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1. Introduction

Planning often involves complex negotiations between diverse stakeholders, including developers, communities, public authorities and various others with different priorities and goals. For instance, developers might prioritise high-density housing for economic gain, while residents might prefer lower density to maintain green spaces and community character. Public authorities might need to balance economic development with environmental protection. These decisions have long-lasting consequences for the environment, social fabric, and economic well-being of a community. Negotiations over them allow exploring trade-offs, finding creative solutions that benefit everyone involved, and mitigating potential negative impacts. This necessitates tools that facilitate efficient and effective decision-making. This report details our work on the project for the Applying Data Science module in collaboration with our industry partner, GeoDesign Hub, a leading provider of innovative digital tools specifically designed to address this challenge.

1.1 About GeoDesign Hub

GeoDesign Hub is a digital platform that empowers collaborative decision-making through sophisticated, digitally powered negotiations. It offers a structured framework, streamlining the process for creating and evaluating alternative scenarios for a given area, enabling stakeholders to explore various possibilities and reach comprehensive solutions through trade-offs. The stakeholders could be property developers, community organisations, portfolio managers, local authorities, urban designers/planners or others. It offers solutions for project expeditions & agreements in domains (GeoDesign Hub, n.d.) such as:

- Urban and regional planning
- Inter-agency coordination
- Public Engagement
- Post-disaster rehabilitation
- Infrastructure Investment
- Tourism Development

- Financial Analysis
- Climate Change Adaptation
- Environmental Management
- Cultural Heritage Protection

Furthermore, GeoDesign Hub provides a suite of software plugins that extend the platform's capabilities. These plugins enable users to conduct advanced spatial and financial analysis directly within the platform, eliminating the need for complex external tools and licences. The plugins are customisable for specific project needs and seamlessly integrate with the negotiation process. A comprehensive list of available plugins can be found on the GeoDesign Hub website.

1.2 Project Deliverables

Our project focuses on addressing a critical requirement: analysis of the financial viability of proposed Geodesigns. Geodesigns are digital representations of potential development plans, often created using GeoJSON, a common data format for encoding geographic data. The deliverables of the project includes:

1. **30-year Financial Modeling**: Development of a 30-year financial model that allows users to:

    - Analyse capital investment requirements for a Geodesign.
    - Assess potential return on investment for different Geodesign scenarios represented by JSON data structures.
    - Save and load financial scenario parameters for comparative analysis.

2. **Financial Comparison Reports of Geodesigns**: Create interactive reports to compare the financial aspects of different Geodesign scenarios represented by JSON data structures.

3. **Interviews with Stakeholders:** Conduct interviews with two stakeholders to gather feedback on the model's outputs and ensure its comprehensibility and practical value.

1.3 How does this help GeoDesign Hub?

This integration directly strengthens GeoDesign Hub's capabilities by:

- **Facilitating Informed Decision-Making**: Financial data could provide a concrete foundation for stakeholders with additional information about financials to evaluate trade-offs and choose Geodesigns that maximise long-term financial benefits.
- **Supporting Transparent Negotiations**: Adding transparency in financial considerations fostering trust and facilitating more constructive negotiations within the platform.
- **Optimising Resource Allocation**: By identifying financially viable options, stakeholders can make informed decisions about resource allocation, leading to more efficient and cost-effective development projects.

1.4 GeoDesign Data

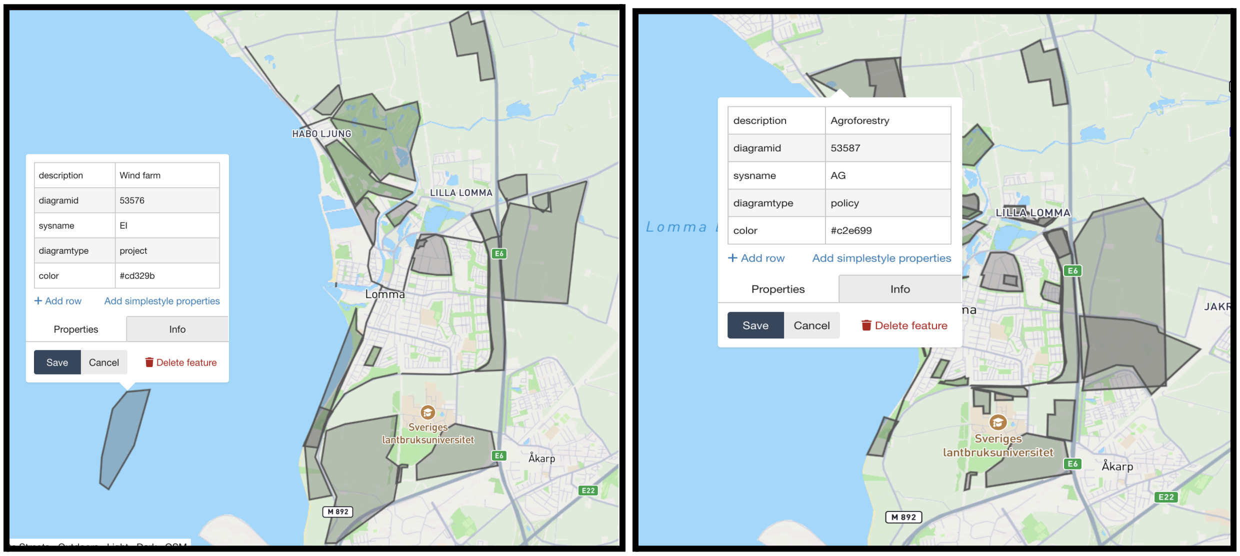


Figure 1. GeoJSON design-a & design-b.

We were provided with two GeoJSON designs, referred to as design-a & design-b, representing a comprehensive spatial plan for land use within a specific area. They consisted of a combination of polygon/linestring-shaped features, each with various properties associated with it:

1. **description**: This provides a label for the feature to help understand the intended purpose or function of the designated area.
2. **diagramid**: This is a unique identifier assigned to the feature within the overall spatial plan. It allows for referencing and tracking specific areas within the data.
3. **sysname**: This represents an internal system name associated with the feature type. Each feature belonged to one of the 9 different system types as shown in Table 1 with their respective sysnames.
4. **diagramtype**: This indicates the broader category of the feature. There are two categories: "project" for development zones & "policy" for areas designated for specific regulations.

5. **color**: This is a colour code associated with the feature, used for visual representation on maps.
6. **geometry:** This property defines the precise location and shape of the feature using a geographic coordinate reference system.

Sysname	System Type
LDH	Low Density Housing
HDH	High Density Housing
IND	Industry & Commerce
INST	Institutional
AG	Agriculture
TRANS	Transport
GI	Green Infrastructure
EI	Energy Infrastructure
BI	Blue Infrastructure

Table 1. Different system types in the Geodesigns.

Given the different types of systems, we prepared a set of assumptions to calculate the financial parameters, wherein the stakeholders could input values for the assumptions and get a comparative dashboard enabling decision-making.

This report is structured to include project management plan, financial modelling, reports, interviews and a group conclusion. First, a clear plan outlining tasks, assigned responsibilities, and a document of key meetings is presented. Recognising the diverse complexities of financial modelling across different land-use scenarios, i.e. the 9 different system types, we have defined a set of assumptions for each type, laying the groundwork for accurate financial calculations. Next, a description of the Python script developed to translate these assumptions into practical financial metrics, calculating key parameters like discounted cash flow, return on investment, net present value, and internal rate of return has been included. To present the financial analysis results, two types of dashboards have been created. A Power BI dashboard allows for interactive comparison of different Geodesigns and their financial parameters. Additionally, an HTML dashboard empowers stakeholders to directly input their assumption values and receive comparison reports of financial parameters of different Geodesigns. An account of feedback received about the understanding of the output by interviewing two stakeholders has also been included. Finally, the report concludes with a reflection of valuable insights gleaned from the project, acknowledging potential limitations and development challenges, summarising the key findings and their implications for stakeholders utilising the GeoDesign Hub platform. We have also reflected on how this project would contribute to our careers ahead in the field of Data Science.

2. Project Management and Team Dynamics

To effectively drive the project forward and ensure quality deliverables, our team divided into two main working groups, each responsible for specific tasks and deliverables:

1. **Financial Modelling Group:** This group with three members conducted in-depth research to define the input assumptions for each system type & created the financial model. Their primary responsibility involved delving into the Geodesign structures, understanding their components, functionalities, and potential revenue streams. This knowledge formed the foundation for researching and selecting appropriate financial models relevant to each system type.

   Through in-depth analysis, the group identified key financial parameters and metrics commonly used for different Geodesigns. They then meticulously designed a set of well-justified assumptions for each system type, considering factors like initial costs, operational expenses, potential revenue generation, system lifespan, and market trends. These assumptions served as the backbone of the financial model's calculations.

Next, the group utilised the defined assumptions to develop a Python script that accurately reflected the financial parameters and calculations for each Geodesign system. This script incorporated the defined assumptions, performed DCF and return analysis, and generated comprehensive financial outputs like NPV and IRR. The script is well-documented and designed for modularity and future modifications.

Finally, the group ensured all financial data generated by the Python script was accurately prepared in a JSON format. This format facilitated seamless integration with the visualisation team's tools for effective data representation.

2. **Reporting & Visualisation Group:** This group with two members utilised the JSON output from the Python script to construct a reporting dashboard. Their primary responsibility involved creating a user-friendly interface that effectively communicated the financial viability of different Geodesign systems to a diverse audience, even those without financial expertise.

   They created two types of dashboards: PowerBI & HTML. The PowerBI dashboard gave a visual comparison of the selected system type & diagram type based on initial input assumptions. While, the HTML dashboard allowed for dynamic input and adjustment of financial assumptions, enabling stakeholders to readily visualise the potential economic benefits of different investment scenarios.

2.1 Internal Team Collaboration:

The two teams maintained clear communication to ensure the data provided by the financial modelling group meets the requirements of the reporting team.

- **Regular Meetings:** The teams met weekly in-person or online to discuss the progress of the project, resolve problems encountered, and plan for future work. These meetings helped us stay on the same page and adjust our strategy in a timely manner.
- **Task Allocation:** At the project's outset, responsibilities and roles were clearly assigned to ensure each team member understands their tasks and expected outcomes.
- **Communication Platforms:** Daily communications were facilitated through dedicated online tools such as WhatsApp, Microsoft Teams meetings & e-mails, ensuring smooth information flow and enabling team members to continuously update progress and share insights.

2.2 Interaction with Industry Partners:

- **Bi-weekly Progress Meetings:** Regular meetings with the industry partner to report on progress, receive feedback, and discuss next steps were conducted. These meetings were crucial for understanding the partner's needs and expectations.
- **Feedback Integration:** Feedback was integrated into the project to ensure that the solutions developed meet actual business needs and user expectations.

3. Financial Modelling

The primary goal of this project is to utilise the financial information (e.g. duration of construction, initial investments) and construct a detailed financial model which evaluates the potential and feasibility of investments over 30 years. The main outcome of this model is to therefore give investors financial insights to predict potential returns - depending on users' capital investments which, in turn, facilitates more strategic decision-making.

In the model, users would be able to input financial scenarios and test out different investment values and outcomes within the time period. The benefit of these simulations is to enhance urban planning efficiency with consideration of different property types in a geographical area. These various systems are industry and commerce, low-density/high-density housing, agricultural, institutional, transport, green infrastructure, blue infrastructure, and energy infrastructure. A cash flow analysis was conducted for six of the systems to evaluate its financial impact - this was considered suitable for the context of urban landscapes due to its well-established use in the evaluation of urban development proposals which prioritise economic and social feasibility (Cochrane, 1971). However, worth noting is that because agricultural, institutional and transportational systems are publicised, a cash flow analysis to assess profitability was not done. Instead, other sustainability metrics like carbon emission reductions and water usage were considered to observe the 30-year socioeconomic impacts of the intended transformations to the area. This consideration enables a holistic view of the potential long-term impacts of urban development beyond financial returns.

As an initial step for the project deliverables, a team of our project group was tasked with producing a sample Excel spreadsheet consisting of formats and calculations for the financial analysis which allow stakeholders/clients to input their assumption values in each of the property types to calculate output values of financial returns. A detailed account of the input assumptions of the various property types will be elaborated below. Then, we input dummy assumption values for each system type as CSV to be used in the Python code (see Appendix A, see Appendix C for downloadable link for the same).

In the development of land, innovative approaches have been characterised as unprogressive due to the lack of understanding in finances, construction and building design sustainability (Mazutis & Sweet, 2022). Thus, this model bridges the gap between these different industries holistically from a financial perspective. A list of assumptions which users would input were considered for these property types to enable different sectors to progressively innovate (see examples in Tables 2-9).

Common assumptions which we have accounted for across all systems are explained as follows:

- **Construction Period in Years**: Considers how long the properties will be built before operating expenses commence

- **Annual Construction Expenses**: Yearly expenses of construction considered before operating expenses
- **Annual Operating Expenses**: Covers costs like production labour, utilities, marketing, maintenance etc. with a growth rate applied every year
- **Initial investment**: Figure that investors would need to initially invest to enable returns analysis. e.g. land purchase, construction, machinery and setup costs
- **Capitalisation rate**: The capitalisation rate is the rate of return on a real estate investment property based on the income that the property is expected to generate. It was used to estimate the potential return by dividing it by the net operating income.
- **Growth rate**: Applied on the operating expenses every year to indicate the rate of increase in costs

Assumptions specific to each system are elaborated as follows:

3.1 Industry and Commerce

- Average Lease Rate: A critical value in calculating Effective Gross Potential Revenue
- Occupancy Rate: Expected percentage of the space leased or utilised which impact GPR calculations

The cash flow analysis underlined the annual revenues and expenses for industry and commerce over the span of 30 years. To calculate the Effective Gross Potential Revenue, the facility size was multiplied by the average lease rate and occupancy rate. The total operating expenses, on the other hand, was initially calculated by adding the construction expenses with operating expenses within the construction period. Once the construction period is over, the operating expenses continue to be applied along with the growth rate. Furthermore, the net operating income was quantified by subtracting the total operating expenses by the effective gross potential revenue. Valuation by the end of 30 years is then taken from the final net operating income, divided by the capitalisation rate.

In addition, the returns analysis section tabulated the outflow from the initial investment, followed by the inflows from the net operating income every year up till Year 30. These values enable the computation of Internal Rate of Return (IRR) overtime.

Input Assumptions
Construction Period In Years
Annual Construction Expenses
Average lease rate/sqft (£)
Operating Expenses, Annual (£)
Occupancy Rate (%)
Initial Investment (£)
Cap Rate (%)
Growth Rate (%)

Table 2. Assumption Input for Industry and Commerce

3.2 Low-density Housing and High-density Housing

- Expected Annual Units Rented: The anticipated number of housing rented out of the total units every year
- Expected Annual Units Sold: The anticipated number of housing units sold every year
- Unit Sale Price: The anticipated value of each unit sold
- Expected Annual Rent per Unit: The anticipated value of each unit rented out every year

The cash flow analysis highlighted the revenues from rent and sales of the housing units over 30 years. Potential rent revenue was calculated by multiplying the expected annual units rented by the expected rent per unit, with a growth rate applied every year. The sales revenue was computed by multiplying the user's input value for the unit sale price with the expected units sold annually also with growth rate. With these values, the gross potential revenue was a total of the rent and sales revenue. Similar to the other system, the total operating expenses for low-density and high-density housing was initially computed by adding construction expenses with operating expenses, followed by only the operating expenses after construction. Finally, the net income subtracted the gross potential revenue by the operating expenses every year, and with the final value of this in Year 30. The valuation by the end of the 30th year is computed by dividing it by the capitalisation rate. The returns analysis to compute the IRR is then tabulated the same as explained in the previous system.

Input Assumptions
Construction Period In Years
Annual Construction Expenses
Expected Annual Units Rented
Unit Sale Price (£)
Annual Operating Expenses (£)
Annual Expected Rent Per Unit
Annual Expected Units Sold
Initial Investment (£)
Cap Rate (%)
Growth Rate, Rent/Sale (%)
Growth Rate, Expenses (%)

Table 3. Assumption Input for Low-density/High-density Housing

Moreover, these 3 following systems used alternative sustainability parameters instead of cash flow analysis, where users are able to input their values for the assumptions and the expected improvement percentage to enable computing the output value by the end of the 30th year:

3.3 Agricultural

- Yield/land area: Total area of land
- Yield Improvements: Comparison of the quantity of yield per unit
- Water Usage Reductions: Comparison of volume of water used within land
- Carbon Emission Reductions: Comparison of weight of carbon emitted within land

Input Assumptions
Initial Investment (£)
Yield/Land Area (units/sqft)
Yield Improvements (%)
Water Usage Reductions (l/sqft)
Carbon Emission Reductions (g/sqft)

Table 4. Assumption Input for Agriculture

3.4 Institutional (e.g. schools, hospitals)

- Capacity: Number of units the facility could hold
- Operational Efficiency: Measure of how well operations are done while minimising costs
- Resource Utilisation Rate: Percentage of the resources used in the facility

Input Assumptions
Initial Investment (£)
Annual Operating Expenses (£)
Capacity (units)
Operational Efficiency (%)
Resource Utilisation Rate (%)

Table 5. Assumption Input for Institutional

3.5 Transport

- Distance/Route Length:
  length of transport route in kilometres which would be expected to reduce if efficiency is aimed
- Average Annual Passengers: number of passengers on average per year
- Capacity Utilisation:
  measure of how much the transport is used out of the maximum capacity
- Route Optimisation: distance of transport travelled per day which would be expected to be reduced if route is optimised
- Fuel Efficiency: the amount of fuel consumed per kilometre
- Travel Time: time taken per kilometres in minutes

Input Assumptions
Initial Investment (£)
Distance/Route length (km)
Average Annual Passengers
Annual Operating Expenses (£)
Capacity Utilisation (%)
Route Optimisation (km/day)
Fuel Efficiency (km/l)
Travel time/km (mins/km)

Table 6. Assumption Input for Transport

3.6 Green Infrastructure

- Annual Insurance Costs: Premiums paid to cover risks associated with the project

- Annual Advertising Revenue: Revenue generated from leasing advertising spaces within the property

The annual expenditure of the GI financial model is derived from the annual construction cost, plus the annual insurance cost. The annual construction cost is only required during the construction period. After the construction period, the cost will no longer include annual construction expenses. At the same time, construction costs increase each year at a set rate, reflecting normal increases due to inflation and escalating maintenance requirements. This ensures realistic forecasts of ongoing financial obligations. In addition, for GI projects, operating income only comes from annual advertising revenue, and operating expenses increase proportionally year by year with the growth rate. Net operating income is quantified by total operating expenses minus effective total potential revenue. The valuation at the end of 30 years and the IRR calculation method are consistent with the previous system description.

Input Assumptions
Initial Investment(£)
Annual Construction Expenses(£)
Construction Period In Years(Year)
Annual Maintenance expenses(£)
Annual Insurance Costs(£)
Annual Advertising Revenue(£)
Growth Rate (%)
Cap Rate (%)

Table 7. Assumption Input for Green Infrastructure

3.7 Blue Infrastructure

- Annual Decommissioning Costs: Costs associated with the dismantling and cleanup of the site at the end of its useful life
- Annual Water Resource Management Costs: Costs to manage and sustain water sources effectively
- Annual Water Quality Monitoring Costs: Expenses related to testing and ensuring the purity of water
- Annual Insurance Costs: Premiums paid for insuring water-related assets and operations against potential risks
- Annual Water Purification Costs: Costs for treating water to meet safety and quality standards
- Entertainment Revenue: Revenue generated from recreational activities such as fishing licences or access fees
- Revenue from Fishing and Aquatic Products: Income derived from the sale of goods produced from water resources

The annual expenditures of the BI financial model come from annual construction costs during the construction life, Annual Decommissioning Costs, annual water management and water purification costs, and annual insurance costs. Potential total revenue included entertainment fees and sales of aquatic products. Net operating income was quantified by total operating expenses minus effective total potential revenue. The valuation at the end of 30 years and the IRR calculation method are consistent with the previous system description.

Input Assumptions
Initial Investment(£)
Annual Construction Expenses(£)
Construction Period In Years(Year)
Annual Decommissioning Costs(£)
Annual Water Resource Management Costs(£)
Annual Water quality monitoring costs(£)
Annual Insurance Costs(£)
Annual Water purification costs(£)
Growth Rate (%)
Cap Rate (%)

Table 8. Assumption Input for Blue Infrastructure

3.8 Energy Infrastructure

- Annual Insurance Costs: Premiums paid for insuring the facility against risks
- Annual Decommissioning Costs: Costs associated with dismantling and cleaning up the site after its useful life
- Annual Fuel Costs: Expenditure on fuel required for energy production
- Energy Sale Price: Revenue generated per unit of energy sold
- Estimated Annual Energy Production: The total predicted energy output per year
- Annual Energy Storage and Distribution Costs: Costs related to storing and delivering the produced energy

Input Assumptions
Initial Investment(£)
Annual Construction Expenses(£)
Construction Period In Years(Year)
Annual Operation and Maintenance Costs(£)
Energy Sale Price(£)
Estimated Annual Energy Production(KW/h)
Annual Decommissioning Costs(£)
Annual Insurance Costs(£)
Growth Rate (%)
Cap Rate (%)

Table 9. Assumption Input for Energy Infrastructure

The annual expenditures of the EI financial model were derived from annual construction costs, annual management costs, Annual Decommissioning Costs, annual insurance costs and Annual Energy Storage and Distribution Costs during the construction life. Potential total revenue was quantified by multiplying the Energy Sale Price by the Estimated Annual Energy Production, which represents annual energy production. Net operating income was quantified by total operating expenses minus effective total potential revenue. The valuation at the end of 30 years and the IRR calculation method are consistent with the previous system description.

The table below outlines the costs users could consider based on systems:

Assumption	System	Description
Initial Investment	IND	- Construction, machinery, and setup costs.
	LDH/HDH	- Land purchase and construction costs.
	AG	- Land preparation (clearing, ploughing, tilling, soil testing) - Infrastructure (storage facilities, irrigation systems, roads) - Equipment (tractors, ploughs, harvesters, misc. tools) - Initial supplies (seeds, fertilisers, pesticides, and other consumables)
	INST	- Construction - Equipment (Purchase of furniture, educational, or medical equipment, depending on the institution) - IT Infrastructure (IT systems, networking equipment, and installation) - Landscaping (Outdoor spaces, parking, accessibility features) - Initial Supplies (Initial stocking of office supplies, educational/medical supplies)
	TRANS	- Land Acquisition (Costs for purchasing land for transport infrastructure) - Construction (Building of stations, terminals, infrastructure) - Vehicles (Purchase of buses, trains, or other vehicles) - Equipment (Purchase of additional equipment like ticket machines, office equipment) - Initial Legal and Administrative Fees
	GI	- Site clearing, landscaping, and soil quality assessments

		- Development of parks, installation of recreational facilities, and setup of urban forests - Gardening tools, ecological monitoring equipment, and sustainable maintenance machines - Native plants, mulch, organic fertilisers, and water-efficient irrigation systems
	BI	- Riverbed modifications, wetland restoration, and sediment control installations - Construction of levees, dams, wastewater treatment plants, and stormwater management systems - Water quality monitoring instruments, pumps, and filtration units - Bioengineered materials for ecological restoration, initial chemicals for water treatment, and erosion control products
	EI	- Land acquisition, environmental assessments, and site preparation for plant construction - Building of power generation plants (solar farms, wind turbines, biomass facilities), and electrical substations - Generators, transformers, turbines, solar panels, and battery storage systems - Initial fuel stock (natural gas, biomass), conductive materials, and safety equipment
Operating Expenses	IND	- Costs like production, labour, utilities, marketing, etc.
	LDH/HDH	- Maintenance, property management, etc.
	AG	- Labour: Salaries and wages for farmworkers and management

		- Maintenance: Upkeep of equipment, vet care - Utilities: Water, electricity for farming operations - Materials: Seeds, fertilisers, pesticides, and other consumables - Insurance: Coverage for crops, equipment, and facilities - Transportation: Costs for distribution and sale of products
	INST	- Maintenance of buildings and facilities - Salaries for administrative, academic or medical staff - Utilities like electricity, water, internet, and other utilities - Security services and equipment - Miscellaneous expenses including marketing, legal fees, etc.
	TRANS	- Regular maintenance of vehicles and infrastructure - Annual salaries for drivers, administrative staff, and maintenance workers - Costs for fuel for vehicles or energy for operations - Insurance costs for vehicles, property, and liability - Advertising and passenger engagement expenses
	GI	- Salaries for environmental scientists, landscapers, and maintenance staff - Upkeep of green spaces, including parks, recreational facilities, and urban forests - Water for irrigation and electricity for lighting and powering facilities within the green infrastructure - Plants, soil, seeds, and tools for landscaping and maintenance - Costs associated with the transport of materials and waste - Regular cleaning and repair of public facilities like benches, lights, and signage - Environmental impact assessments, community engagement activities, and educational programs

	BI	- Salaries for water management specialists, hydrologists, and maintenance crews - Maintenance of water-related infrastructure like dams, levees, and stormwater systems - Energy for pumping stations and treatment plants, water for maintaining water bodies - Equipment for water treatment and pollution control, materials for repairs and upgrades
	EI	- Salaries for engineers, technicians, and operational staff - Regular maintenance of power generation facilities and energy grids - Electricity for operations, cooling, and control systems - Maintenance of generation facilities, substations, and transmission lines - Licensing fees, environmental compliance, market analysis, and public relations

Table 10. Detailed account of the initial investment and operating expenses users could take into account for each system.

4. Python Script for Financial Metric Calculation

This Python script automated the financial analysis of Geodesigns and handled different system types with varying assumptions and financial considerations. It performed cash flow analysis and calculated key financial metrics as explained below.

A breakdown of the script's functionality is as follows:

1. **Data Access**:

- The script assumes a specific file structure (external) such that the data is read from/output to a folder called "GeoDesign Hub" (present in the local system, for this project) with sub folders for assumptions, Geodesigns & analysis output as explained in Table 2.
- A list named design_files (in the script) contains the filenames of the Geodesigns to be analysed.

Data	Data Format	Folder Path	Naming Convention
Geodesigns	GeoJSON	GeoDesign Hub/GeoDesigns/	design-a.geojson
Assumptions	CSV	GeoDesign Hub/Assumptions/design-a/	design-a_csv - BI.csv
Analysis Output	JSON	GeoDesign Hub/Analysis/	analysis_design-a.json

Table 11. Details of File organisation for input & output data for python script.

2. **Financial Analysis Function:** This function takes a pandas DataFrame representing the design data as input. It iterates through each unique system type identified in the design data. For each system type, the function reads the corresponding assumption data from the relevant CSV file and merges the assumption data with the design data based on the

diagramid field. Looping through each diagram, it calculates year-wise cash flow based on gross potential revenue, operating expenses, net income, growth rate, construction period using system-specific assumptions. Then, it applies discounting to the calculated cash flows. The formulas for gross potential revenue & operating expenses for each system type are shown in Table 3.

- **Net income:** For each year, it is calculated as the difference between gross potential revenue and operating expenses.
  Net Income = Gross Potential Revenue - Operating Expenses
- **Growth Rate:** The growth rates are applied to adjust revenue and expenses over the analysis period, reflecting potential market trends and inflation.
- **Construction Period:** The script accounts for the construction period by considering only construction-related costs during that time. Once the construction period is over, revenue generation begins based on the system type's specific revenue streams.
- **Discounting:** To account for the time value of money, future cash flows are discounted using a specified discount rate. The discounted cash flow for each year is calculated as:

  Discounted Cash Flow = Net Income / (1 + Discount Rate)^Year

  Finally, key return on investment metrics like Net Present Value (NPV) and Internal Rate of Return (IRR) are calculated for the overall analysis period.
- **NPV**: The project's expected value at the end of analysis value, often determined as its potential sale price.

  NPV = discounted_net_income/ (Cap Rate (%)/100)
- **IRR:** IRR is the discount rate at which the NPV of a project becomes zero. It is a measure of the project's profitability, indicating the expected annualised return on investment. The *numpy.irr* function from the NumPy library is used to calculate the IRR which takes an array of cash flows as input, where the first element typically represents the initial investment (negative value) and subsequent elements represent the net cash flows for each year (positive or negative values) and returns IRR.

System Type	Gross Potential Revenue	Operating Expenses
LDH	Annual Expected Rent Per Unit * Expected Annual Units Rented + Annual Expected Units Sold * Unit Sale Price	Annual Operating Expenses
HDH	Annual Expected Rent Per Unit * Expected Annual Units Rented + Annual Expected Units Sold * Unit Sale Price	Annual Operating Expenses
IND	(Average Lease Rate/sqft * area) * (Annual Occupancy Rate (%)/100)	Annual Operating Expenses
GI	Annual Advertising Revenue	Annual Maintenance Expenses + Annual Insurance Costs
BI	Entertainment Revenue + Revenue From Fishing And Aquatic Products	Annual Water Resource Management Costs + Annual Insurance Costs + Annual Water Quality Monitoring Costs + Annual Water Purification Costs + Annual Decommissioning Costs
EI	Energy Sale Price * Estimated Annual Energy Production	Annual Operation and Maintenance Costs + Annual Insurance Costs + Annual Fuel Costs + Annual Energy Storage and Distribution Costs

Table 12. System specific formulas for different system types.

The python script outputs the calculated financial metric in a JSON file for the Geodesigns mentioned in the "design_files" list. See Appendix B for format of the outputs produced for design-a & design-b.

Discounted Cash Flow	**Year 0**	**…**	**Year 30**
Effective Gross Potential Revenue (£)			
Operating Expenses (£)			
Net Operating Income (£)			
NPV			
IRR			

Table 13. Sample format for financial output for each system type based on input values.

The link to the code repository has been attached in Appendix B.

5. Comparative Financial Analysis Reports

For any property investment, making informed decisions hinges on a comprehensive understanding of the financial viability and potential returns of each property. To empower investors with this crucial knowledge, we have developed two interactive dashboards: a PowerBI dashboard and an HTML financial visualisation tool (See Appendix B for the file links). Each serves a distinct purpose and offers unique functionalities, catering to different user needs and analysis preferences.

While both dashboards delve into financial analysis, they cater to different levels of user engagement either of which could be integrated by GeoDesign Hub within their platform:

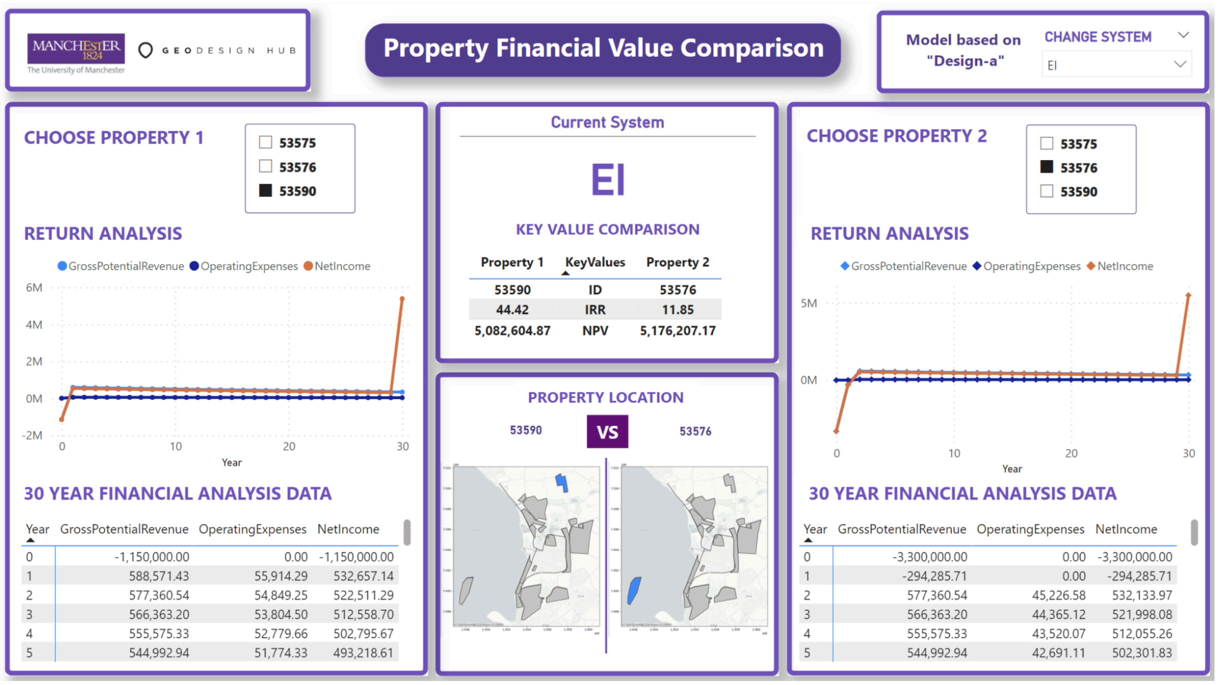
5.1 PowerBI Report:

Power BI is a powerful business intelligence platform developed by Microsoft. It allows users to connect to various data sources, transform and analyse data, and create interactive visualisations and reports. Power BI has the following benefits:

- **Visual Storytelling**: It transforms complex financial data into clear and engaging visuals making it easier for investors to grasp trends, identify patterns, and gain valuable insights.
- **Interactive Features**: The ability to filter, drill down, and slice data within the dashboard allows for deeper analysis and exploration of specific aspects of a property's financial performance.
- **Side-by-Side Comparison**: The Power BI dashboard facilitates the direct comparison of two diagram ids, enabling investors to quickly assess which one offers better returns and aligns more closely with their investment goals.

This report visualises the JSON output obtained by running the python script based on the input assumptions and compares the 30-year financial performance of different properties under the selected system model. The financial metrics of each property were presented through clear graphs and tables, along with a comparison of core investment evaluation indicators like Internal Rate of Return (IRR) and Net Present Value (NPV), allowing users to quickly and accurately assess which property performs better as a long-term investment.

Our visual design concept made information easy to access and understand through clear interface layouts and intuitive interactive elements. Figure 2 demonstrates a sample comparison visualisation report for EI system type, diagram ID 53590 and 53576. Using a dual-pane layout, users can compare two properties side-by-side while key financial metrics such as Internal Rate of Return (IRR) and Net Present Value (NPV) are highlighted in an eye-catching format for quick identification. In addition, drop-down menus, clickable maps and colour-coded charts enhance user engagement and analytical efficiency. Tooltips and hover details clearly explain the data, optimising the user experience and enabling users to make investment decisions quickly and confidently. Through this seamless and visually rich interface, we aimed to provide powerful analytical tools to facilitate effective property investment analysis.



Year	GrossPotentialRevenue	OperatingExpenses	NetIncome
0	-1,150,000.00	0.00	-1,150,000.00
1	588,571.43	55,914.29	532,657.14
2	577,360.54	54,849.25	522,511.29
3	566,363.20	53,804.50	512,558.70
4	555,575.33	52,779.66	502,795.67
5	544,992.94	51,774.33	493,218.61

Year	GrossPotentialRevenue	OperatingExpenses	NetIncome
0	-3,300,000.00	0.00	-3,300,000.00
1	-294,285.71	0.00	-294,285.71
2	577,360.54	45,226.58	532,133.97
3	566,363.20	44,365.12	521,998.08
4	555,575.33	43,520.07	512,055.26
5	544,992.94	42,691.11	502,301.83

Figure 2. Sample comparison visualisation report for EI system type, diagram ID 53590 and 53576.

Key Features:

1. **System Selection:** The drop-down menu enables users to choose a System for analysing a property's financial performance. The ""CHANGE SYSTEM" drop-down menu expands a list of system options.

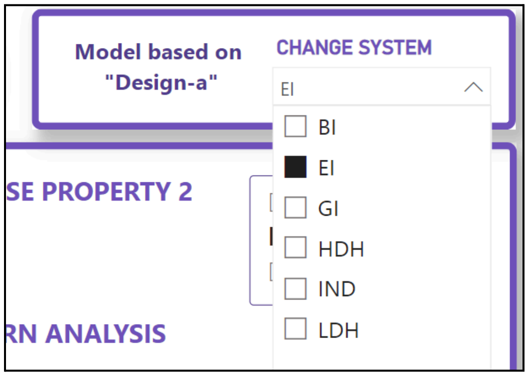


Figure 3. Display of system selection feature in the Power BI dashboard

2. **Diagram Selection:** Each box contains a list of diagram IDs for analysis. Users can select one diagram in the "Choose Property 1" box and another in the "Choose Property 2" box to compare their financial performances. "

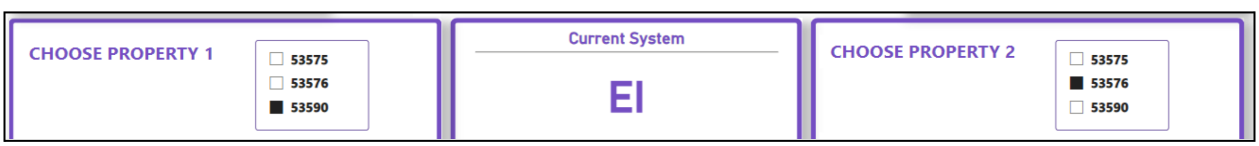


Figure 4. Display of diagram selection feature in the Power BI dashboard

3. **Return Analysis:** The "Return Analysis" graph provides a detailed visualisation of the financial metrics of a property over a 30-year span, using a timeline to demonstrate the trends in Gross Potential Revenue, Operating Expenses, and Net Income.

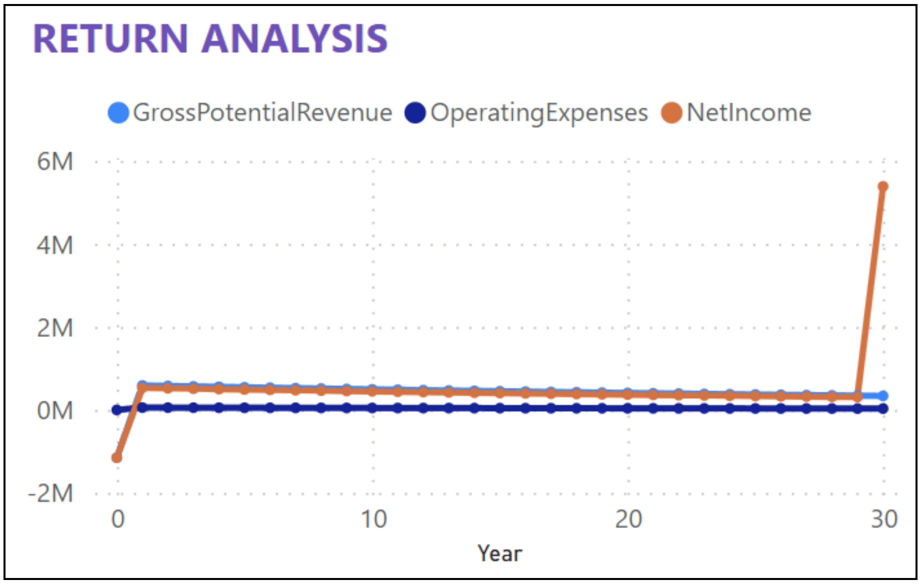


Figure 5. Display of cash flow & return analysis in the Power BI dashboard

a. Colour-Coded Lines

- **Light Blue Line**: Represents Gross Potential Revenue, indicating the maximum income the property could generate.
- **Dark Blue Line**: Represents Operating Expenses, including all costs of maintaining and managing the property.
- **Orange Line**: Represents Net Income, showing the actual earnings from the property.

b. Tooltip Functionality

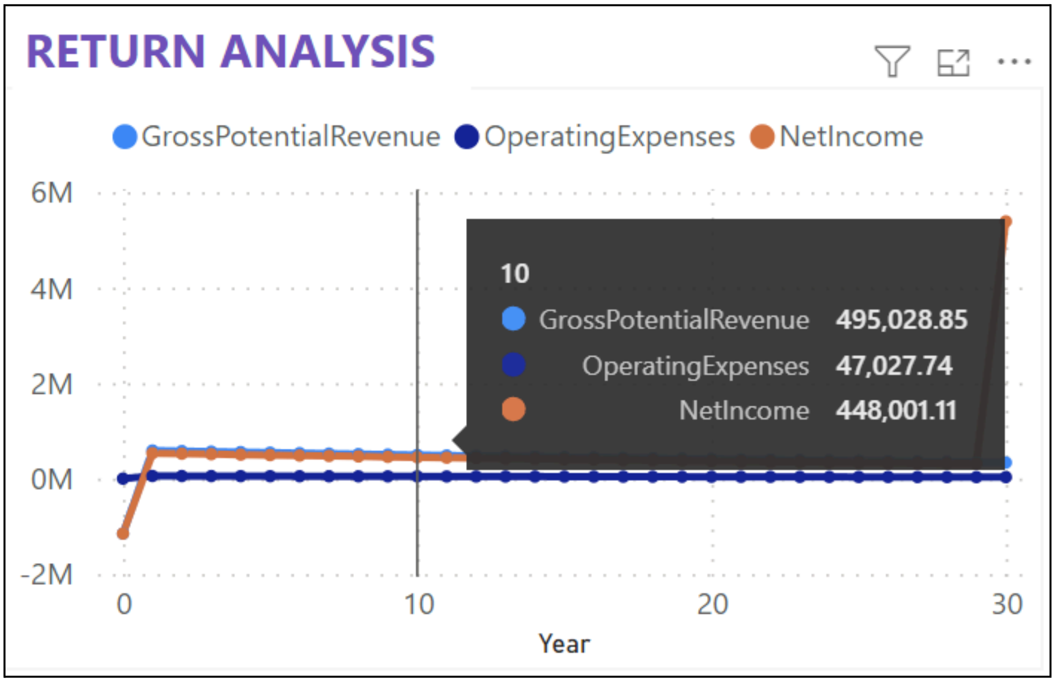


Figure 6. Illustration of Toolkit functionality in the Power BI dashboard

- As shown in Figure 6, hovering over any point on the graph provides a tooltip with precise financial figures for that particular year. For example, in Year 10:
    - **Gross Potential Revenue**: £495,028.85
    - **Operating Expenses**: £47,027.74
    - **Net Income**: 448,001.11

4. **30 Year Financial Analysis Data Table:** This table complements the "Return Analysis" graph by providing specific numerical insights into the property's financial performance annually over a 30-year period.

30 YEAR FINANCIAL ANALYSIS DATA

Year	GrossPotentialRevenue	OperatingExpenses	NetIncome
0	-1,150,000.00	0.00	-1,150,000.00
1	588,571.43	55,914.29	532,657.14
2	577,360.54	54,849.25	522,511.29
3	566,363.20	53,804.50	512,558.70
4	555,575.33	52,779.66	502,795.67
5	544,992.94	51,774.33	493,218.61

Figure 7. Display of numerical financial analysis data in the Power BI dashboard

5. **Property Location Comparison:** This feature is designed to help users evaluate the geographical context of each property, which is crucial for assessing potential marketability, accessibility, and overall investment attractiveness. Features of these maps include:

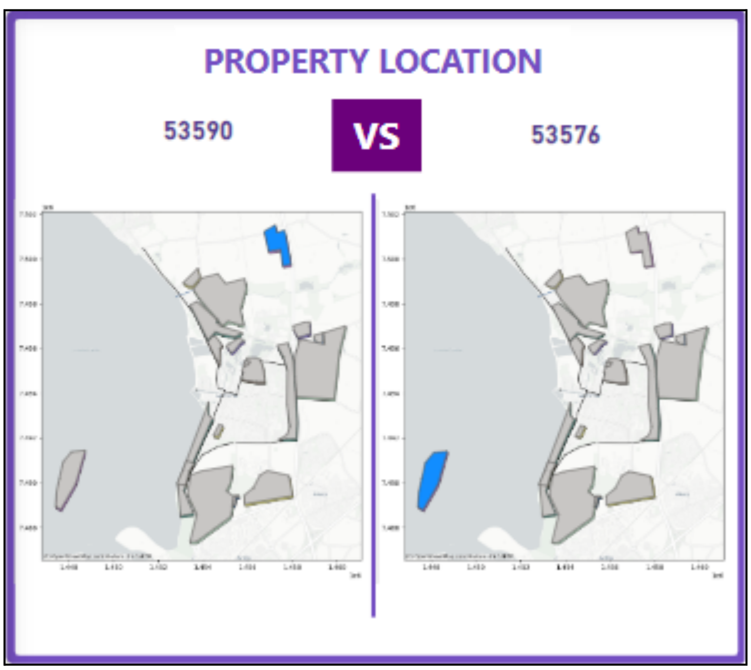
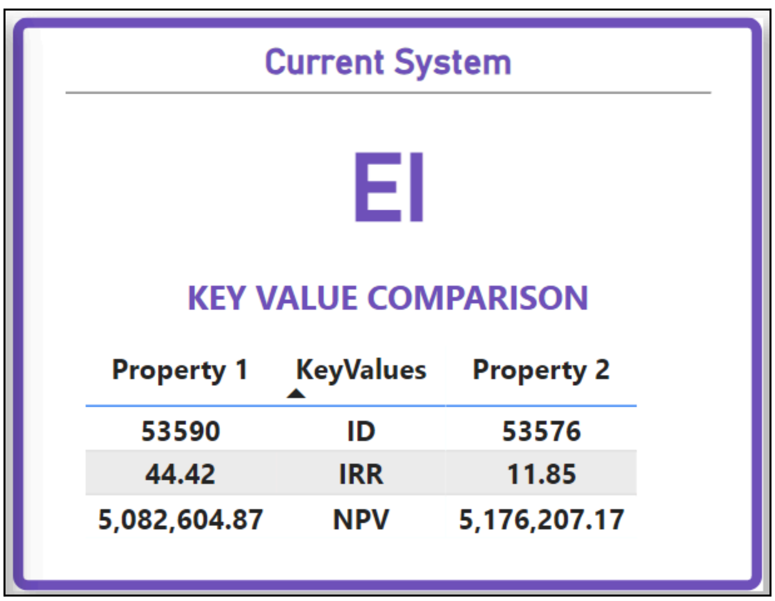


Figure 8. Display of selected diagram ID location in the Power BI dashboard

- **Visual Indicators**: Each map highlights the specific location of a property within its surrounding area. Different colours or markers may denote the property's location clearly.
- **Scale and Orientation**: The maps are scaled to provide a clear view of the property's surroundings, including nearby roads, natural features, and other relevant landmarks.
- **Comparison Format**: The comparison allows for a visual comparison of the location of the two properties, enabling the user to quickly assess factors such as location, proximity to essential services, etc. for both.

6. **Key Value Comparison:** This section focuses on comparing the overall financial metrics such as IRR & NPV that are crucial in assessing the investment potential of the diagram IDs.



Property 1	KeyValues	Property 2
53590	ID	53576
44.42	IRR	11.85
5,082,604.87	NPV	5,176,207.17

Figure 9. Display of key financial metrics comparison for each diagram ID in the Power BI dashboard

5.2 HTML Financial Visualisation Tool:

Unlike the Power BI dashboard, which relies on a JSON input format received from the python script, the HTML tool allows users to directly input financial parameters within the user interface. A JavaScript code attached to each HTML dashboard, tailored to different system types acts as the calculation engine. This code dynamically calculates key financial metrics like Gross Potential Revenue, Operating Expenses, and Net Operating Income based on the user-defined inputs. This streamlines the data input process and potentially simplifies integration with the GeoDesign Hub platform.

Figure 10 shows an illustration of the HTML dashboard for the GI system type. Screenshots of remaining 5 system types are included in Appendix C.

MANCHESTER 1824
The University of Manchester

GI Financial Model

Enter Financial Parameters:

Initial Investment(£): 2000000

Annual Construction Expenses(£): 100000

Construction Period In Years(Year): 2

Annual Maintenance Expenses(£): 50000

Annual Insurance Costs(£): 10000

Annual Advertising Revenue(£): 200000

Growth Rate (%): 2

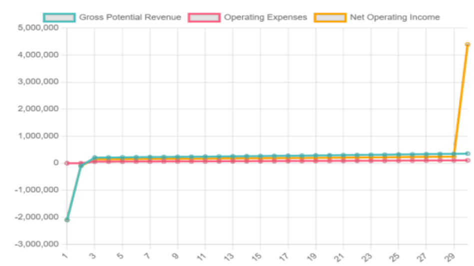
Cap Rate (%): 6

Compute and Draw Chart

Valuation for Year 30: 4143637.61

IRR: 8.14%

30-year Financial Chart



Financial Data Table

Year	Gross Potential Revenue	Operating Expenses	Net Operating Income
1	-2100000.00	0.00	-2100000.00
2	-102000.00	0.00	-102000.00
3	208080.00	62424.00	145656.00
4	212241.60	63672.48	148569.12
5	216486.43	64945.93	151540.50
6	220816.16	66244.85	154571.31
7	225232.48	67569.75	157662.74
8	229737.13	68921.14	160815.99
9	234331.88	70299.56	164032.31
10	239018.51	71705.55	167312.96
11	243798.88	73139.67	170659.22
12	248674.86	74602.46	174072.40
13	253648.36	76094.51	177553.85
14	258721.33	77616.40	181104.93
15	263895.75	79168.73	184727.03
16	269173.67	80752.10	188421.57
17	274557.14	82367.14	192190.00
18	280048.28	84014.49	196033.80
19	285649.25	85694.77	199954.47
20	291362.23	87408.67	203953.56
21	297189.48	89156.84	208032.64
22	303133.27	90939.98	212193.29
23	309195.93	92758.78	216437.15
24	315379.85	94613.96	220765.90
25	321687.45	96506.23	225181.21
26	328121.20	98436.36	229684.84
27	334683.62	100405.09	234278.54
28	341377.30	102413.19	238964.11
29	348204.84	104461.45	243743.39
30	355168.94	106550.68	4392255.87

Figure 10. HTML tool for financial analysis for a GI system type.

Key Features:

1. **User-Defined Inputs:** Users can directly input system type specific financial parameters within the user interface eliminating the need for any external files (like csv for Power BI dashboard).

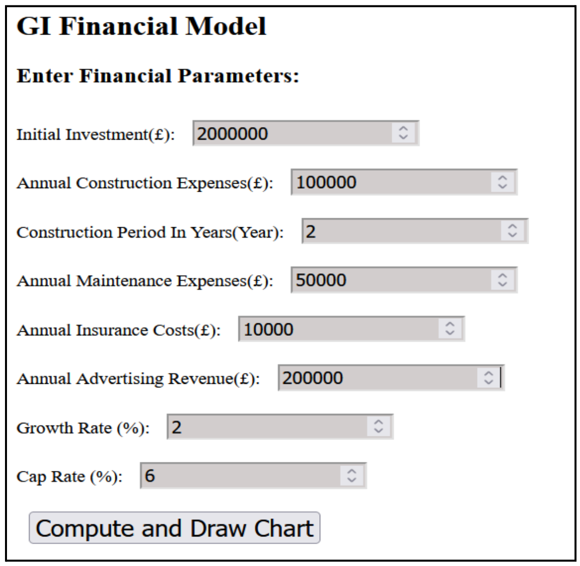


Figure 11. Display of user input feature in HTML dashboard.

2. **Visualisation:** Financial results are visualised in a graph along with key financial metrics, providing a concise overview of the key financial metrics' trends over the 30-year period.

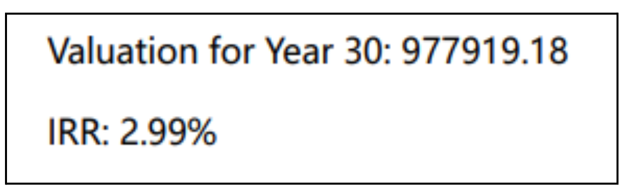


Figure 12. Display of key metrics in HTML dashboard.

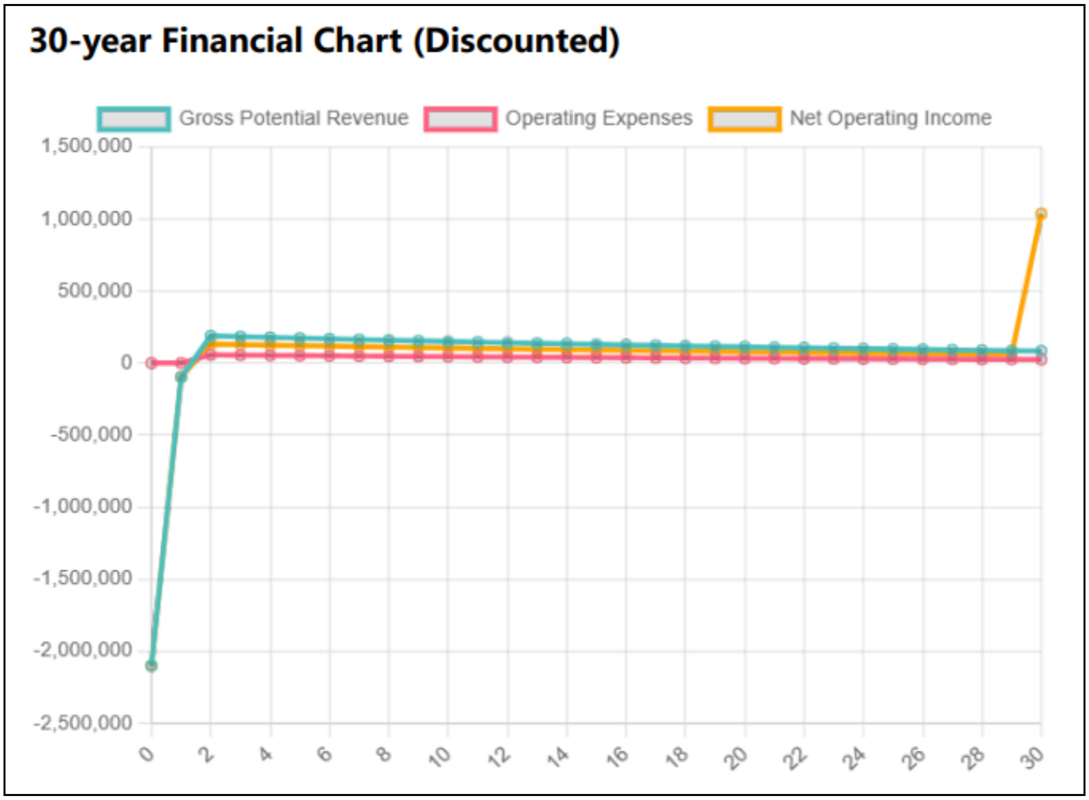


Figure 13. Display of cash flow analysis in HTML dashboard.

3. **30 Year Financial Analysis Data Table:** This table complements the cash flow analysis graph by providing specific numerical insights into the property's financial performance annually over a 30-year period.

Financial Data Table

Year	Gross Potential Revenue	Discounted Gross Potential Revenue	Operating Expenses	Discounted Operating Expenses	Discounted Net Operating Income
0	-2100000.00	-2100000.00	0.00	0.00	-2100000.00
1	-102000.00	-97142.86	0.00	0.00	-97142.86
2	208080.00	188734.69	62424.00	56620.41	132114.29
3	212241.60	183342.27	63672.48	55002.68	128339.59
4	216486.43	178103.92	64945.93	53431.18	124672.75
5	220816.16	173015.24	66244.85	51904.57	121110.67
6	225232.48	168071.95	67569.75	50421.58	117650.36

Figure 14. Display of numerical financial analysis data in the HTML dashboard

6. Interviews with Stakeholders

The interviews aimed to test and validate the understanding and usefulness of our model outputs, particularly from the perspectives of two academics with specialised backgrounds in urban development whom we anonymised due to ethical reasons. The first academic focuses on public land policy and its linkages with the housing market, which enables a more in-depth model assessment from a property economics perspective. The other academic's experience covers town planning and long-term settlement patterns research, with particular expertise in social and geographic network analysis, enabling model evaluation from a planning and social structure perspective.

Interviews with these two experts provided professional insights into how the model can be applied in the real world and ensure that the model design and results are aligned with the Sustainable Development goals and the current needs of the town planning and property markets. This professional feedback was also essential for adjusting and refining the model to ensure its accuracy, relevance and operationalisation.

6.1 Our Plan

Prior to the interview, we planned the following four-part session flow:

	Topic	Description
1.	General overview (2-3 minutes)	A brief overview of GeoDesign Hub and our project background to ensure the project's goals and scope are understood.
2.	Financial modelling presentation (5-8 minutes)	Six system types were detailed: BI, EI, GI, HDH, IND, and LDH, with their financial modelling, cash flow analysis, return analysis, internal rate of return (IRR), and NPV. We

		also explained the alternative analysis for the systems AG, TRANS, & INST as well as outlining the system types and the basis for the assumptions.
3.	Presentation of the report (5-8 minutes)	Creation of two output calculation methods: HTML document and Power BI report. The session presented these reports, explained the inferences, and explained user guidance.
4.	Q&A session (30 minutes)	In this section, the following questions for models and reports were asked: 1. Do these match your expectations? 2. What are the most important elements? 3. What are the least important elements? 4. In your experience with finance models and urban planning, what additional indicators/perspectives would you recommend for our models & reports - e.g. what works best/not? 5. Regarding the presentation format of the report, what do you think needs improvement?

6.2 Recommendations

Based on our interviews, the most significant recommendation from the first academic noted that using Discounted Cash Flow calculations, known as DCF modelling, will help value the investment more accurately than a cash flow analysis. In terms of the financial model, it was also suggested to start the cash flow analysis from 'Year 0' rather than 'Year 1', as that’s a common practice. We adjusted the analysis accordingly. A positive feedback we received was also that NPV and IRR are typically the most critical metrics for evaluating return on investment, as we correctly displayed.

Apart from that, several other recommendations were provided to enhance our financial model, however, due to the time constraint of our scheduled interview to our project deadline, these recommendations should be noted for future considerations. For the reports demonstration, separate charts which show rents and a terminal value should have been shown in the visualisation tool to view the information more clearly. Furthermore, adding a background map to show the project boundaries more distinctly can help investors and stakeholders better understand where the project is geographically located.

The second academic who provided suggestions from a more socioeconomic perspective recommended that we take into account macro-level changes which are critical to long-term investment decisions - such as UN population projections and climate change parameters. Both interviewees also posited that a 30-year time horizon may be too long due to the rapidly changing economic and environmental conditions. With this in mind, future modelling should assess whether to shorten the timeframe or provide model outputs for different periods to reflect these potential impacts.

7. Conclusion

This project successfully delivered a financial modelling framework for the GeoDesign Hub platform, empowering stakeholders to evaluate the financial viability of proposed development plans. Here's a comprehensive analysis of our achievements, challenges, learnings, and the project's impact on the industry partner:

7.1 Goals Achieved

Building on the foundation provided by urban development literature (Mazuti & Sweet, 2022) and industry partner insights, we systematically developed and analysed financial models for nine distinct Geodesign sectors and created visualisations for the same. This granular approach provided a detailed view of financial viability and potential returns across various sectors, encompassing operational expenses, revenue streams, and return analysis. This information can significantly ease negotiations among potential investors with diverse backgrounds. Additionally, the ability to adjust financial parameters within the model promotes reproducibility and allows users to immediately see the impact of these changes. Overall, the successes include:

- **Financial Modeling Framework:** We developed a Python script that translates user-defined assumptions into key financial metrics like Net Present Value (NPV) and Internal Rate of Return (IRR) for various Geodesign scenarios.
- **Interactive Dashboards:** Two dashboards were created: a Power BI dashboard for visual comparison of financial parameters and an HTML dashboard for dynamic input adjustments, allowing stakeholders to explore different investment possibilities.
- **Stakeholder Feedback:** Interviews with stakeholders confirmed the model's comprehensibility and its potential to facilitate informed decision-making.

7.2 Bottlenecks and Challenges:

Through interviews with stakeholders, we identified a significant limitation: the strict 30-year timeframe. The rapid pace of change in technology, environmental policy, and market dynamics can introduce substantial uncertainty and diminish the accuracy of long-term forecasts. The current models don't fully account for drastic changes in regulatory or economic environments, which could significantly alter project outcomes. This suggests a need to adjust the models for shorter time frames, potentially enhancing their relevance and applicability to investment decisions.

Another bottleneck, identified through reflection and feedback, was the lack of financial modelling knowledge within all team members. The project demanded sophisticated modelling techniques, and comprehending analysis like DCF and return analysis presented a steep learning curve. However, we successfully acquired this knowledge through support from the industry partner and academic experts. This highlights the importance of a well-managed project timeline to allow for a higher proficiency in these areas and facilitate the incorporation of recommended improvements.

7.3 Learnings and Career Development:

From developing the financial model to visualising it from code, this project significantly enhanced our expertise in data science, particularly in applying financial analytical techniques to real-world scenarios. We improved our ability to communicate complex financial and geographic data to diverse audiences, gained a deeper understanding of financial model creation, and honed our skills in using sophisticated tools like GeoDesign. These skills have laid a solid foundation for our future roles in data-driven planning and decision-making within industry partnerships.

Here is a breakdown of the key learnings and career development aspects

- **Financial Modelling:** We gained practical experience in financial modelling, including defining assumptions, selecting relevant metrics, and translating financial concepts into code.
- **Data Visualisation:** The project honed our skills in data manipulation with Python and data visualisation using tools such as PowerBI & HTML for effective communication of financial results.
- **Project Management:** We practised effective team collaboration through communication channels, task allocation strategies, and regular progress meetings. This experience will be valuable for managing data science projects in the future.
- **Insight into an Industry Project:** This project provided valuable insight into the practical realities of working with clients in the future as most of us did not have prior working experience.
- **Course Integration:** The project allowed us to apply theoretical concepts learned in Data Science courses to a real-world scenario. Additionally, the project highlighted areas where further knowledge acquisition might be beneficial, such as advanced financial modelling techniques.

References

Cochrane, R. A., & Womble, J. E. (1971). Discounted Cash Flow Analysis and Plan Evaluation. *Journal of the American Planning Association*, 37(5), 338-343.

Mazutis, D., & Sweet, L. (2022). The business of accelerating sustainable urban development: A systematic review and synthesis. *Journal of Cleaner Production*, 357, 131871.

GeoDesign Hub. (n.d.). Retrieved from https://www.geodesignhub.com/