Discovering optionality in corporate strategic decisions with Simulation Decomposition

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Abstract. Corporate strategic decisions are often supported by evaluation with real options framework. However, the majority of real options studies choose to analyze generic types of real options. In this extended abstract, we demonstrate how customized real options can be systematically discovered by employing a recently developed approach called Simulation Decomposition or SimDec. SimDec is an enhancement of Monte Carlo simulation, which allows tracing how different input factors and their interactions affect the outcome(s) while preserving the holistic picture of the overall uncertainty. We show the application of SimDec to the two cases of corporate strategic decision-making: 1. Investment strategy and 2. Compliance with emissions regulations. Both cases demonstrate that SimDec reveals previously hidden interactions of factors in a model and provides actionable outcome by discovering optionality in strategic decisions.

Keywords. simulation decomposition, Monte Carlo simulation, investment profitability, emission reduction, strategic management

Extended abstract

Corporate strategic decisions, such as mergers and acquisitions, research and development projects, growth in adjacent markets and various other investment projects involve significant upfront costs, substantial uncertainty and often multiple execution strategies. The real options framework provides an excellent toolbox for analysis of such projects due to its ability to recognize the value of flexibility under uncertainty. However, the majority of real options studies choose to analyze generic types of flexibilities or real options (Kozlova, 2017; Trigeorgis & Tsekrekos, 2018), and only rare cases recognize customized real options, obtained by collaborative work of engineers and business people (Ceseña, Mutale, & Rivas-Dávalos, 2013).

In this extended abstract, we demonstrate how customized real options can be systematically discovered by employing a recently developed approach called Simulation Decomposition or SimDec (Kozlova, Collan, & Luukka, 2016). SimDec is an enhancement on top of Monte Carlo simulation. During the simulation, along with the output values, the input values are recorded as well, and then used to decompose the resulting probability distribution into scenarios comprised of combinations of different states of inputs. Such a visualization allows tracing how different input factors together with their interactions affect the outcome(s) while preserving the holistic picture of the overall uncertainty.

SimDec has been used to generate valuable insights for multiple contexts, including renewable energy policy (Kozlova et al., 2016), carbon-capture and storage investments (Kozlova & Yeomans, 2019), life-cycle emissions (Deviatkin, Kozlova, & Yeomans, 2021), geology (Kozlova & Yeomans, 2020), air traffic electrification (Kozlova, Nykänen, & Yeomans, 2022), and agriculture (Raul, Liu, Leifsson, & Kaleita, 2022). The visualization approach employed by SimDec method was shown to be superior to other available alternatives (Kozlova & Yeomans, 2021). In this paper, we show the application of SimDec to the two cases of corporate strategic decision-making: 1. Investment strategy and 2. Compliance to emissions regulations.

Case 1. Investment strategy

A company is evaluating a wind farm project under three different strategies: (A) going to the market with volatile electricity prices, (B) entering a bilateral agreement with a fixed price, and (C) applying for a state subsidy. The numeric details on the case are not relevant for the purposes of this abstract, though the interested reader can access them here (Kozlova, Mariia & Yeomans, 2020). The calculation of investment profitability is determined for the three different pricing strategies *ceteris paribus*. For each strategy, a Monte Carlo simulation is run. Its results are presented in Figure 1.

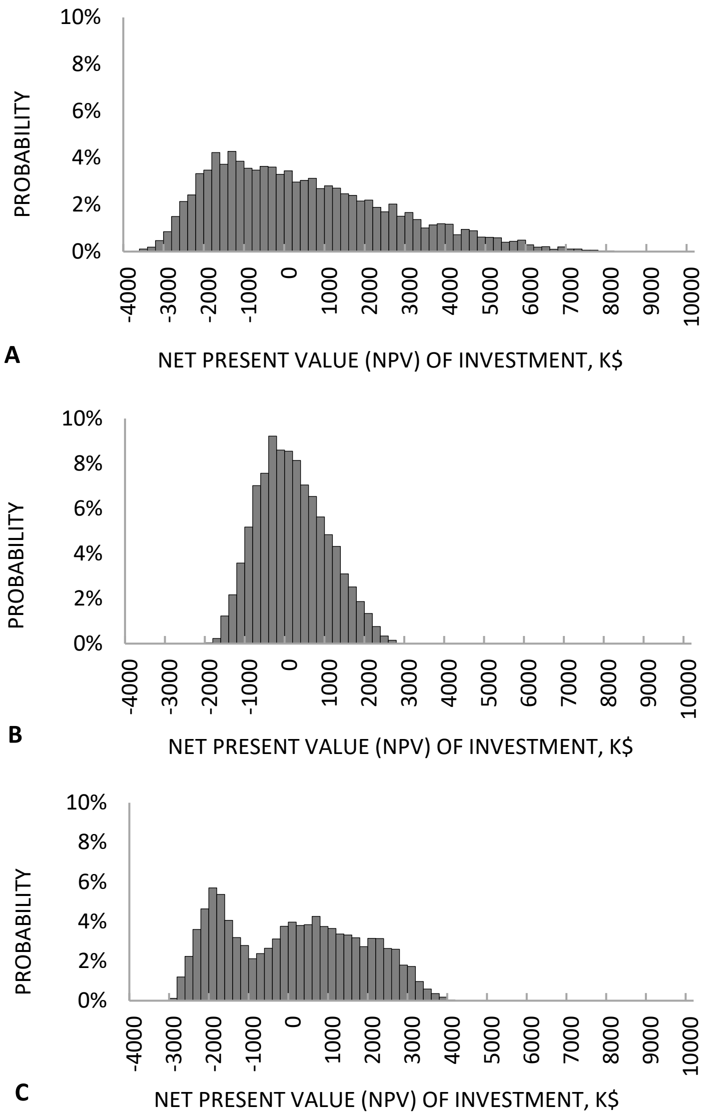

Figure 1. Simulation of investment profitability under (A) the price uncertainty, (B) bilateral contract, and (C) governmental support

Based on these analytical results, the bilateral contract direction (strategy B) appears to be the most promising with minimized magnitude of risks involved (the maximum loss in B is 2M$, while in A and C >=3M$).

Figure 2 portrays the same distributions, but decomposed by electricity production level (low, medium, and high) and the investment cost (pessimistic, realistic, and optimistic).

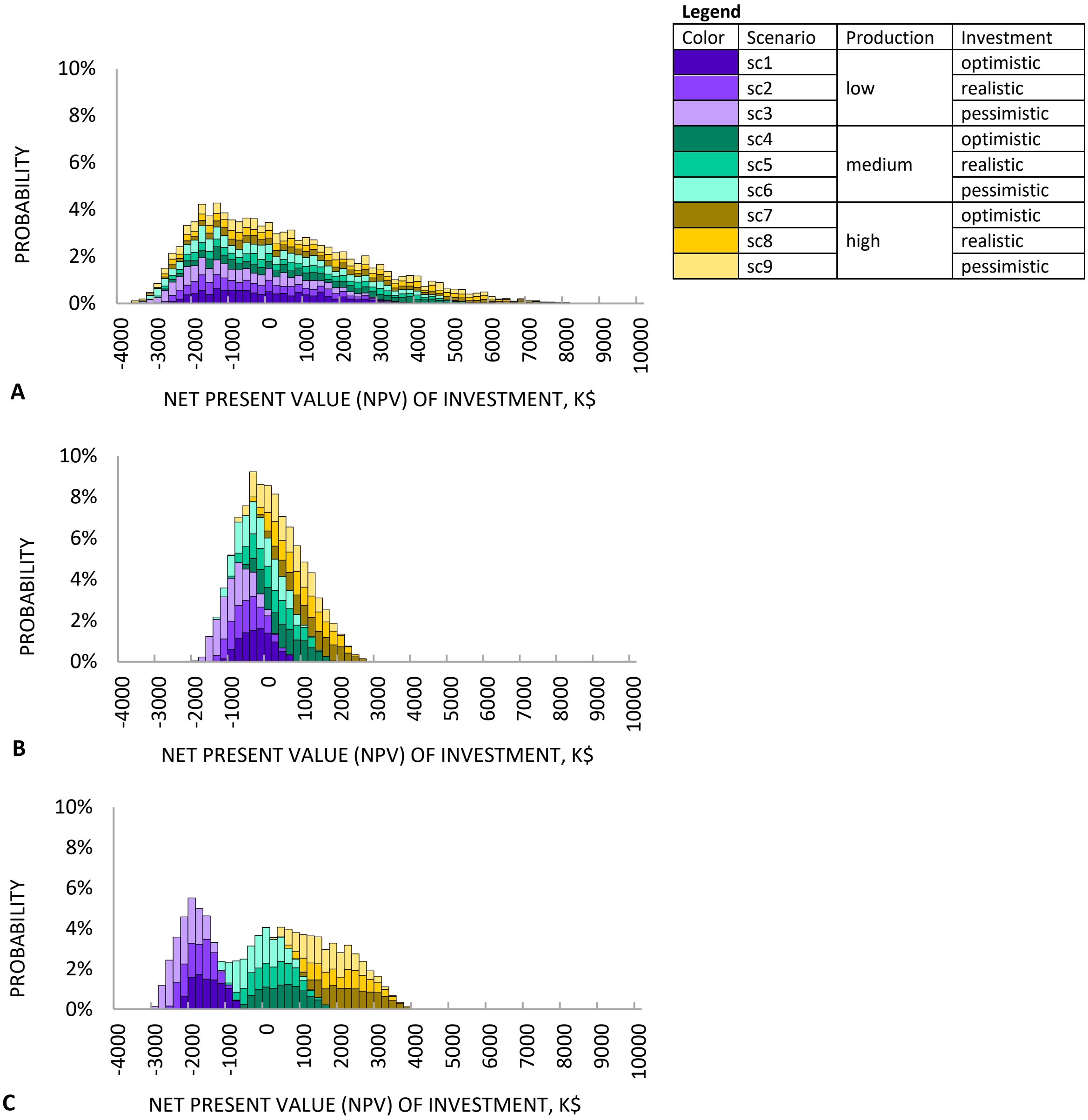

Figure 2. Decomposition of investment profitability under (A) the price uncertainty, (B) bilateral contract, and (C) governmental support

We can observe that in the going-to-market strategy, the influence of the level of electricity production and investment cost is diluted by the price volatility – all scenarios are lying on top of each other (Figure 2A). In the bilateral contract case, the scenario with optimistic cost and high production performance lies predominantly in the positive zone (Figure 2B). However, in the subsidy case, all scenarios with high production performance are above zero (Figure 2C), meaning guaranteed profitability of the investment, if a windy site is secured for the wind farm. The decomposition approach reveals how differently the input factors affect the outcome in the three strategies and allows to identify the combination of factors that lead to a successful investment.

Case 2. Compliance with emissions regulations

A transportation company is looking into reducing emissions to comply with new regulations. Life-cycle emissions of a specific element are analyzed – wooden transportation pallets. There is a substantial variability in multiple factors surrounding the usage of pallets, including the number of uses, the size of trucks and the transportation distance, characteristics of materials used by different pallet manufacturers, as well as the way of end-life utilization – incinerating or landfilling. The numeric details of the case can be found in (Deviatkin et al., 2021).

Figure 3 depicts the distribution of the total life-cycle emissions under the above-mentioned variations in operations. There is some binary pattern observable in the graph, and it can be further explored by changing the ranges of input variables or fixing some of them to check the influence of others. However, the model has eight uncertain variables, and, thus, numerous combinations need to be checked before arriving at any firm conclusions.

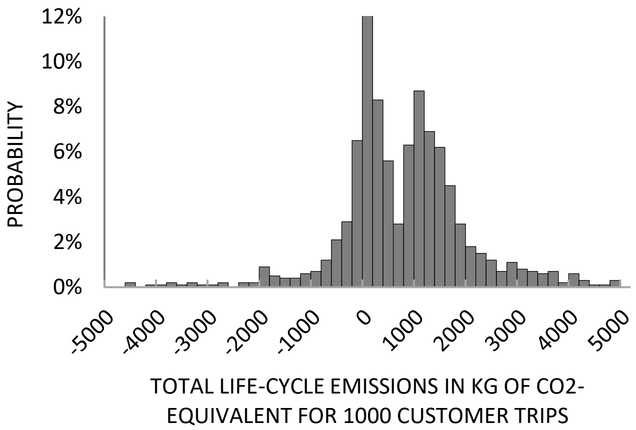

Figure 3. Simulation of the total life-cycle emissions from wooden pallets

The results of the decomposition are presented in Figure 4. The factors 'End of life' and 'Number of uses' are found to be the most insightful for the graphics.

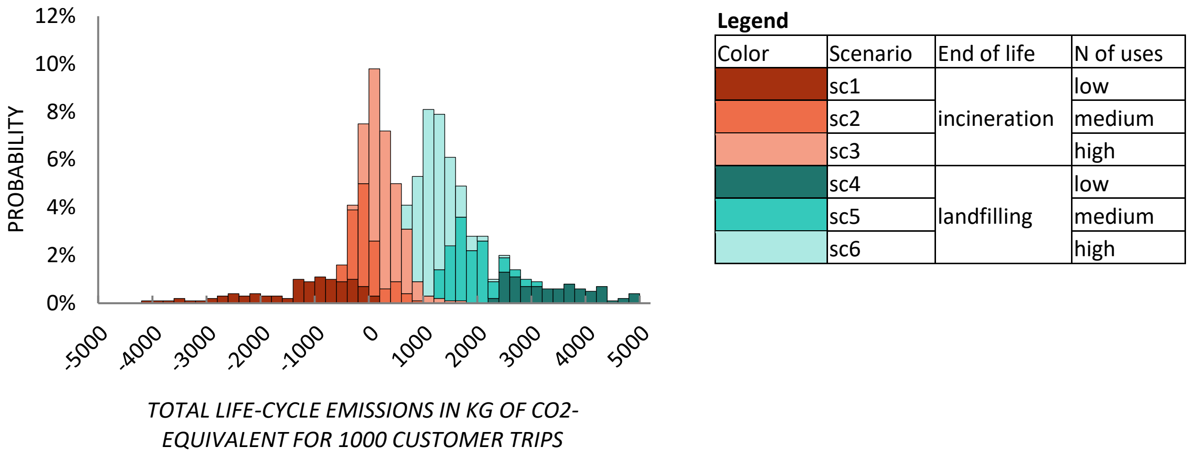

Figure 4. Decomposition of the total life-cycle emissions from wooden pallets

It becomes obvious from the graph that the binary pattern originates from the 'End of life' variable. But more importantly, a crucial interaction is revealed. If pallets are landfilled, then the higher the number of uses, the lower the emissions, which is expected. However, if pallets are incinerated, the higher number of uses generates more emissions, not less. Moreover, the combination of incineration and low number of uses produces negative emissions only. This effect appears due to specific element of emission accounting, when burning the wood generates energy and offsets possible fossil-fuel usage. And although from sustainability and the commonsense point of view, the usage should be pushed up, the emission accounting works in this specific way and this loophole can be used to legitimately reduce the emissions in the reporting.

Both cases considered here demonstrate that SimDec reveals previously hidden interactions of factors in a model and provides actionable outcome by discovering optionality in strategic decisions. SimDec can be adapted to all existing simulation models with negligible additional design effort and computational cost. Matlab codes (Kozlova, Collan, & Luukka, 2018) and an Ms. Excel template (Kozlova, Mariia & Yeomans, 2020) are freely available.

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References

Deviatkin, I., Kozlova, M., & Yeomans, J. S. (2021). Simulation decomposition for environmental sustainability: Enhanced decision-making in carbon footprint analysis. *Socio-Economic Planning Sciences, 75*, 100837.

Kozlova, M., & Yeomans, J. S. (2019). Multi-variable simulation decomposition in environmental planning: An application to carbon capture and storage. *Journal of Environmental Informatics Letters, 1*(1), 20-26.

Kozlova, M., Collan, M., & Luukka, P. (2016). Simulation decomposition: New approach for better simulation analysis of multi-variable investment projects. *Fuzzy Economic Review, 21*(2), 3.

Kozlova, M., & Yeomans, J. (2021). Visual analytics in environmental decision-making: A comparison of overlay charts versus simulation decomposition. *Journal of Environmental Informatics Letters, 4*(2), 93-100.

Kozlova, M. (2017). Real option valuation in renewable energy literature: Research focus, trends and design. *Renewable and Sustainable Energy Reviews, 80*, 180-196.

Kozlova, M., Nykänen, T., & Yeomans, J. S. (2022). Technical advances in aviation electrification: Enhancing strategic R&D investment analysis through simulation decomposition. *Sustainability, 14*(1), 414.

Kozlova, M., & Yeomans, J. S. (2020). Monte Carlo enhancement via simulation decomposition: A "Must-have" inclusion for many disciplines. *INFORMS Transactions on Education,* https://doi.org/10.1287/ited.2019.0240

Kozlova, M., Collan, M. & Luukka, P. (2018). Matlab function for simulation decomposition. Retrieved from https://www.researchgate.net/publication/322211201_matlab_function_for_simulation_decomposition

Martínez Ceseña, E. A., Mutale, J., & Rivas-Dávalos, F. (2013). Real options theory applied to electricity generation projects: A review. *Renewable and Sustainable Energy Reviews, 19*(0), 573-581.

Raul, V., Liu, Y., Leifsson, L., & Kaleita, A. (2022). Effects of weather on Iowa nitrogen export estimated by simulation-based decomposition. *Sustainability, 14*(3), 1060.

Trigeorgis, L., & Tsekrekos, A. E. (2018). Real options in operations research: A review. *European Journal of Operational Research*, *270*(1), 1-24.