticulous contracts to avoid delays because of misunderstanding of the contract by the contractors. Also, fast controversy solution finding institutions are needed to stay away from time wasting. Time is gold for projects.

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