Choosing a Norwegian City to Live in

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Decision Analysis with Artificial Intelligence

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1. Executive Summary

This project identifies the ideal city in Norway for a young professional woman completing a master's in computational engineering, focusing on job opportunities, PhD prospects, cost of living, environmental quality, and recreation. Using multi-criteria decision analysis and AI-driven insights, six cities were evaluated based on career prospects, financial factors, personal growth, and environmental quality, with projections to 2026 for key variables.

Findings: Trondheim emerged as the optimal choice, excelling in career opportunities, environmental quality, and recreation. Further validation through benefit-cost trade-offs, Monte Carlo simulation, and sensitivity analysis confirmed Trondheim's robustness unless income weighs heavily favored Oslo.

Conclusion: Trondheim is recommended as it best aligns with the decision maker's career goals, affordability needs, and lifestyle preferences.

2. Introduction

a. Decision Maker and Main Objectives

The decision maker is a woman in her mid to late twenties, who lives in Norway and will finish her master's degree in computational engineering in 2026. She has already decided to continue living in Norway. However, the next critical decision that must be made is to choose the most suitable city to start a professional career in and establish long-term residence. Moreover, she does not have any previous knowledge about the cities she is to choose from and is not biased against any of them. Her decision will be made only based on data. To choose an ideal city, she considers objectives that are based only on her personal preferences, such as career prospects, living conditions, environment, and social life. Overall, her main objectives are to optimize her chances of getting hired as soon as possible with a satisfactory salary, while reducing everyday spending, enhancing her social life, and enjoying the environment. This decision could impact her future career, health, relationships, education, and financial status.

The decision maker wants to get a job as soon as possible with the highest salary and the lowest living costs. In the future she would like to have an opportunity to continue her education, due to that under consideration are also PhD programs offered in the city. Moreover, she values fresh air and a safe environment and does not like rainy weather. In terms of personal growth, she prefers to have a lot of possible places to meet with people and discover new hobbies. For that, the decision maker wants to have a lot of various activities in town. Her preferred means of transportation is riding a bike, but also, she would like to have a monthly ticket for public transportation in the city that she lives in, due to possible emergencies or longer routes.

b. Problem Statement

The decision is to select a city in Norway that maximizes career prospects for the decision maker, optimizes income potential while minimizing living expenses (with a focus on affordable housing, food, and transportation), and enhances personal growth through a wide range of recreational activities. Additionally, the city should offer favorable environmental conditions, considering weather, air quality, and safety (crime rate).

Since the decision will be made in 2026 upon the decision maker's graduation, all data projections carry inherent uncertainties. The major uncertainties of this analysis will be job market fluctuations, housing supply-demand imbalances, economic uncertainties, climate change, and the uncertainties in the projection itself. These factors are crucial to ensure a well-rounded and data-driven choice that aligns with the decision maker's goals for career advancement, financial stability, and quality of life.
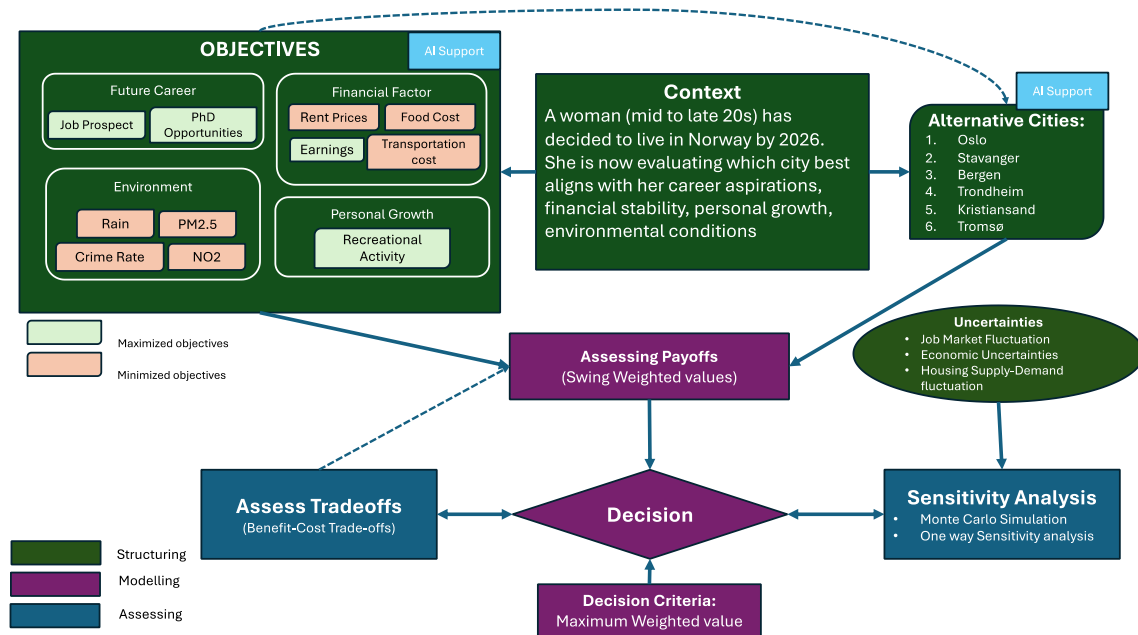
3. Methodology

a. Concept Map

Figure 1 Concept Map

b. Values, Objectives, and Attributes of the Problem

The values, objectives, and attributes of the project is defined on Table 1.

Table 1 Values, Objectives, and Attributes

Objectives	Attributes and Sources
Values 1: Career Prospects	
Maximize employment opportunities	Number of employments [1]
Maximize PhD opportunities	Number of individuals admitted to doctorate program in Engineering and Technology [2]
Values 2: Financial Factors	
Maximize earnings	Median salary for woman aged 25-39, NOK/month [3]
Minimize rent prices	Predicted monthly rent for 3-rooms apartment (including bedroom and living room), NOK/month [4]
Minimize transportation costs	Cost of a monthly public transportation pass for unlimited travel within 1 zone, NOK/month (local public transport authority)
Minimize food prices	Estimated monthly food cost per person, based on a Western-style diet (2400 calories per day), NOK/month [5]
Values 3: Personal Growth	
Maximize recreational activity options	Number of recreational opportunities (sport, culture, outdoor, hiking, ski, mall, bars) (Google Maps)
Values 4: Environmental Conditions	
Minimize crime rate	Number of serious offenses, punished usually with jailtime, such as sexual, alcohol, and drug offenses and violence and maltreatment [6]
Minimize PM2.5 rate	Daily average concentration of PM2.5, moles [7]
Minimize NO2 rate	Daily average concentration of NO2, moles [7]
Minimize rainfall frequency	Mean annual rainfall, mm3 [8]

An Online LLM model – ChatGPT was used to categorize recreational and leisure activities in each city, covering sports (gyms, indoor sports facilities, organized classes), cultural venues (museums, theaters, cinemas), and outdoor options (fishing spots, beaches, parks, forests, hiking trails, and ski resorts). The social scene was assessed by the number of malls, bars, clubs, and restaurants. See Appendix A to see the exact output from the model.

Several attributes –Job Prospect, Earnings, and Rent Prices—are forecasted into 2026 using linear regression to incorporate the historical data it has. While attribute Crime Rate was also projected to 2026 based on historical reports from 2014 to 2024 to estimate future safety levels. Whereas the rest of the attribute relies on the latest available data due to limited historical data or inflation affecting all alternatives similarly.

c. Alternatives

Based on these objectives, and with the support of AI-driven analysis, we have identified several alternatives that may meet the criteria for an ideal place to live:

1. **Oslo**: As Norway's capital and largest city, Oslo has a diverse job market, numerous personal growth activities, and some of the highest median earnings in the country.
2. **Stavanger**: Known as the "Oil Capital," Stavanger offers ample job opportunities in oil and energy, high median earnings, and moderate living costs.
3. **Bergen**: A center for marine technology, energy, and environmental science, Bergen provides easy access to nature with nearby mountains and fjords.
4. **Trondheim**: Home to NTNU, Trondheim offers strong PhD opportunities in engineering and technology and maintains low pollution levels year-round.
5. **Kristiansand**: This coastal city provides excellent recreational access to beaches and lower living costs than most major cities.
6. **Tromsø**: Renowned for outdoor activities like skiing and hiking, Tromsø has a comparatively low cost of living.

4. Discussion

a. Modelling and Evaluating

To evaluate the decision, a payoff matrix (Table 2) has been constructed to assess each alternative in relation to the defined objectives. The rightmost column indicates the function aligned with the decision-maker's primary objectives: "Max" signifies that the decision-maker aims to maximize the given attribute, while "Min" indicates that a lower attribute value is preferable.

Table 2 Payoff Matrix

Attributes		Actual Alternatives						Function
		Oslo	Stavanger	Bergen	Trondheim	Kristiansand	Tromsø	
Job Prospects	**Obj1**	636357.17	107788.45	208934.94	151243.29	73592.85	55866.52	Max
PhD Opportunities	**Obj2**	89.00	112.00	10.00	886.00	65.00	49.00	Max
Earnings	**Obj3**	56488.88	50894.48	50749.82	50449.54	47014.66	49897.23	Max
Rent prices	**Obj4**	18267.93	13667.50	14304.59	14707.26	12413.63	14920.22	Min
Transportation Cost	**Obj5**	897.00	680.00	795.00	899.00	902.00	580.00	Min
Food cost	**Obj6**	5215.59	4719.56	4892.62	4824.18	4763.17	4712.56	Min

Attributes		Actual Alternatives						Func tion
		Oslo	Stavanger	Bergen	Trondheim	Kristiansand	Tromsø	
Recreational	Obj7	396.00	203.00	274.00	293.00	159.00	169.00	Max
Weather	Obj8	2.84	4.10	6.33	1.99	2.71	2.45	Min
PM2.5	Obj9	32.07	30.92	21.64	24.08	28.48	26.37	Min
NO2	Obj10	13.78	10.73	5.54	11.08	3.98	11.80	Min
Crime rate	Obj11	18042.00	7878.00	7562.00	6589.00	6216.00	5768.00	Min

To account for differences in objective importance, weights will be assigned using the swing weighting method, which ranks objectives based on their relative impact in distinguishing between alternatives [9]. Starting with a hypothetical alternative combining all worst-performing attributes, one attribute is "swung" to its best level, and this process is repeated until a full ranking of attributes is established. Each attribute is then weighted accordingly.

Scores are converted to a 0-100 scale for comparability, using a linear function to maximize and minimize objectives. For Obj1 and Obj2, where high outliers are present, a logarithmic function is applied to preserve relative differences while reducing the gap between extreme values. This approach prevents any single outlier from skewing results and ensures moderately high values are proportionately represented.

Table 3 Swing Weighted Decision Matrix

Objectives				Values					
Name	Swing Rank	Abs. Weight	Norm. Weight	Oslo	Stavanger	Bergen	Trondheim	Kristiansand	Tromsø
Obj1	2	95	0.1444	100.00	27.01	54.22	40.94	11.33	0.00
Obj2	4	66	0.1003	48.75	53.88	0.00	100.00	41.74	35.44
Obj3	1	100	0.1520	100.00	40.95	39.42	36.26	0.00	30.43
Obj4	3	85	0.1292	0.00	78.58	67.70	60.82	100.00	57.18
Obj5	11	20	0.0304	1.55	68.94	33.23	0.93	0.00	100.00
Obj6	9	39	0.0593	0.00	98.61	64.20	77.81	89.94	100.00
Obj7	7	50	0.0760	100.00	18.57	48.52	56.54	0.00	4.22
Obj8	5	65	0.0988	80.47	51.39	0.00	100.00	83.32	89.36
Obj9	10	38	0.0578	0.00	11.03	100.00	76.61	34.42	54.65
Obj10	8	40	0.0608	0.00	31.12	84.08	27.55	100.00	20.20
Obj11	6	60	0.0912	0.00	82.81	85.38	93.31	96.35	100.00
Total Value		658	1	50.12	50.19	49.74	62.73	49.15	47.18

Based on the swing weighted analysis, Trondheim was selected as it generates the highest sum weighted score. In addition, the performance of each alternative across individual objectives can be further assessed through a visual comparison using spider plots for both the unweighted and weighted values.

The unweighted spider plot shows that no single alternative excels across all objective attributes; instead, each alternative displays varying strengths and weaknesses. However, when we analyze the weighted spider plot, Oslo demonstrates a significant advantage in Obj1 and Obj3, which are assigned higher weights compared to the other objectives. This suggests that while Oslo may not lead overall, its strong performance in these crucial areas makes it a favorable option. Additionally, Trondheim performs relatively well across all objectives, demonstrating consistent, balanced performance. Although Trondheim may not dominate in any single objective, its overall steady performance across both high- and low-weight criteria makes it a possible best choice in this decision.
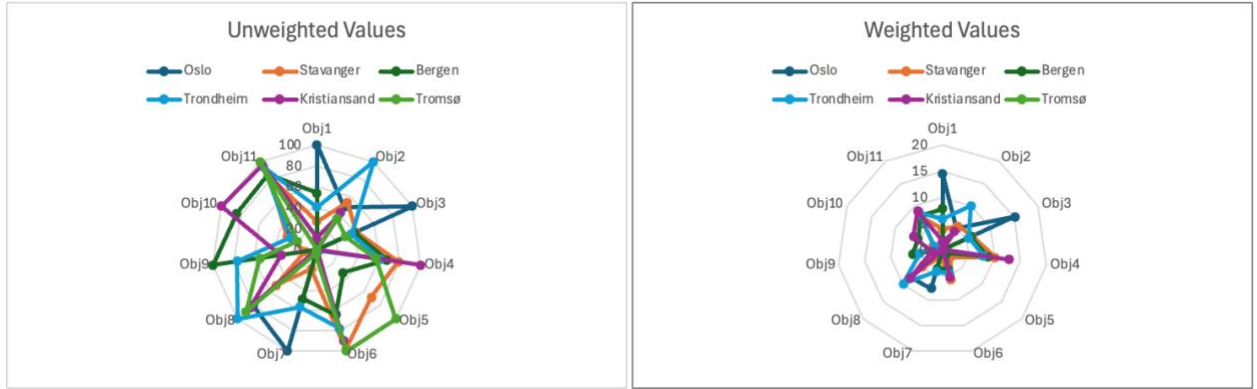
Figure 2 Unweighted and Weighted Spider Plot Values

b. Assessing and Deciding

In analyzing the benefit-cost trade-offs in Figure 3, Stavanger and Bergen are both dominated by Trondheim in terms of weighted benefits and costs. Thus, Stavanger and Bergen can be excluded from further analysis. Furthermore, a closer examination of the chart reveals that Tromsø offers only a slight cost advantage over Trondheim but incurs a significant disadvantage in terms of benefits. Intuitively, Tromsø could also be excluded based on this trade-off; however, due to the complex units comprising the benefit and cost measures, it is quite hard to assessed the trade off without comprehensive analysis. A second iteration of the analysis was conducted after excluding Stavanger and Bergen with the same weights as before. This iteration reveals that Kristiansand and Tromsø are also dominated by Trondheim, leaving Oslo and Trondheim as the efficient frontier options.
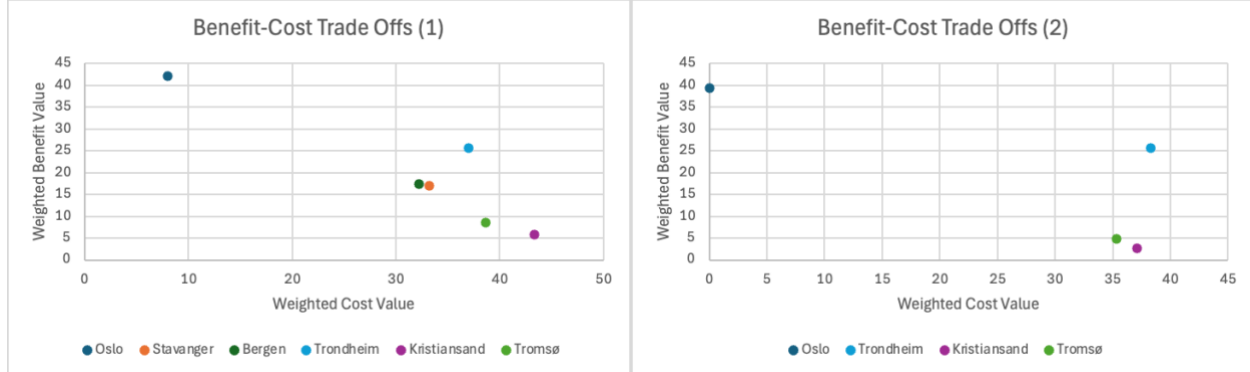

Figure 3 Benefit-Cost Trade Offs (1) first iteration: 6 alternatives (2) second iteration: 4 alternatives

Given the complexity of the problem, a multi-variable sensitivity analysis will be conducted to account for simultaneous changes across all variables, guided by the probability distributions of each variable [9]. To re-evaluate the dominance of Trondheim, which was not clearly visible in the first iteration of the Benefit-Cost Trade-Off analysis, a Monte Carlo simulation was performed across four alternatives—Oslo, Trondheim, Kristiansand, and Tromsø. This simulation is a process that generates random number inputs for uncertain values which are then processed by a mathematical model, so that many scenarios can be evaluated [10]. In this case, we varied all attributes, as each inherits uncertainties stemming from job market fluctuations, economic instability, housing supply-demand imbalances, climate change, and the inherent unpredictability of projecting data to 2026. Due to limited specific knowledge about these uncertainties, we assumed a normal distribution for each, with 95% of values within two standard

deviations. Additionally, a constraint was applied to ensure that all generated values remained non-negative. Following the initial benefit-cost trade-off assessment, Stavanger and Bergen were excluded from the Monte Carlo simulation.
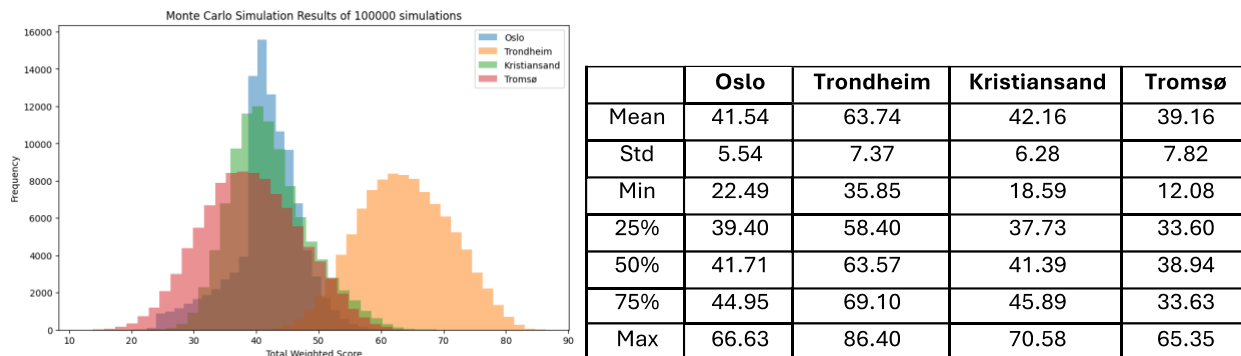

	Oslo	Trondheim	Kristiansand	Tromsø
Mean	41.54	63.74	42.16	39.16
Std	5.54	7.37	6.28	7.82
Min	22.49	35.85	18.59	12.08
25%	39.40	58.40	37.73	33.60
50%	41.71	63.57	41.39	38.94
75%	44.95	69.10	45.89	33.63
Max	66.63	86.40	70.58	65.35

Figure 4 Monte Carlo Simulation Results

Based on the Monte Carlo Simulation of 100,000 simulations, it was found that Trondheim exhibits the highest mean score of 63.74, indicating that, on average, it outperforms the other alternatives. In comparison, Kristiansand, Oslo, and Tromsø have relatively similar mean scores of 42.16, 41.54, and 39.16, respectively, suggesting that these alternatives perform comparably on average, albeit with differences in variability and range.

Trondheim and Tromsø show high standard deviations, indicating greater sensitivity to input changes and variability in performance. Trondheim stands out with the highest maximum score (86.40), showing its potential for top outcomes, and the highest minimum score (35.85), suggesting strong performance even under unfavorable conditions.
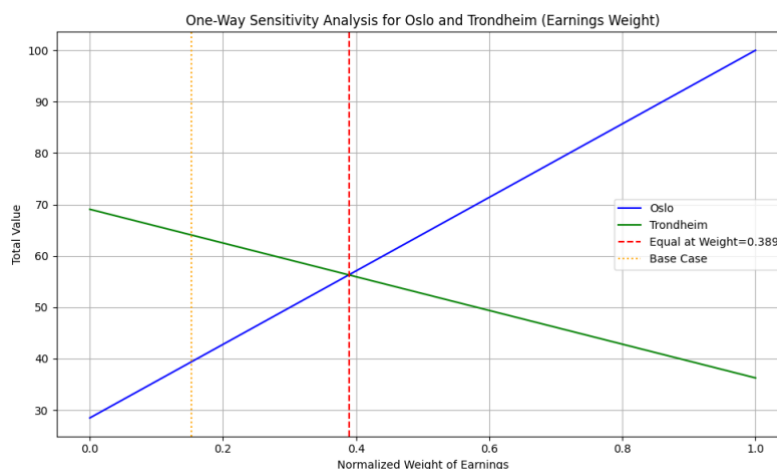

Figure 5 One-way Sensitivity Analysis of Normalized Earnings Weights

We will conduct a one-way sensitivity analysis on the highest-weighted objective, Obj3, to assess Trondheim's robustness against its closest competitor, Oslo. Kristiansand and Tromsø are excluded, as Trondheim's dominance over them was confirmed in the second Benefit-Cost iteration and Monte Carlo simulation. Additionally, Trondheim's Obj3 attribute surpasses that of Kristiansand and Tromsø, making them unlikely to dominate even with weight adjustments, while Oslo has a higher Obj3's attribute than Trondheim.

Figure 5 demonstrates that, at the base case normalized weight of 0.1520 for Obj3, Trondheim is an optimal choice, consistent with the results in Table 1. Furthermore, Trondheim remains the preferred option for any Obj3 weight between 0 and 0.389.

Above this threshold, Oslo emerges as the preferable option. This suggests that if the weight for Obj3 remains within the range of 0 to 0.389, the decision remains robust. Given that we are

considering 11 objectives, it is unlikely for any single objective to hold nearly 40% of the total weight, making a weight above 0.389 improbable.

c. Comparison with LLM Output

1. We initially overlooked one of the potential cities (Kristiansand), which may have been critical for the decision maker.
2. LLMs suggested more options when consulted for the subcategories of recreational activities, which were skiing or going to the theaters
3. LLM was asked, for comparison purposes only, to assign importance to factors in this decision, which are included in appendix A and shows that LLM prioritizes based on patterns in their training data rather than holistic human judgment.
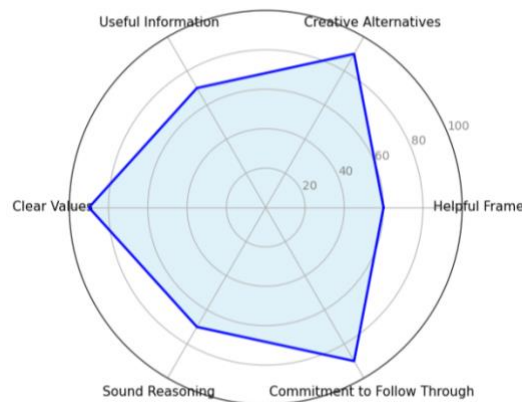
d. Decision Quality Assessment

Figure 6 Spider Plot of DQ Chain

Helpful Frame: The problem is clearly framed—choosing the best city for career, lifestyle, and environmental preferences. The scope and objectives are well-defined, focusing on chosen factors. The only thing that was not specified completely clearly is what is not being decided. **Creative Alternatives**: Having identified multiple cities across Norway, each representing a viable option, ensuring there are enough alternatives to explore. All of the choices are doable, and they solve the problem.

Useful Information: The analysis is based on relevant data that was extrapolated to predict future conditions, ensuring that the decision reflects future trends. The is room for uncertainties, such as changing inflation, global warming or other hard-to-predict possibilities that will disturb prediction of the future data.

Clear Values: The decision maker's values are clear, and they have gone through various metrics and weights, understanding trade-offs between them.

Sound Reasoning: The analysis methods ensure logical, sound reasoning. The only thing that cannot be completely justified in our reasoning is that the choice is based on the decision maker's personal preferences.

Commitment to follow through: Once the decision is made, it should lead to clear, actionable steps, such as moving to the chosen city. There are some uncertainties about that, for example getting a better paying job in another city.

e. Reflection and Limitation

1. The data projection method to 2026 may have limitations in accurately capturing future trends, particularly due to seasonal variations.
2. The absence of expert knowledge in defining uncertainties limited the Monte Carlo simulation to a normal distribution; incorporating expert insights could improve sensitivity analysis.
3. Unpredictable shifts in climate and economic conditions could impact the decision outcome.

5. Conclusion and Recommendation

a. Summary and Remarks

Through a multi-criteria analysis, Trondheim emerged as the top choice among six Norwegian cities based on its balance of career opportunities, environmental quality, affordability, and recreational options, and considering the major uncertainties: job market fluctuation, economic uncertainties, and housing supply demand imbalance. This is also supported by the weighted value analysis, benefit-cost trade-offs, Monte Carlo simulation, and one-way sensitivity analysis.

b. Recommendation

1. Use updated projection methods, such as ARIMA, to better capture seasonal variations.
2. Conduct a more comprehensive sensitivity analysis across a wider range of normalized weights, not limited to only the highest weighted factor.
3. Incorporate expert knowledge to more accurately define uncertainties, leading to improved sensitivity analysis.

6. References

[1] Statistisk Sentralbyrå, "Number of Employments and Earnings (Table 13926)," [Online]. Available: https://www.ssb.no/en/statbank/table/13926/. [Accessed 17 October 2024].

[2] Statistisk Sentralbyrå, "Research Personnel (Table 13896)," [Online]. Available: https://www.ssb.no/en/statbank/table/13896/. [Accessed 17 October 2024].

[3] Statistisk Sentralbyrå, "Number of Employments and Earnings (Table 11652)," [Online]. Available: https://www.ssb.no/en/statbank/table/11652/. [Accessed 17 October 2024].

[4] Statistisk Sentralbyrå, "Rental Market Survey (Table 09897)," [Online]. Available: https://www.ssb.no/en/statbank/table/09897/. [Accessed 17 October 2024].

[5] Numbeo, "Food Prices," [Online]. Available: https://www.numbeo.com/food-prices/.

[6] Statistisk Sentralbyrå, "Offences and Victims Reported to the Police (Table 08486)," Statistisk Sentralbyrå, [Online]. Available: https://www.ssb.no/en/statbank/table/08486/. [Accessed 13 October 2024].

[7] WAQI, "World's Air Pollution:Real-time Air Quality Index," WAQI, [Online]. Available: www.waqi.info. [Accessed 13 October 2024].

[8] Norsk Klimaservicesenter, "Norsk Klimaservicesenter," [Online]. Available: https://seklima.met.no/ . [Accessed 13 October 2024].

[9] R. B. Bratvold and S. H. Begg, Making Good Decisions, Society of Petroleum Engineers, 2010.

[10] D. C. Skinner, Introduction to decision analysis : a practitioner's guide to improving decision quality, Probabilistic, 1999.

7. Appendixes

A. LLM Outputs
B. Calculation Table (Excel)
C. Python Code and Other Data