**ENGINEER 3PX3**

*Engineering Economics*

Course Project - Winter Semester, 2024

# 1. Introduction

Every day engineers face a world full of challenges ready to be solved. With new developments in technologies and research, engineers view their selected problems with changing perspectives. Engineers collaborate across professions to implement the best tools for the task and fully understand the problem. A problem can include human, environmental, technological, and business impacts. In this course project, you will not be tasked with a specific scenario but will have the opportunity to select your own. You will work in small teams to identify a real-world problem, develop a new product or service, and deliver the business case for your solution.

The business case will span the topics taught and discussed in this course and will culminate in a comprehensive final report that touches on course cornerstones. Across the project weeks, Check-Ins and interviews will take place to manage progress and help deliver refinements to your project.

The project will require self-arranged groups of 4, with at least two different engineering streams represented in each group. This must include people within your own Design Studio (DS) section. Anyone who does not sign up in a group on Avenue within the first week of the project will be auto-assigned a group by the second project week. Those who enroll in groups with fewer than 4 members may be separated to fit all remaining students into groups.

# 2. Background

Throughout this project, you will have the opportunity to collaborate in multidisciplinary groups to explore engineering economics and its applications in design. Assessing the economic viability of this project will allow you to determine the feasibility of the design and aid in decision-making throughout the process. In this project, you will examine the scale of your design solution to estimate how real-world products are developed. This project will apply all course content concepts, including net value functions, sensitivity analysis, optimization, project management, and Monte Carlo simulations.

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# 3. Mark Breakdown

|  |  |  |
| --- | --- | --- |
| **Design Project Component** | | **Weight** |
|  | Progress Check-Ins/Participation\* | **9%** |
|  | Simple Report Draft  Final  Interview | **18%**  4%  10%  4% |
|  | Complex Report Draft  Final  Interview | **28%**  5%  15%  8% |
|  | Design Project Self-Reflections Inter-Group Discussions  Self-Reflection | **5%**  2%  3% |

*\*Students must attend their assigned Design Studio sessions. Design Studios are dedicated to collaborating with teams on this project. Instructional staff (i.e., faculty mentors, IAI, and TAs) will be available for support during your scheduled time. Attendance will be recorded and will contribute to the student’s Design Studio participation grade.*

# 4. Overview of Submissions

|  |  |  |
| --- | --- | --- |
| Week | Submission | Date |
| 2 | Enroll in groups | Night of DS |
| 3 | Progress Check-In | During DS |
| 4 | Progress Check-In | During DS |
| 5 | Progress Check-In, Draft of Simple Report due | Night of DS |
| 6 | Inter-group Discussions | During DS |
| 7 | Reading week |  |
| 8 | Progress Check-In, Simple Report due | During DS, Night after DS |
| 9 | Team interviews | During DS |
| 10 | Progress Check-In, Draft of Complex Report due | During DS, Night after DS |
| 11 | Inter-group Discussions | During DS |
| 12 | Progress Check-In, Complex Report due, Self-Reflection Due | During DS, night after DS, 2nd night after DS |
| 13 | Team final interviews | During DS |

*All late submissions will receive a deduction of -20% per day. When a word count is specified, submissions with more than XX words or less than YY words will receive a deduction of -10% per 50 words.*

# 5. Weekly Breakdown

## Design Studio Week 2 – Idea Generation and High-Level NVF

In the first Design Studio session, students will form groups of 4 with a minimum of two different engineering streams included. Within your groups, you will brainstorm potential problems you would be interested in addressing. After discussing each potential problem, your team will select one to focus on. This may change throughout the design process. The selected problem should address a real-world issue and impact a significant number of people. It may be beneficial for future technical analysis to choose an area you have background or stream-specific knowledge in.

Demonstrate an understanding of the problem, its impact on society, and the context of the scenario at hand. Research and record background information about the scenario (you don't need to research in extreme detail for this project, just enough to be able to propose a reasonable NVF). For example, important questions may include (but are not limited to):

* What is the problem? Why is it important?
* What are the design criteria and constraints of the problem?
* Who or what does the current problem affect?
* What are the current solutions to the problem?
* Who are the stakeholders? (Who is impacted, positively or negatively, by the project)

Outline a high-level net value function (NVF) for your selected problem. Detail all areas of interest of your problem, including benefits towards users and cost that your business with incur. Describe you NVF in qualitative terms only (for example, *NVF = benefit of solution – cost of space – cost of time – cost of labour - …).* Include general terms in your function, that may be applicable to a variety of solutions. This NVF will be updated with every iteration of your design and become more detailed as your solution is developed. Do not consider the time value of money (e.g., optimize for best operating cost, evenly distributing startup costs over lifespan) or uncertain outcomes (e.g., risk & risk management) at this stage in the project.

Determine potential solution concepts. Before moving forward with a solution, ensure you have identified various technical analysis aspects that you can later explore. These may include concepts you have learned in other engineering courses and can apply to this project. Note the technical analyses methods along with the course code of the class you previously learned/applied this knowledge in. Determining the applicable scale of the solution will also aid in future economic analysis. Narrow down concepts to one solution to explore further.

*Each team member must enroll in Groups on Avenue. Teams of 4 are required, and all team members must enroll in their group by the end of the week. If there are not 4 members in your group, you will be automatically assigned to a group. Groups should come to Design Studio Week 3 with a proposed solution to present to the TA in a progress Check-In.*

## Design Studio Week 3 – Solution Design and NVF Assessment

*Progress Check-Ins during Design Studio (ungraded).*

As a team, document initial team planning, organization, and structure. This should include the following, but is not limited to:

1. Draft a Gantt chart in Microsoft Project that includes all the project tasks your group will complete during this course project (include tasks completed in the previous Design Studio). For now, use estimates where necessary, as the Gantt chart can be continually updated throughout the project to adjust for changes and unexpected developments.
2. Outline the timing and organization of meetings (purpose, location, etc.) and how you will document the meetings (meeting minutes, action items/plans, etc.)
3. Identify each team member’s roles and responsibilities.
4. Decide upon methods of project process documentation (e.g., how are you going to track your progress on the project? Discuss your plan for collaborating on the progress check-ins).

This week, you will further explore your selected solution. Groups will present their solution proposal to their TA during the Design Studio session, and refine the idea based on given feedback if required. Before proceeding with the design, complete the following:

1. Identify any initial assumptions, constraints, and objectives of the solution.
2. Determine how you can evaluate if your solution is successful (i.e., a basic NVF (without any conversion factors) and constraints. “We will be successful if we maximize/minimize Net Value (defined by this draft function) while staying within the constraints of Y1, Y2, etc.”)

Describe the framework of your solution through economic analysis. Reassess your NVF and include performance parameters of your solution. Replace terms with monetary conversions. Conversion factors can be estimated to the best of your ability. Justify the presence of terms included in your NVF. Justify the omission of terms that were considered but not included. For this stage of the project, only consider operating costs and revenue for a given time period (e.g., 1 year), and divide any one-time start-up costs over the expected lifetime of the project (this is fine for the Simple Report - we won't include detailed time value of money calculations until the Complex Report). For example, consider the following (where applicable) for your NVF:

* Bill of materials and itemized cost to create your solution (for example, purchasing of materials, labour, time) - **Note:** you don't need to do extensive research, and instead can estimate costs. The purpose is to show you know how to work with the data, not to get perfect data itself as a result of extensive time researching things.
* Acquisition cost (for example, tax/shipping)
* Estimated market price of solution
* Size of market estimation
* Sales revenue
* Benefits of your solution to society

Determine environmental benefits and costs relative to the control case (current solution/no solution). Identify applicable environmental regulatory requirements and any potential impact on wildlife or local ecosystems. Discuss the regulatory requirements of the solution based on its intended usage. Identify areas of ethical considerations of its development and use. Consider equity, diversity, and inclusion (EDI) in your solutions.

Adjust your NVF as needed and use it to determine the NV of your proposed design – does this look like a good project?

*There is no submission for Design Studio Week 3. Groups should aim to have documented project organization (Gantt chart, roles, responsibilities, etc.), a description of the solution, and a net value function including terms specific to the solution. Groups will discuss these topics in the progress Check-In in Week 4. Along with your progress check-in submission prior to Design Studio Week 4, include a proposal for the Technical Analysis you'll each do individually for the project in the Current Status section of your submission. You should wait until you've completed the Technical Analysis lecture (Lecture 5, the second one in Week 3) before drafting this. Specifically, lay out which decision variable(s) you're going to relate to optimization parameters and other decision variables, and which course's content you're planning to use to help you do this. This will let you get feedback on your plan during Design Studio Week 4.*

## Design Studio Week 4 – Technical Analysis

*Progress Check-Ins during Design Studio (graded).*

Further describe your solution design, going into detail in some areas of it as needed in order to describe it in terms of new *design parameters* (e.g., thickness of this bracket), then perform individual technical analysis to relate the parameters to each other and to *performance parameters* (the parameters that are directly included in your NVF). For example, you may include sketches/models, a list of materials, workflow diagrams, design plans, design validation plans, and quality assurance plans as applicable to your solution (you do not need to describe all parts of your solution design in detail, go into detail only where you need to in order to set up your technical analysis). Determine functional and technical specifications (i.e., how the solution should be used, and how the product will be built). Perform *individual* technical analysis based on background or stream-specific knowledge (using information from a course you took that not every stream takes, and *not* using new research that you perform now.). Each group member must choose a different aspect (or subcomponent) of the project to analyze. Utilize previous knowledge from other classes to complete these analyses. For example, you may include descriptions of the following engineering topic and technical analysis methods in your solution:

|  |  |
| --- | --- |
| Stream | Example Topic Areas for Technical Analysis |
| Electrical/Computer | Data communication systems, signal processing, microelectronics, power engineering, signal processing, circuit and system design and testing, computer-aided design, etc. |
| Engineering Physics | Statics & dynamics, digital & analog circuits, energy systems, E&M, embedded systems, heat transfer, sensor design, multiphysics, fluid mechanics, optics, electronics, solid state physics, metrology, signals & systems, nuclear engineering, quantum mechanics, space systems |
| Software | Software lifecycle, documentation, testing and verification, data structures, algorithmic design strategies, digital interfacing, computer architecture, revision control, etc. |
| Mechatronics | Embedded systems, data structures, automation, algorithm analysis, modelling, electromagnetism, dynamics and dynamic models, design, and analysis of analog and digital electrical circuits, etc. |
| Mechanical | Variable conversion elements, signal amplification, measurement of train and force, pressure, flow, temperature, power, modelling, kinematics and dynamics, thermodynamics, manufacturing, etc. |
| Civil | Decision support systems, passive and semi-active structural control, design codes, large-scale testing, durability/service life modelling, concrete technology, energy efficiency, environmental analysis, geotechnical engineering, information technology for construction, transportation, etc. |
| Materials | Materials processing, recycling, electronic and structural materials, physical chemistry, modelling and experimental techniques, biomaterials, molecular dynamics, corrosion and environmental degradation of materials, energy conversion, thermodynamics, measurements, etc. |

(This list notwithstanding, you can do technical analysis of any topic area if it's based on applying information you learned in an undergrad course that not every stream takes.)

Update your NVF with any new terms and values based on your groups technical analyses. Provide reasonable monetary values for identified design parameters. Assumptions of values will likely be required in both cost estimates and calculations. Use as many assumptions as needed, and simply state the assumption in clear terms. Use assumptions and known values to determine a final result for your NVF. Interpret these results and compare with your metric for success that you stated in Design Studio Week 3.

Note that the content of the technical analysis is not as important as the implementation of results into the NVF. Please focus on effort and bringing things to a close in technical analysis, not on performing an exact calculation.

*There is no submission in Design Studio Week 4. Groups should aim to perform their technical analysis and update their NVF. Note that the draft submission of the Simple Report will be due the night of Design Studio Week 5 and includes content from Design Studio Weeks 2-5. Groups will discuss these topics in the progress Check-In in Week 5.*

## Design Studio Week 5 – Sensitivity Analysis

*Progress Check-Ins during Design Studio (graded).*

Perform sensitivity analysis on the NVF you expressed in terms of decision variables for last week:

1. For each [independent] decision variable:
   1. Identify an initial value it should take on and a range of values you want to explore for it (typically should be in +/- x% from the initial value)
2. For each other parameter your NVF depended on (e.g., conversion factors that weren't further broken down, or parameters conversion factors depended on)
   1. Identify the possible range of values it could have (e.g., because you had to estimate it), or
   2. Point out that this is fixed & known exactly (and so you don't need to explore how sensitive the model is to it).
3. Set up your NVF in excel.
4. Evaluate your NVF over the range of parameters (or decision variables) you identified, creating both a spider plot and tornado plot.
5. Comment on what the plot reveals about these terms:
   1. For terms you (as designer) get to choose about your solution (i.e., independent decision variables), identify whether you should increase, decrease, or keep their initial values (you don't yet need to fully *optimize* the solution by choosing the best combination of all decision variables; we'll do that next week)
   2. For terms you estimated but *don't* get to choose (like conversion factors or parameters they depended on), identify which one(s) are the most important to get more data for and improve the estimates (i.e., reduce uncertainty for)
6. Review and make any necessary changes to your NVF in light of the sensitivity analysis (you can also state after reviewing that you feel your NVF is OK, and you don't need to change it at this time).

Note: It's fine (and expected!) that you'll adjust your NVF and/or solution because of new information from time to time. If that happens, be sure to document the change and your reasons for it. You don't necessarily need to make major changes after the sensitivity analysis considering its results, but if you do, be sure to include new spider and/or tornado plots on the resulting model so that you are working with the most up to date sensitivity analysis you can.

*The draft of the Simple Report is due the night of Design Studio Week 5. See below for more details on the content of this report and the associated rubric. Note that the draft report will include Design Studio Weeks 2-5, and the final Simple Report will include Design Studio Weeks 2-6 and be due the night of Design Studio Week 8. Inter-group Discussions will occur during Week 6’s Design Studio.*

## Design Studio Week 6 – Optimization

*Inter-group Discussions during Design Studio (graded).*

This week, you will build off your previous NVF to determine optimal values of decision variables to maximize the net value your solution will produce. Examine your NVF and determine which variables you have control over (decision variables) and set numerical values to all other variables. State any initial assumptions, constraints, and objectives of the project. Constraints may be based on available resources or size capacity (these do not have to be exact accurate values and can be estimated with a reasonable justification). Your objective function should be to maximize your NVF. State your constraints and object function in an organized notation and note a short description to justify and interpret the function.

Complete linear or nonlinear optimization (using one of the three techniques in Excel, as shown in class) to identify the best set of decision variable values. Discuss your results and information presented by Excel's "Sensitivity" output report, identifying how the optimum is sensitive to your decision variables and constraints. Update your design solution according to this analysis. Ensure to document this iteration.

Repeat your sensitivity analysis on the NV after substituting in the optimum decision variable values, including regenerating a spider plot.

The final version of the Simple Report is due the night after your Design Studio in Week 8. See below for more details on the content of this report and the associated rubric. Groups will discuss their progress Check-In in Week 8.

## Design Studio Week 7 – Reading Week

## Design Studio Week 8 – Project Management

*Progress Check-Ins during Design Studio (graded).*

Goals for DS Week 8: set up your *Project Plan* to be ready for Time Value of Money (TVM) analysis next week.

1. Work Breakdown Structure (WBS): Create a WBS laying out all tasks that need to happen to make the project a reality over the complete lifecycle of the project. Consider not only tasks the development team would do, but also tasks anyone whose perspective is in the scope of your NVF would need to do specifically for this as well. Include everything that impacted the NVF you optimized in the previous DS and everything else that needs to happen from cradle to grave for the project (this exercise will likely make you realize things you perhaps should've included in the earlier NVF, but don't go back and change the previous report sections to include them - just include them now for the complex report's NVF),
   1. In other words, detail the lifecycle of your design from start to finish. You should include the initiation, planning, execution, monitoring, and closure stages of your design. Include tasks like commissioning, development, design testing, design validation, and decommissioning. Identify all resources required to complete each task (labour, materials, equipment, etc.).
   2. Note: not all projects require the same number of tasks in a WBS. For the purposes of this project, you should have between 10 and 20 sub-tasks (i.e., tasks at the bottom level rather than headings) in your WBS, ideally spread out over the full lifecycle of the project.
2. CPM: Complete a node network diagram for the project tasks. Estimate the duration of tasks, specify any relationships between them, determine early and late start and end dates, calculate floats, and identify the critical path.
3. Create a task list (as a new part of the excel sheet you set up to optimize your NVF, as shown in Lecture 10), and specify when each happens (e.g., determine and/or plan and/or estimate, with reference to your CPM, when it will start and end; the timeframe it happens over),
4. Enter functions to determine the value impact for each task in monetary terms (i.e., additional benefit minus costs from this one task but put in dollar terms. In many cases, these will match parts of your NVF). Keep previous decision variables and parameters as variables (rather than literals, i.e., make sure it's a function that will update as inputs and parameters change, not just a number). Specify values for parameters and input decision variables in a table (specifying which is which). Introduce any new decision variables that occur to you with this layout of tasks. Here are some tips to help you with this process:
   1. Adding up the NVF impact of every item in the WBS (other than the newly added tasks you didn't consider before) over the time it occurs should give the previous NVF - make sure you didn't miss a task if it doesn't add up.
   2. For this to work, the "task list" should list anything that impacts NV, whether or not it's necessarily a "task"
   3. List value impacts in nominal terms (i.e., use conversion factors to money based on current prices like you did in the simple report, don't worry about time value of money yet) - we'll include TVM to convert them to present value terms next week.

*The final version of the Simple Report (content from Design Studio Weeks 2-6) is due the night after your Design Studio Week 8. See below for more details on the content of this report and the associated rubric. Team interviews will take place in Design Studio Week 9.*

## Design Studio Week 9 – Net Value Function Regeneration with Time Value of Money

*Team interviews during Design Studio.*

This week we'll perform a TVM analysis to better compare NV impacts for the project that occur at different times (identified in the previous week's project plan) by converting them into NPV impacts in some reference "present" year.

1. Create a *value* flow diagram detailing value change (like a "cash flow diagram” but including anything that impacts net value) for the tasks you laid out in the task list in the previous DS.
2. Select (with a *very* *brief* justification) a discount rate for your project,
3. Use your discount rate to determine the TVM-conversion factor to put every value change in the task list into present value terms for your benchmark year (and specify your benchmark year, i.e., specify when will be considered the "present" for NPV)
   1. Note: If you are doing this in Excel, and leave the discount rate as a variable in a cell you can change later to make the MARR calculation easier,
4. Code the NPVF when considering these TVM conversion factors into your Excel worksheet,
   1. Do this by multiplying each NV impact by its TVM conversion factor (which depends on when its NV impacts occur) to determine its NPV impact, then sum up the NPV impacts.
5. Determine the NPV of your project with the working set of your input decision variables (i.e., whatever you selected at the last optimization for input decision variables that existed at that time, and whatever you now decide to use as the working values for any new decision variables you've introduced since then)
   1. Note: don't optimize NPV yet, we'll do this in the stochastic sensitivity analysis section in two weeks.
6. If possible, determine your project's IRR (over your project's timeline, with the working set of your input decision variables). If impossible, explain & show why. If your client sets a real MARR of 15%, does your project currently meet this constraint?

The draft of the Complex Report is due the night after your Design Studio Week 10. See below for more details on the content of this report and the associated rubric. Note that the final Complex Report will be due the night after your Design Studio Week 12. Groups will discuss their progress Check-In in Week 10.

## Design Studio Week 10 – Risk Management

*Progress Check-Ins during Design Studio (graded).*

1. Brainstorm any events that may happen that could either benefit or detract from your project’s NV. State the NV impact for each potential outcome of each event and the chance of that outcome occurring (each can be continuous or discrete probability, and you don't have to stick to one type for all events).
   1. You should brainstorm at least 6 events total including at least 3 risks (potential events with a *negative* impact on NV)
   2. Risks can be "parameter X is different than estimated", especially where that may be the case and would have a significant impact.
2. Lay out the risks in a *risk matrix.*
   1. When organizing the risks into a risk matrix, you don't need to have something for every cell. You can also have more than one event in a specific cell. The likeliness axis can be in terms of "chance this happens at all over the life of the project" or "expected rate of occurrence" (e.g., 1 per 100 years, 1 per 10 years, 1 per year, 1 per month, 1 per week, 1 per day, etc.).
3. Identify the 3 most critical risks (ones with the largest *expected* NV impact [i.e., the largest expected change in NV], determined by multiplying the NV impact if they do happen with the chance they happen, or the NV impact per occurrence with the expected rate of occurrence)
   1. Update your task list to include the impact of these risks taking place, with random variables to account for the probability they happen (it's OK if these are not technically "tasks").
   2. You can optionally add additional events or risks to your task list in this way, but you must add at least these 3 most significant risks.
4. Propose mitigation strategies for the 3 most critical risks. Estimate the cost of implementing these risk mitigation strategies and the changes they make to the NV impact and/or chances of each risk outcome.
   1. Strategies can (and at least one must) be listed with flexibility (e.g., new continuous or discrete decision variables capturing whether to use a strategy, which alternative ones to use, or the degree to which you will use a strategy).
5. Update the NPV calculation to include the impact of these risks and potential mitigation strategies.
   1. Set this up with two different versions - one that uses the “current roll” of random variable cells (i.e. one set of random values) to create the "stochastic model" for NPV, and another that uses expected values of things impacted by random variables to create the "deterministic model" for NPV (i.e., doesn’t rely on random variables).
   2. For now, you can create a draft version of the deterministic model with simple expected value calculations. In DS Week 11 for the Final Complex Report we'll improve the deterministic model with Monte Carlo analysis, use the Solver on it to find optimum input decision variable values, and analyze the expected NPV and its sensitivity using the stochastic model.
   3. e.g., for impactful parameters with substantial uncertainty, convert existing parameter cells into values drawn from a probability distribution for the stochastic model, but have the draft deterministic model use the expected value of the parameter. In Week 11, with the help of Monte Carlo analysis, upgrade the deterministic model to instead use the expected value of dependencies, given the parameter’s distribution where this is necessary (i.e., where those dependencies are nonlinear).

*Note the difference between the stochastic/deterministic models here:*

* **Week 10:** Stochastic model - calculate NPV including inputs from random variable cells.
* **Week 10:** Draft Deterministic Model - set cells that rely on random variable cells to their expected values and/or set the random variable cells to their expected values. Used to determine a rough estimate of the NPV of your working design for the draft complex report only.
* **Week 11:** Deterministic Model - use Monte Carlo analysis where necessary to determine better expected values (e.g., via effective conversion factors) to model your real stochastic model as closely as possible with a deterministic model (so that you can run Solver on it and optimize)

*The draft of the Complex Report is due the night after your Design Studio Week 10. See below for more details on the content of this report and the associated rubric. Note that the final Complex Report will be due the night after your Design Studio Week 12. Inter-group Discussions will occur during Week 11’s Design Studio.*

## Design Studio Week 11 – Stochastic Sensitivity Analysis

Inter-group Discussions during Design Studio (graded).

1. Select final decision variable values: Re-optimize the NVF you've built up to now include project planning, TVM, and risk management, identifying and determining all values of independent decision variables from your tech analysis, project implementation plan, and risk management.
   1. First use a Monte Carlo simulation to establish "effective conversion factors" (or "effective conversion functions") to convert the stochastic model into a deterministic one, then use Solver to determine the optimal values for any decision variables for this new deterministic model.
      1. Where possible, you can instead convert parts of the stochastic model to deterministic using math instead of a Monte Carlo analysis.
   2. If you have discrete decision variables (e.g., "whether to use risk management strategy A or B"), then incorporate them using IF statements and the evolutionary Solver (as shown in class in Lecture 9).
   3. Determine which plan (i.e., set of decision variable values) maximizes expected NPV and what that maximum expected NPV is.
   4. Be careful that your conversion from stochastic to deterministic model considers nonlinear interactions between decision and random variables and is still valid around the optimal set of decision variable values. For complicated interactions you may need to iterate. Convert to deterministic model around the working set of decision variable values, then run Solver to get the set of optimum decision variable values. Re-convert to deterministic model around this set, then re-run Solver on this updated deterministic model, etc. until it converges. If so, make sure to document the process.
2. Stochastic Sensitivity Analysis: For this optimal set of decision variable values, return to the stochastic model and determine the actual expected NPV, its standard deviation, and chance the project has a positive NPV.
   1. Do this by entering the optimal set of input decision variables into the stochastic model and performing a Monte Carlo analysis. Determine the NPV result for a large number of iterations using what-if analysis and analyzing the resulting dataset.
   2. Note that for this final part of the report, determining the standard deviation of your expected NPV is the only sensitivity analysis you need to do - you do not need to perform a *further* sensitivity analysis to explore how sensitive these results are to your model’s parameters like you did at the end of the Simple Report (just note that you could, and for a real project you might want to).
3. Finally, make a recommendation about whether we should pursue this project.

*The final Complex Report will be due the night following your Design Studio Week 12. The Self-Reflection is due the night after this report is due. Please see the Design Project Self-Reflection section below for instructions and rubric. Groups will discuss their progress Check-In in Week 12. Team interviews will take place in Design Studio Week 13.*

## Design Studio Week 12 – Work Period

*Progress Check-Ins during Design Studio (graded).*

*Design Studio Week 12 will be in class time to finalize your Complex Report. See instructions and rubric below. The Self-Reflection is due two nights after Design Studio Week 12 (one night after the Complex Report is due). Please see the Design Project Self-Reflection section below for instructions and rubric.*

## Design Studio Week 13 – Interview Week

*Team final interviews happen during Design Studio.*

# 6. Progress Check-Ins (9%)

Progress Check-In meetings will occur in all Design Studio Weeks that do not contain Team Interviews or Inter-group Discussions, starting in Week 3.

Submit your completed Check-In documentation *prior* to arriving in Design Studio. The template for this document can be found on Avenue. The submission should include a one-page summary of your project updates and future work, in point form. Attach/paste a copy of your updated Gantt Chart to this document.

During Design Studio, each group will meet with one TA and IAI/Faculty Mentor for 10 minutes to discuss their progress. Marks will be awarded based on the completion of previous weekly tasks and timely progression of the project based on the group’s Gantt Chart. Week 3’s Check-In will be ungraded.

Check-In documents should include all project updates since the *previous* Check-In (for example, in Week 3, the Check-In will summarize progress since Week 2). The future work should detail tasks that are to be completed before the *next* Check-In (for example, in Week 3, summarize tasks completed before Week 4).

# 7. Inter-Group Discussions (1% each)

Intergroup discussions will occur during Design Studio Weeks 6 and 11. Groups will be paired off with another group in the DS section. Each team will present a short (~5 minute) presentation that includes:

1. Brief description of your problem
2. Explanation of your designed solution and implementation timeline
3. Results of economic and sensitivity analysis (Week 6 only)
4. Results of optimization, project management, time value of money, and risk management (Week 11 only)
5. Next steps

Following the presentation there will be a 2-minute discussion to give the group feedback. Some suggested questions:

1. Why (and/or how) did you choose that design variable?
2. Why (and/or how) did you choose that solution to explore?
3. What surprised you from the sensitivity analysis? (and why)?
4. How did the course help you to complete this analysis?

Once everyone has presented, there will be a 30-minute period for individuals to complete a written reflection that will be due during the Design Studio. The reflection should be approximately ½-1 page, 12-point font, and singly spaced. Individuals will reflect on the feedback they received (and on the presentations and how your and the other group approached the problem), in the "What? So what? Now what?" framework.

## Inter-Group Discussion Reflection Rubric

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Category | Level 0 | Level 1 | Level 2 | Level 3 | Level 4 |
| Content (X/3) | Incorrect content or missing large amounts of information. | A few descriptions or analyses not well defined or not well justified. | At least one description or analysis of feedback is given. | Clear observation and reflection on feedback received. | Thoughtful and sophisticated observations, with evidence that feedback has been reflected upon. |
| Format and Delivery (X/1) | Major issue that impacts readability of the reflection, such as corrupted file submitted. | Not all required content is available in the reflection. Poor formatting. | Minor issues with formatting or font type/size. | No minor issues in the formatting of the reflection and all required content are included. | Reflection  presented professionally, with clear and concise content. |
| Technical Writing Quality  (X/1) | Reflection is difficult to read, lacks logical progression, or major errors in grammar and structure. | Poorly written (e.g., run-on sentences, sentence structure, repeats information, spelling, or grammar errors present). | Inadequate use of professional language. Frequent changes in voice, tense, or tone. | Well written. Ideas presented in a logical sequence. | Writing is cohesive and easily has logical transitions. |

# 8. Simple Report (18%)

The Simple Report will include the first half of course content (Lectures 1-9) and will include the following topics:

1. Idea Generation (Design Studio Week #2)
2. Design Solution (Design Studio Week #3)
3. Technical Analysis (Design Studio Week #4)
4. Net Value Functions (Design Studio Week #2-4)
5. Sensitivity Analysis (Design Studio Week #5)
6. Optimization (Design Studio Week #6)

The Simple Report will contain two submissions. The first will be a draft due the night of your Week #5 Design Studio. This report will include topics #1-5 from the list above. Teams will submit a pdf version of their report named *Group\_#\_Draft\_SimpleReport* along with any supplementary Excel files.

Following the submission of the draft, teams will receive TA feedback. Teams shall implement the suggested changes as well as topic #6 from the above list. The final submission of the Simple Report will be due the night after your Week #8 Design Studio. The final submission will include a Change Log, which will summarize all additions or updates in the report since the draft submission. Teams will submit a pdf version of their report named *Group\_#\_SimpleReport* along with any supplementary Excel files. Note that word limits do not include figures or tables. Supplementary material may be placed in an appendix.

The structure of the *draft* Simple Report should be as follows:

Contribution List - List each team member and the sections they take responsibility for.

1. Problem Identification (maximum 300 words)

Define your selected problem. Describe why it is important and who it affects. Qualitatively describe existing and potential solutions to consider. List the benefits and costs to consider in your NVF, from whose perspective(s) you'll consider them, and the constraints a solution must meet to be considered valid.

1. Detailed NVF and Conversion Factors (maximum 600 words)

Present and explain a high-level NVF written in terms of performance parameters of potential solutions, including the conversion factors that allow you monetize these parameters. Justify your conversion factors and present any relevant assumptions. Describe environmental considerations identified and the associated monetary values where applicable. Discuss identified regulatory requirements, ethical and EDI considerations applicable to potential solutions, and their impact on the NVF or accompanying constraints.

1. Initial Solution Comparison (maximum 600 words)

By estimating solution parameter values, compare the resulting NV of at least two alternative and/or baseline solutions (other than your proposed solution). Present and describe your proposed solution and estimate its performance parameters (Include relevant cost estimates identified in Design Studio Week #3. Ensure that you detail your solution’s operating costs and revenue as applicable). Finally, substitute your solution into the NVF to determine your initial estimate of the NV of this proposed solution (it doesn't need to be a clear winner over the alternatives, but hopefully shows enough promise to warrant the further investigation that is this report).

1. Technical Analysis Overview & Detailed NVF (maximum 900 words)

Present the setup, resulting equations, and incorporation into the NVF for each of your individual technical analyses from Design Studio Week #4. Identify the team member who was responsible for each technical analysis and present the results, but place the actual technical analysis in the appendix, referring to each here where appropriate. Write the detailed NVF in terms of decision variables and present the allowed ranges of parameters and decision variables for this NVF to be valid.

1. Sensitivity Analysis (maximum 600 words)

Present the results of your sensitivity analysis including visual results (spider plots and tornado plots) that you developed in Week #5. Explain how sensitive your solution's NV is to a) each of your decision variables in your detailed NVF, b) other parameters your NVF relies on which are potentially incorrect, changing, and/or unpredictable, like important conversion factors, performance parameters you haven’t further broken down into functions of decision variables, or other parameters used in the NVF. Explain what your sensitivity analysis shows, describing your conclusions in the form of a business strategy (i.e., don't just identify what it shows that's important, but say what we need to keep in mind and how best to go forward in light of it).

The structure of the *final* Simple Report should be as follows:

Contribution List - List each team member and their sections they take responsibility for.

1. Change Log

Include a table identifying the changes made since the draft submission of the Simple Report. The table should have the following structure.

* Change Number
* Type: Identify if the change was an addition, deletion, or revision.
* Source of the Change: Identify why the change was needed (e.g. feedback from TA, group discussion, etc.)
* Original: Original version of the text (prior to the change)
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1. Problem Identification
2. Detailed NVF and Conversion Factors
3. Initial Solution Comparison
4. Technical Analysis Overview & Detailed NVF
5. Sensitivity Analysis
6. Optimization (maximum 600 words)

Include the results of your optimization performed in Design Studio Week #6. Present and justify your strategy for optimizing NVF (e.g., which method(s) did you use and why?). Place any extensive calculations needed prior to the optimization in the appendix and refer to them here (e.g., linearization if using linear optimization on a nonlinear function). Present the optimization program in an organized notation. Include and interpret the results of your optimized decision variable values. Present the updated sensitivity analysis for your optimum decision variable values, including updated spider plots for other relevant variables. State your conclusions based on the optimized results and describe the sensitivity of your optimal values. Describe how these results impact your design solution, and how much confidence you should place in the conclusions in light of the sensitivity.

1. Final Design (maximum 300 words)

Summarize your key findings. Present your final solution based on the discoveries of the economic, sensitivity analysis, and optimization. Describe your iterative process and summarize your changes leading to your final design. Present the limitations to the conclusions and the confidence your clients should place in them as a result.

## Simple Report Rubric

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Category | Level 0 | Level 1 | Level 2 | Level 3 | Level 4 |
| Problem Identification (X/8) | Problem not well defined, leaving ambiguity in who the problem affects, existing solutions, and constraints. Benefits and costs are not described. | Problem identified with minimal justification or explanation. Major issues with descriptions of who the problem affects, existing solutions, and constraints. Benefits and costs are poorly described. | Adequate identification of the problem. Some issues with description of problem, existing solutions, and constraints. Benefits and costs are described. | Chosen problem clearly defined. Description includes who the problem affects, existing solutions, and constraints. Benefits and costs are well described. | The problem is clearly defined and discussed thoroughly, including who the problem affects, existing solutions, and constraints. Benefits and costs are well described. |
| Detailed NVF and Conversion Factors (X/10) | No clear identification and discussion of the NVF. Conversion factors missing.  Environmental and ethical considerations not stated. Regulations and EDI are not mentioned. | Net value function  does not incorporate relevant information. No assumptions are  stated. Limited conversion factors are included. Cost descriptions are missing critical information. Environmental and ethical considerations stated with lack of explanation. Regulations and EDI are not tied into design. | NVF expressed in limited detail. Conversion factors stated with any necessary assumptions. Environmental and ethical considerations stated with lack of explanation. Regulations and EDI are not tied into design. | NVF expressed in detail and justifies present and omitted terms Conversion factors stated. Discussion of environmental benefits and costs is well incorporated. Relevant regulatory requirements included, with inclusion of EDI in design solution. Results of NVF are interpreted. | Identifies frame of reference for NVF. NVF expressed in concise detail and justifies present and omitted terms. Conversion factors stated with necessary assumptions. Discussion of environmental benefits/costs is well incorporated and relevant to solution. Relevant regulatory requirements included, with discussion of EDI. Results of NVF are clearly interpreted. |
| Initial Solution Comparison (X/10) | Potential solutions not compared, proposed solution not defined, or large amount of information is missing from final NVF. | Solution identified with minimal justification or explanation. Alternate solutions not effectively discussed. No appropriate final estimate of the NVF is reached (i.e. final result in monetary value). | Adequate description of solution. Alternate solutions stated but not competently compared. A final estimate of the NVF is listed (i.e. final result in monetary value). | Chosen solution clearly defined. Alternate solutions discussed and quantitatively compared in NVF. An appropriate final estimate of the NVF is reached (i.e. final result in monetary value). | Solution is clearly defined and discussed thoroughly, including alternate solutions with justification of why they were not pursued with reference to the NVF. An appropriate final estimate of the NVF is reached (i.e. final result in monetary value). |
| Technical Analysis Overview & Detailed NVF (X/12) | Technical analysis is inappropriate (e.g., not analysis), or irrelevant (e.g., not tied back into NVF in any way that allows optimization). No supporting material. | Some technical analysis completed to create equations concerning decision variables, but substantial problems with the analysis and/or its incorporation into the NVF pose major questions concerning the justification for it and/or its relevance to economic analysis. No technical analysis supporting material provided in the appendix | Adequate technical analysis done and reasonably well incorporated into NVF, but possibly with low relevance, missing parameter values, or somewhat questionable validity. Lack of technical analysis supporting material provided in the appendix | Technical analysis done for necessary number of decision variables, presented with clear valid ranges of parameters, and results incorporated into the NVF. Technical analysis supporting material provided in the appendix | Meaningful and believable technical analysis completed and presented clearly for relevant design parameters, including incorporation into economic analysis via the NVF. Technical analysis supporting material provided in the appendix. Valid parameter ranges are clearly presented for decision variables and other parameters, along with reasonable explanations for these ranges. |
| Sensitivity Analysis (X/10) | No sensitivity analysis section is identified in the report, or no Excel workbooks are submitted with report. | Sensitivity analysis has been performed with logical or calculation errors. The spider plot or tornado plot are inaccurately presented. Connections back to solution are not made. | Sensitivity analysis has been performed, with limited discussion on how these variables affect the net value. Spider plot and tornado presented. Connections back to solution are not made. | A sensitivity analysis has been performed, with discussion on how these variables affect the net value. Spider plot and tornado plots are presented and connect back to the parameters impacting the solution. | A sensitivity analysis of the key project variables has been performed, with discussion on how these variables affect the net value. Spider plot and tornado plots are presented in a professional manner, with clear connections to the parameters impacting the solution. Conclusions maximize NVF and are presented in a logical/professional way. |
| Optimization (X/10) (Final report only) | No clear identification or discussion of optimization setup, methods, or results. | Objective function and/or constraints identified are not reasonable or improperly formulated. Relevant errors in optimization. Linear program incorrectly stated. No interpretable results. | Objective function and/or constraints are properly formulated. Linearization is described (if required). Many assumptions are valid and described. Results of optimization are not interpreted, and no conclusions are made. | Objective function and constraints are properly formulated, well justified, and all assumptions are stated. Function correctly linearized (if required). Discussion on optimized variables included. | Objective function and constraints are correctly formulated, well justified, and all assumptions are stated. Function correctly linearized (if required). Results are thoughtfully discussed and analyzed. Implementation and relevance to the NVF and the overall project is made exceedingly clear. |
| Final Design (X/5) (Final report only) | No summary attempted. | Limited conclusions with errors in judgements and misleading summary. | Some relevant findings are included. Weak discussion or poor presentations of results. | Clear explanation of relevant findings. Logical presentation of results with minor gaps. | Clear explanation of relevant findings. Logical and professional interpretation of results. Written with a high technical knowledge. |
| Change Log (X/2) (Final report only) | Section missing. | Section does not describe changes implemented. | Section inadequately defines changes implemented. | Changes clearly defined. | Changes clearly defined and presented in an organized and precise manner. |
| Report Format and Content (X/5) | Major issue that impacts readability of the report, such as corrupted file submitted. | Not all required content is available in the report. Poor formatting. | Minor issues with formatting, font type/size OR images either not labelled/not referenced in the text. | No minor issues in the formatting of the report and all required content are included. | Sections divided and presented professionally. Figures and tables are clear and relevant, with captions. References follow IEEE formatting. |
| Technical Writing Quality (X/5) | Report difficult to read, lack logical progression, or major errors in grammar and structure. | Poorly written (e.g., run-on sentences, sentence structure, repeats information, spelling, or grammar errors present). | Inadequate use of technical language. Frequent changes in voice, tense, or tone. | Well written. Ideas presented in a logical sequence. | Sections are cohesive and easily relate to each other through logical transitions. Terminology and sentence structure across sections are consistent. |

# 9. Complex Report (28%)

* Draft: 5%
* Final: 15%
* Interview: 8%

The Complex Report will continue from the end of the Simple Report to include considerations from the second half of course content (Lectures 10-19), covered in design studio weeks 8 to 12.

The Complex Report will contain two submissions. The first will be a draft due the night after your Week #10 Design Studio. This report will include topics from up to DS #10. Teams will submit a pdf version of their report named *Group\_#\_Draft\_ComplexReport* along with any supplementary Excel files.

Following the submission of the draft, teams will receive TA feedback. Teams shall implement the suggested changes and include the final parts of the report addressed in DS #11. The final submission of the Complex Report will be due the night *after* your Week #12 Design Studio. The final submission will include a Change Log, which will summarize all additions or updates in the report since the draft submission. Teams will submit a pdf version of their report named *Group\_#\_ComplexReport* along with any supplementary Excel files (or readable files from other programs used). Note that word limits do not include figures or tables, but they do include equations. Supplementary material can be placed in an appendix.

The structure of the *draft* Complex Report should be as follows:

Contribution List - List each team member and their sections they take responsibility for.

1. Change Log

Include a table identifying the changes made since the final submission of the Simple Report. The table should have the following structure. For the type of change, identify if the change was an addition, deletion, or revision.

* Change Number
* Type: Identify if the change was an addition, deletion, or revision.
* Source of the Change: Identify why the change was needed (e.g. feedback from TA, group discussion, etc.)
* Original: Original version of the text (prior to the change)
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Part 1: Simple Report

1. (Include all sections of the simple report)
2. (Sections already marked twice will not be re-marked in detail at this stage, but if you change them considering future information you should still identify changes in the Change Log)
3. (You *should* correct & update your Optimization and Final Design sections based on feedback received in the Final Simple Report, as we *will* re-mark these sections where changes are indicated in the Change Log.)

Part 2: Project Management, TVM, and Risk

1. Project Plan (maximum 600 words)

Summarize the results of Design Studio Week 8’s project management planning. Include and explain your WBS, CPM, and task list, describing the complete set of tasks to bring your solution to market and decommission it at the end of its lifecycle, including each task’s NV impact in nominal terms. Highlight any new decision variables. Refer to the instructions Week 8 Design Studio to ensure you have included your complete plan.

1. NPV (maximum 600 words)

Summarize the results of Design Studio Week 9’s TVM calculations. Include and explain your value flow diagram (in nominal terms), discount rate and reference year for present value calculations, conversion factors to determine NPV of items in your task list, and the resulting NPV using working values of decision variables. Determine and explain whether you should pursue this version of your project with a MARR of 15%, and what the IRR of your project is. Highlight any new decision variables. Refer to the instructions for Week 9 to ensure that you have included your complete NPV model and all TVM considerations.

1. Risk Management (maximum 600 words)

Summarize the results of Design Studio Week 10’s risk management. Include and explain your risk matrix, plans to deal with the 3 most critical risks, and how you updated the task list and NVF to include the impact of risk. Highlight any new decision variables and random variables, and any parameters replaced with probability distributions. Explain how you converted the NVF into a stochastic model, converted this into a draft deterministic model for later improvements and optimization, and report the NPV of your project at the working set of input decision variables according to your draft deterministic model. Refer to the instructions for Week 10 to ensure that you have included your entire risk management plan.

The structure of the *final* Complex Report should be as follows:

Contribution List - List each team member and their sections they take responsibility for.

1. Change Log

Include a table identifying the changes made since the draft submission of the Complex Report. The table should have the following structure. For the type of change, identify if the change was an addition, deletion, or revision.

* Change Number
* Type: Identify if the change was an addition, deletion, or revision.
* Source of the Change: Identify why the change was needed (e.g. feedback from TA, group discussion, etc.)
* Original: Original version of the text (prior to the change)
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Part 1: Simple Report

1. (Include all sections of the Simple Report)
2. (Sections already marked twice will not be re-marked in detail at this stage, but if you change them in light of future information you should still identify changes in the change log)

Part 2: Project Management, TVM, and Risk

1. Project Plan
2. NPV
3. Risk Management
4. Stochastic Sensitivity Analysis (maximum 600 words)

Summarize the results of Design Studio Week 11's re-optimizing the final version of your NVF that includes project planning, time value of money, and risk management. Include and explain how you converted the stochastic model into an updated deterministic one, and the results of optimizing the deterministic model, along with any iterations to this process (i.e., developing a new deterministic model around the first iteration's optimum decision variable values and re-optimizing). Include and explain how you determined the final expected NPV for the stochastic model using the optimum input decision variables, its standard deviation, and the likelihood the project has a positive NPV.

1. Final Recommendations (maximum 300 words)

Describe your iterative process of optimizing and assessing the potential economic viability of this project and summarize your changes leading to your final design. Discuss how and why your results from the Simple Report are different from your results now. Summarize your key finding - What is the best your solution could do, and should you pursue it?

## Complex Report Rubric

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Category | Level 0 | Level 1 | Level 2 | Level 3 | Level 4 |
| Simple Report - Optimization (X/10) | * No clear identification or discussion of optimization setup, methods, or results. | * Objective function and/or constraints identified are not reasonable or improperly formulated. * Relevant errors in optimization. Linear program incorrectly stated. No interpretable results. | * Objective function and/or constraints are properly formulated. * Linearization is described (if required). * Many assumptions are valid and described. * Results of optimization are not interpreted, and no conclusions are made. | * Objective function and constraints are properly formulated, well justified, and all assumptions are stated. * Function correctly linearized (if required). * Discussion on optimized variables included. | * Objective function and constraints are correctly formulated, well justified, and all assumptions are stated. * Function correctly linearized (if required). * Results are thoughtfully discussed and analyzed. * Implementation and relevance to the NVF and the overall project is made exceedingly clear. |
| Simple Report - Final Design (X/5) | * No summary attempted. | * Limited conclusions with errors in judgements and misleading summary. | * Some relevant findings are included. * Weak discussion or poor presentations of results. | * Clear explanation of relevant findings. * Logical presentation of results with minor gaps. | * Clear explanation of relevant findings. * Logical and professional interpretation of results. * Written with a high technical knowledge. |
| Change Log (X/2) | * Section missing. | * Section does not describe changes implemented. | * Section inadequately defines changes implemented. | * Changes clearly defined. | * Changes clearly defined and presented in an organized and precise manner. |
| Project Plan (X/10) | * WBS, CPM, and task list, are not included in the submission and are not explained. * NV impact missing or incomplete for most tasks. | * WBS, CPM, or task list, is missing or incomplete. * Lacks explanation. * NV impact missing or incomplete for many tasks. | * Includes WBS, CPM, and task list, describing the set of tasks required to bring solution to market. * Missing tasks related to decommissioning solution. * Explanation of WBS CPM, and task list is limited. * NV impact missing or incomplete for some tasks. * WBS bottom level includes less than 10 subtasks | * Includes and explains WBS, CPM, and task list, describing the set of tasks required to bring solution to market and decommission it at the end of its lifecycle. * Each task’s NV impact is included and stated in nominal terms. Some effort to reconcile with previous NVF. * WBS bottom level includes 10-20 subtasks. | * Includes and thoroughly explains WBS, CPM, and task list, describing the complete set of tasks required to bring solution to market and decommission it at the end of its lifecycle. * Each task’s NV impact is included and stated in nominal terms, and reconciled with previous NVF. * WBS bottom level includes 10-20 subtasks, that are spread out over the lifecycle of the project. |
| NPV (X/10) | * Value flow diagram is not included. * Discount rate is not stated. * Reference year and TMV-conversion factors are not stated. * NPV is missing. * IRR is not determined OR a description of why the IRR couldn’t be determined is not included. * Explanation on whether the project should be pursued with a 15% MARR is missing. | * Value flow diagram is included but incomplete. * Discount rate is not stated. * Reference year and TMV-conversion factors are not stated or are incorrect. * NPV is included but is incomplete. * IRR is not determined OR a description of why the IRR couldn’t be determined is not included. * Explanation on whether the project should be pursued with a 15% MARR is missing. | * Value flow diagram is included with some of the value impacts that were identified in the Project Plan. * Discount rate is not explicitly stated. * Reference year and TMV-conversion factors are not clearly stated. * NPV is included and contains working decision variable values. * IRR is determined, OR a description of why the IRR couldn’t be determined is included. * Explanation on whether the project should be pursued with a 15% MARR is unclear. | * Value flow diagram is included and complete with most the value impacts that were identified in the Project Plan. * Discount rate is explicitly stated. * Reference year and TMV-conversion factors are stated. * NPV is included and contains working decision variable values. * IRR is determined for project’s timeline, OR a description of why the IRR couldn’t be determined is included. * Explanation on whether the project should be pursued with a 15% MARR is present. | * Value flow diagram is included and complete with all the value impacts that were identified in the Project Plan. * Discount rate is explicitly stated and justified. * Reference year and TMV-conversion factors are stated and explained. * NPV is included and contains working decision variable values. * Any new decision variables are highlighted. * IRR is determined for project’s timeline, OR a detailed description of why the IRR couldn’t be determined is included. * Explanation on whether the project should be pursued with a 15% MARR is present and justified. |
| Risk Management (X/10) | * No risk matrix presented. * No risks are discussed, and mitigation strategies are incomplete. * Updated NVF is not presented. * Stochastic and draft deterministic model not correctly developed | * Incomplete or inappropriate risk matrix presented. * Less than 3 risks are discussed, and mitigation strategies are incomplete. * Updated NVF is not presented. * Stochastic and draft deterministic model not correctly developed. | * Risk matrix presents an overview of various risks the project may encounter. * At least 3 risks are discussed, and mitigation strategies are presented. * Updated NVF is not presented. * Stochastic and draft deterministic model presented. * NV estimate is stated. | * Risk matrix presents an overview of various risks the project may encounter. * At least 3 critical risks are discussed with reference to the task list and NVF and mitigation strategies are presented. * Updated NVF is presented with emphasis on new variables/parameters and their associated probabilities. * Stochastic and draft deterministic model presented. * NV estimate and working set of decision variables are stated. | * Risk matrix presents a comprehensive overview of various risks the project may encounter. * At least 3 critical risks are discussed with reference to the task list and NVF and mitigation strategies are presented with their associated costs. * Updated NVF is presented with emphasis on new variables/parameters and their associated probabilities. * Stochastic and draft deterministic model presented (uses a set of random values with their expected values to determine rough NV estimate). * NV estimate and working set of decision variables are clearly stated. |
| Stochastic Sensitivity Analysis (X/10) (Final report only) | * Re-optimized version of NVF is not included. * Stochastic and deterministic model not presented. * Results of optimizing the deterministic model are missing. * Missing or largely incomplete or incorrect explanation of the final expected NPV, its standard deviation, or the likelihood the project has a positive NPV. | * Re-optimized version of NVF is included but project planning, time value of money, or risk management are not adequately incorporated. * Stochastic and deterministic model presented with no explanation of how the stochastic model was converted to an updated deterministic model. * Results of optimizing the deterministic model are incomplete or missing. * Iterations of the process of optimizing the deterministic model are not explained. * Somewhat incomplete explanation of the final expected NPV, its standard deviation, or the likelihood the project has a positive NPV. | * Re-optimized version of NVF that includes most of the identified project planning, time value of money, and risk management is included. * Stochastic and deterministic models are presented with an unclear explanation of how the stochastic model was converted to an updated deterministic model. * Results of optimizing the deterministic model are included. * Iterations of the process of optimizing the deterministic model are not well explained. * Unclear description of how the final expected NPV for the stochastic model was determined using the optimum input decision variables, or how its standard deviation or the likelihood the project has a positive NPV was determined. | * Re-optimized version of NVF that includes project planning, time value of money, and risk management is included and explained. * Stochastic and deterministic models are presented with an explanation of how the stochastic model was converted to an updated deterministic model. * Results of optimizing the deterministic model are included and explained. * Any iterations of the process of optimizing the deterministic model are included and explained. * Presents and explains the final expected NPV for the stochastic model (and how it was determined using the optimum input decision variables), its standard deviation, and the likelihood the project has a positive NPV. | * Re-optimized version of NVF that includes project planning, time value of money, and risk management is included and clearly explained. * Stochastic and deterministic models are presented with a clear explanation of how the stochastic model was converted to an updated deterministic model. * Results of optimizing the deterministic model are included and explained. * Any iterations of the process of optimizing the deterministic model are included and explained. * Presents the final expected NPV for the stochastic model (and a clear and informative explanation of how it was determined using the optimum input decision variables), its standard deviation, and the likelihood the project has a positive NPV. |
| Final Recommendations (X/5) (Final report only) | * Optimization iteration is not described. * Economic viability and final design are not included. * No findings, comparisons, nor recommendations are presented. | * Optimization iteration is not well described. * Economic viability and final design lack detail. * Complex report results are not well discussed and not compared with the Simple report. * Key findings are summarized, but no future recommendations are presented. | * Optimization iteration is described. * Economic viability and final design are included. * Complex report results are discussed but not compared with the Simple report. * Key findings are summarized, but no future recommendations are presented. | * Clear description of iterative processes taken to optimize the NVF. * Economic viability and final design are correctly presented. * Comparison between the Simple and Complex report results are discussed. * Key findings are summarized with next steps for the project. | * Clear and informative description of iterative processes taken to optimize the NVF. * Economic viability and final design are stated in a logical and professional manner. * Comparison between the Simple and Complex report results are discussed and provide key insights on impact of various analyses performed. * Key findings are systematically summarized with future recommendations for the project. |
| Report Format and Content (X/5) | * Major issue that impacts readability of the report, such as corrupted file submitted. | * Not all required content is available in the report. * Poor formatting. | * Minor issues with formatting, font type/size OR images either not labelled/not referenced in the text. | * No minor issues in the formatting of the report and all required content are included. | * Sections divided and presented professionally. * Figures and tables are clear and relevant, with captions. * References follow IEEE formatting. |
| Technical Writing Quality (X/5) | * Report difficult to read, lack logical progression, or major errors in grammar and structure. | * Poorly written (e.g., run-on sentences, sentence structure, repeats information, spelling, or grammar errors present). | * Inadequate use of technical language. * Frequent changes in voice, tense, or tone. | * Well written. * Ideas presented in a logical sequence. | * Sections are cohesive and easily relate to each other through logical transitions. * Terminology and sentence structure across sections are consistent. |

# 10. Team Interviews (4%, 8%)

Team interviews will be performed by one TA/IAI per group. Group members will be marked individually. Interviews will take place in Design Studio Weeks #9 and #13. They will follow the submission of the simple and Complex Reports. Each interview will be scheduled for 20 minutes. TA’s will ask students a total of 2-3 questions from the following question bank per student.

Team Interview #1

1. Idea Generation
   * What is the problem you are addressing? Why is it important?
   * What are the design criteria and constraints of the problem?
   * Who or what does the current problem affect?
   * What are the current solutions to the problem?
2. Solution Design
   * What assumptions did you make when designing your solution?
   * What constraints limit your solution?
   * What is the objective of your solution?
   * What defines success in your solution?
   * Who are the stakeholders in the project?
   * What was your selected technical analysis of your solution? How did you perform this?
3. Net Value Functions
   * Describe your NVF and the conversion factors it contains.
   * Which terms were omitted from your NVF? Why?
   * What is the size of your market? How did this affect your design and NVF?
   * How did you set the price of your solution?
   * How did you determine which environmental considerations to include? How did they affect your design and NVF?
   * How did you determine which ethical considerations to include? How did they affect your design and NVF?
   * What regulatory requirements did you consider? How did they affect your design and NVF?
   * How did you determine which EDI considerations to include? How did they affect your design and NVF?
   * What were the results of your NVF?
4. Technical Analysis
   * Describe your chosen design parameters and performance parameters.
   * How did you perform your technical analysis and why impact did it have on your solution design?
   * What were the results of your technical analysis? How did this affect your design?
   * How did your NVF change based on the results of your technical analysis?
5. Sensitivity Analysis
   * Describe the steps of your sensitivity analysis.
   * How did you determine the possible ranges of parameters? What were they?
   * What were the results of your sensitivity analysis? How did this affect your design?
   * Which parameters were the most/least sensitive? Why?
6. Optimization
   * Describe the steps of your optimization.
   * What were your assumptions? How did this affect your model?
   * What constraints did you use in your model? How did you select these values?
   * Which optimization method did you use and why?
   * What were the results of your analysis? How did this affect your design?

Team Interview #2

1. Project Management
   * Describe an example of a task included in your WBS. How did you identify the tasks?
   * Describe a key phase in the lifecycle of your design.
   * Which key resources were required to complete the identified tasks?
   * Which task has the largest cost (i.e. value impact)? How does this impact your design?
   * Describe an example of an internal relationship in your node network diagram.
   * What is the critical path of the project? Why is this important?
2. Net Value Functions with Time Value of Money
   * What is the lifespan of your solution?
   * How did you create your value flow diagram? What information did the diagram describe?
   * What discount rate did you choose? Why?
   * Describe a TVM conversion factor you considered.
   * What is the payback period of the project? How did you determine if this is reasonable?
   * What is the rate of return of the project? How was it determined?
   * Where can you improve the financial performance of the project?
3. Risk Management
   * What are the critical project risks? How do they affect your solution?
   * What were the mitigation strategies proposed for your 3 most critical risks?
   * What assumptions were you required to make in risk analysis?
   * Which risk has the largest NV impact? Why is that relevant?
   * How did you determine the likelihood of risks in your risk matrix?
4. Stochastic Sensitivity Analysis
   * Describe the steps you took to perform the Monte Carlo simulation. What were the results?
   * How did you convert the stochastic model into a deterministic one?
   * Which set of decision variable values maximized your expected NPV? Is this what you expected?
   * What level of uncertainty did you implement? Why?
   * How did you model stochastic uncertainty?
   * Do you expect your project to be successful. Why?
   * How did the results of your simulation affect your decision variable values?
5. Conclusions
   * What are the next steps of your solution?
   * What unexpected challenges did you face in this project? How did you solve them?
   * What would you change about the project if you could do it again?

## Team Interview Rubric

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Category | Level 0 | Level 1 | Level 2 | Level 3 | Level 4 |
| Knowledge (X/1) | No questions answered. | Individual expressed a clear lack of knowledge and participation in the project. | Individual expressed a working knowledge of the project and its connections to course content. | Individual expressed a clear and sufficient understanding of the project, the current progress, and next steps. | Individual expressed a clear and knowledgeable understanding of the formulated problem, the designed solution, and the applications of course content. Connections were made to real-world problems and significance of analysis. |
| Delivery (X/0.25) | No attempted answers. | Incorrect responses with no justification. | Answers most questions appropriately. | Appropriately answers questions and provides justification. | Answers all questions confidently, accurately, and without hesitation. |

# 11. Design Project Self-Reflection (3%)

Due 11:59 pm on the night *after* Design Studio Week 12.

|  |
| --- |
| Course Learning Outcomes that will be focused upon for the reflection assignment:   1. Utilize economic principles to make decisions in engineering projects. 2. Formulate Net Value functions to evaluate and compare the value and cost of alternative engineering decisions. 3. Make reasonable assumptions or perform necessary research to cope with ambiguity and uncertainty in required tasks. 4. Apply the fundamentals of cost, price, present value, and other financial metrics. 5. Manage group projects and interpersonal relations, especially building project management skills, preparing agendas, and diagnosing team dynamics. 6. Professionally communicate complex decisions following an economic analysis. |

Write a reflection that addresses each of the prompts below. Please consider the Design Project in your reflections. (Length 400 – 600 words + ILO Survey).

**Description**

* What was your Design Project about?
* Who did you work with? What were your contributions?
* What were your group members’ contributions?

**Feelings**

* What did you hope to gain from this project?
* Did you feel equipped to take on this project? Why or why not?
* Do you feel the Design Studios and lectures help you to take on this project? Why or why not?

**Evaluation**

* How did it go? What was your initial reaction to the experience?
* Did this experience meet your expectations? Why or why not?
* What do you think went well?
* What do you think could be improved upon for next time?
* How did the 3PX3 course help you to be prepared for the Design Project?

**Analysis**

* What past experiences helped equip you for this experience?
* Regarding the Intended Learning Outcomes (ILO) of the course, how did this experience bring you closer to achieving these outcomes?
  + Is there an ILO that this experience helped to achieve? Which one? Why or why not?
  + Is there a particular ILO that this experience did not help as much as you expected? Which one? Why or why not?

**Conclusion**

* What skills/techniques employed during this experience do you find valuable and useful for future experiences (either similar or different to this experience)?
* If you had to work on this project again, what would you do differently or similarly?

|  |
| --- |
| Our Design Project focused on exploring prefab housing automation as a potential solution to address the housing shortage in Ontario. I worked with Karol Lukowski, Dexter Holst, and Liam Walker on this project. My main contributions included looking at the automation software for embedded systems to control the robots, creating a detailed Net Value Function (NVF), and determining conversion factors. Karol worked on technical analysis overview and risk management. Liam focused on sensitivity analysis and final recommendations, while Dexter worked on the change log, solution comparison, optimization, and Net Present Value (NPV).  Through this project, I hoped to gain a deeper understanding of how to apply economic principles such as sensitivity analysis, NPV, and financial analysis to evaluate the feasibility of an engineering solution for prefab housing automation. However, I didn't feel fully equipped for this project since it was a completely different topic than I had worked on before. My experience was mainly in software-as-a-product service, so working on embedded systems and software for a civil-based project provided a limited scope. The lectures provided a good introduction to economic concepts, but they didn't significantly help with the software analysis for the project, as prefab housing mainly concerns mechatronics and civil engineering, which were the other team members' disciplines.  Due to health-specific reasons, I wasn't able to participate in many design studio sessions, making it difficult to contribute meaningfully to the project. Despite this, I think the project went well overall, as Karol, Dexter, and Liam seemed very passionate about it. I tried to ask how I could help, but often found it challenging to grasp my full usefulness within the project's scope. I understand this may affect my grade, but ultimately, I wanted to learn more about economics, even though I have yet to find these concepts directly applicable.  I did find that learning about the NVF helped encapsulate the problem definition and scope. I believe I can make reasonable assumptions and perform necessary research to cope with ambiguity in required tasks, as well as apply some fundamentals of cost, price, and present value in the Intended Learning Outcome (ILO) metrics that I achieved. However, I realized that I couldn't fully utilize economic principles to make decisions because I lacked sufficient technical knowledge in civil and mechatronics aspects, making it difficult to apply what we learned in class.  In conclusion, while I faced challenges in contributing to the project due to my limited expertise in the specific domain, I still gained valuable insights into applying economic principles and financial analysis to evaluate engineering solutions. I appreciate the opportunity to work with a diverse team and learn from their knowledge in different disciplines. Moving forward, I would seek out projects that better align with my software background to more effectively apply the concepts learned in this course. |

**ILO Survey:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***To what extent have you achieved the Intended Learning Outcome of the course? (Mark an X)*** | Strongly disagree | Disagree | Neither agree nor disagree | Agree | Strongly agree |
| I can utilize economic principles to make decisions in engineering projects. |  | x |  |  |  |
| I can formulate Net Value functions to evaluate and compare the value and cost of alternative engineering decisions. |  |  |  | x |  |
| I can make reasonable assumptions or perform necessary research to cope with ambiguity and uncertainty in required tasks. |  |  | x |  |  |
| I can apply the fundamentals of cost, price, present value, and other financial metrics. |  |  |  | x |  |
| I can manage group projects and interpersonal relations, especially building project management skills, preparing agendas, and diagnosing team dynamics. |  |  | x |  |  |
| I can professionally communicate complex engineering decisions following an economic analysis. |  |  | x |  |  |

## Self-Reflection Rubric

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Level 0 | Level 1 | Level 2 | Level 3 | Level 4 |
| Description  (0.25/5) | No description of the project is given. | Description of the project does not include personal perspective. | Description of the project is thorough, but it is written in a poor, confusing, or vague manner. | Description of the project is thorough and well written. It includes responsibilities, contributions, others’ contributions, and goal. |  |
| Feelings  (0.5/5) | No description of thoughts and feelings was given. | Description of thoughts and feelings is surface level and does not contribute to personal reflection. | Description of thoughts and feelings is thorough, but it is written in a poor, confusing, or vague manner or does not contribute to personal reflection. | Description of thoughts and feelings is thorough, well written and contributes to personal reflection. The section does not consider expectations or earlier experiences in the course. | Description of thoughts and feelings is thorough, meaningful, well written and contributes to personal reflection. It includes feelings at the beginning of the project, expectations and mentions the inputs of earlier experiences in the course. |
| Evaluation  (1/5) | No evaluation of what was positive and negative was given. | Evaluation of what was positive and negative is surface level and does not contribute to personal reflection. | Evaluation of what was positive and negative about the experience is thorough, but it is written in a poor, confusing, or vague manner or does not contribute to personal reflection. | Evaluation of what was positive and negative about the experience is thorough, well written and contribute to personal reflection. The section does not consider expectations or aspects of 3PX3 course that helped in prepared students. | Evaluation of what was positive and negative about the experience is thorough, meaningful, well written and contributes to personal reflection. It includes expectations, positive aspects, aspects that could be improved and aspects of 3PX3 course that helped in prepare students. |
| Analysis  (1/5) | No analysis of what was positive and negative was given. | Analysis is surface level and does not contribute to personal reflection. | Analysis is meaningful and thoughtful, but it is written in a poor, confusing, or vague manner or does not contribute to personal reflection. | Analysis is meaningful and thoughtful, well written and contributes to personal reflection. The section does not consider past experiences or clear reference to the ILOs | Includes meaningful and thoughtful analysis from the student’s experience, is well written, and contributes to personal reflection. It includes students’ past experiences and clear reference to the ILOs, reflecting on those that helped the most and those that did not helped as much as the student expected. |
| Conclusion  (1/5) | No reflection on what student learned from the experience was given. | Reflection on what was learned is surface level and does not contribute to personal reflection. | Reflection on what was learned is meaningful and thorough, but it is written in a poor, confusing, or vague manner or does not contribute to personal reflection. | Reflection on what was learned is meaningful and thorough, well written and contributes to personal reflection. The section does not consider valuable skills/techniques or what student would do similarly or different in the future. | Meaningful reflection on what the student learned from the experience, is well written, and contributes to personal reflection. It includes valuable skills/techniques for future activities, what student would do similarly or different. |
| Writing/  Grammar  (1/5) | Awkward sentences, repetitive. Numerous errors that make the essay difficult to understand. | Many errors in grammar, spelling, and mechanics. | Most sentences are well constructed. Few errors in grammar, spelling, and mechanics. | Well-constructed sentences, few errors in grammar, spelling, and mechanics. | Well-constructed sentences, no errors in grammar, spelling, and mechanics. |
| Survey (0.25/5) | Did Not Complete Survey |  |  |  | Completed Survey |

|  |  |
| --- | --- |
| List of Penalties: | Deduction |
| Late submission | -20% per day |
| More than XX words or less than YY words | -10% per 50 words |