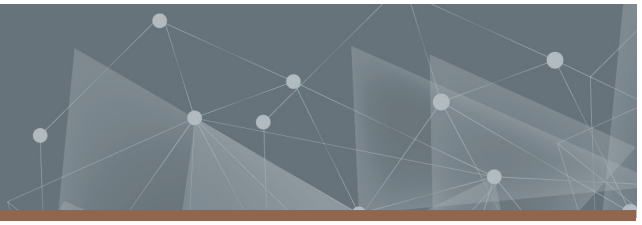
CHALMERS



Simulation game for training employees at Philips Domestic Appliances in the new simplified product development process

Master's thesis in Product Development

RAHUL GOPINATH

DEPARTMENT OF INDUSTRIAL AND MATERIALS SCIENCE

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2021
www.chalmers.se

Master's thesis 2021

Simulation game for training employees at Philips Domestic Appliances in the new simplified product development process

RAHUL GOPINATH

CHALMERS
UNIVERSITY OF TECHNOLOGY

Department of Industrial and Materials Science
Division of Product Development
Chalmers University of Technology
Gothenburg, Sweden 2021

Simulation game for training employees at Philips Domestic Appliances in product development process

RAHUL GOPINATH

Supervisor: Ms. Suzanne van Egmond, Philips Domestic Appliances
Dr. Göran Gustafsson, Chalmers University of Technology

Examiner: Professor Johan Malmqvist, Department of Industrial and Materials Science

Master's Thesis 2021
Department of Industrial and Materials Science
Division of Product Development
Chalmers University of Technology
SE-412 96 Gothenburg
Telephone +46 31 772 1000

Typeset in LaTeX
Printed by Chalmers Reproservice
Gothenburg, Sweden 2021

Abstract

This report presents a master thesis on the development of a simulation game, in collaboration with Philips Domestic Appliances. The objective of the thesis was to develop a simulation game to help train the employees at Philips Domestic appliances to the new product development process and to help them attain the right direction and mindset required for the new development process.

Throughout the development process of the simulation game, different methods and techniques were used to generate and eliminate the concepts. A few concepts made it to the top. The final concept was developed in detail, and a few iterations of the game concept were run to make it better. The final concept was called the "Skyscraper Game", which is based on the idea of developing a product. The game revolved around a team of 3 to 5 members running the pre-development activities required to take a few decisions to help a major builder build a Skyscraper. The thesis resulted in a promising game that still requires a bit more polishing around the edges, which can be sorted by running a few more iterations of the game.

Keywords: simulation game, weighted shortest job first, decision logic, learning cycle, learning plan, time boxing, repository cards.

Acknowledgements

Above all, two people have helped me hugely during this thesis project. These people are Ms. Suzanne van Egmond, the representative from Philips Domestic Appliance, and Dr. Göran Gustafsson, my supervisor from Chalmers. They have both been very helpful throughout the entire project, and without their inputs, the project would not have achieved desired results. I would like to thank the volunteers from Chalmers and Philips for their help in the testing and for providing valuable feedback. And lastly, I thank Professor Johan Malmqvist and Philips Domestic Appliances for facilitating the project and for all their support.

Contents

1 Introduction **1**
- 1.1 Project Background . . . 1
- 1.2 Mission and Goal . . . 2
- 1.3 Scope . . . 2

2 Background **3**
- 2.1 Company Background . . . 3
- 2.2 Simplified Product Development Process . . . 3
  - 2.2.1 FFE: Fuzzy Front End . . . 4
  - 2.2.2 S-AD: Simplified- Advanced Development . . . 6
- 2.3 Process Breakdown . . . 7
  - 2.3.1 Time-Box . . . 7
  - 2.3.2 Rapid Learning Cycles . . . 8
  - 2.3.3 Decisions at the Last Responsible Moment . . . 8

3 Process Analysis **11**
- 3.1 Learning Objectives . . . 11
- 3.2 Requirements . . . 13

4 Concept Generation and Evaluation **17**
- 4.1 Concept Generation . . . 17
- 4.2 Concept Evaluation . . . 19
  - 4.2.1 0th iteration . . . 19
  - 4.2.2 Game Concepts . . . 20
    - 4.2.2.1 Not The Same Old Monopoly Game . . . 20
    - 4.2.2.2 The Skyscraper Game . . . 21
    - 4.2.2.3 Logic Puzzle . . . 22
    - 4.2.2.4 The Mini Project . . . 23
    - 4.2.2.5 The Flying Machines . . . 23
    - 4.2.2.6 The Boring Case Study . . . 24
  - 4.2.3 1st iteration . . . 25
  - 4.2.4 2nd Iteration . . . 26

5 Detailed Design **29**
- 5.1 Game Platform . . . 29
- 5.2 Game Setup Layout . . . 29
- 5.3 Instructions Tab . . . 29

5.3.1 Decision and Decision Logic . . . 31
5.3.2 Knowledge Gaps . . . 32
5.3.3 Repository Cards . . . 32
5.3.4 Learning Plan . . . 33
5.3.5 Execute the Plan . . . 34
5.4 Concept Tab . . . 35
5.4.1 Surface Knowledge Gaps . . . 35
5.4.2 Weighted Shortest Job First . . . 36
5.4.3 Learning Cycle with Time-Box . . . 36
5.4.4 Decision at the Last Responsible Moment . . . 36
5.5 The Game Body . . . 37
5.5.1 Decision and Decision Logic . . . 37
5.5.2 Brainstorm and Prioritize Knowledge Gaps . . . 38
5.5.3 Match with Repository Cards . . . 39
5.5.4 Learning Plan and Learning Cycle . . . 39
5.5.5 Execute the Learning Plan . . . 40
5.6 Repository Cards . . . 41
5.6.1 Surveys and Graphs . . . 41
5.6.2 Newspaper Articles . . . 43
5.6.3 General Information . . . 45
5.6.4 Tests and Calculations . . . 46
5.6.5 Government Notices . . . 48
5.7 Summary Slide . . . 50

6 Testing **51**
6.1 Initial Test and its Findings . . . 51
6.1.1 Improvements and Changes . . . 52
6.2 Final Test and its Findings . . . 53
6.2.1 Improvements and Changes . . . 53

7 Discussion **55**
7.1 Results . . . 55
7.2 Limitations . . . 55

8 Recommendation **57**
8.1 Further Development . . . 57

9 Conclusion **59**
9.1 The Simulation Game . . . 59
9.2 The Company . . . 59

Bibliography **61**

A Repository Cards **I**

1
Introduction

This report presents the work carried out during the Master thesis in the *Product Development* program at Chalmers University of Technology. It was carried out in collaboration with Philips Domestic Appliances, Netherlands. The thesis was affected by the Covid-19 pandemic, forcing limitations on the thesis work. The report includes the background of the project, the work that has been carried out, and the results and conclusions.

1.1 Project Background

Over the past decade or two, the consumer market has changed drastically; more and more companies have entered the market aiming for a higher share and profits. That has made the consumer market very competitive, and this called for better product development techniques for waste elimination and an efficient way of using resources. A lot of research has been put towards this cause in the last couple of years to study product development patterns in the industry and develop techniques or ways of working to achieve the goal of efficient product development.

Philips Domestic Appliances has been working with traditional methods of product development and is in course to launch their new simplified product development process that boasts a more efficient way of developing products using lean product development techniques. The new process involves the use of multiple concepts that required the right mindset and way of working to reap the maximum advantages. With this, there remained a question on how to train the employees to attain this mindset required for this new development process. This brings us to the reason behind this thesis, to help the users of the process understand the different concepts involved, and attain the right direction and mindset required for it.

The training approach put forward was a 'Simulation Game'. To develop a fun and interesting game that the employees can play to simulate the new development process and understand it better to learn the right mindset and way of working required for it. As part of the thesis, the simplified product development process must be studied, broken down into different concepts, and analyzed to extract the mindsets and ways of working related to it. This thesis focuses on designing a simulation game that can successfully train the employees in these concepts and mindsets. An exact path to reach it is not specified, but a few requirements set by Philips DA were,

1. The game must be designed to be run online, but with a possibility to be run offline as well
2. The total game time must be below 3 hours

1.2 Mission and Goal

The thesis was set to pursue the mission of developing the apt game for the employees at Philips Domestic Appliances by abiding with the requirements set by Philips themself. The most effective way to attain this was found to be, breaking down the product development process and understanding each of the concepts involved. Each of these concepts has a particular working mindset that was needed to be studied as well. Ultimately, the goal was to develop a simulation game that included most of the concepts, with the ability to convey them in the most fun and exciting way without losing the employees' interest.

1.3 Scope

To achieve the mission of the thesis, several directions are possible to choose from. However, due to requests by the company and to avoid increased complexity of the simulation game, and overlapping with other training happening within Philips, a scope had to be set. Also, lean product development is more visible at the front end of the development process, so the scope of the thesis project was limited to a part of the whole product development process.
It was decided the game would cover the phases:

- FEE- Fuzzy Front-End
- S-AD- Simplified- Advanced Development

Concepts for these two areas, i.e., from the start of FEE to the end of S-AD, are explored in this thesis. The primary scope was to start with breaking down the concepts from each of the areas and study them to develop ideas to stimulate them in the game.

2
Background

This chapter explains in detail the product development process that the thesis is dealing with, and its breakdown into different concepts. It also presents the background of the mission holder Philips Domestic Appliances and their products.

2.1 Company Background

Philips Domestic Appliances started as a division of Koninklijke Philips N.V. or the Royal Philips. Philips was founded by Gerard Philips and his father Frederik in 1891 and is headquartered in Amsterdam, the Netherlands. It currently employs around 80,000 people across 100 countries. Philips was formerly one of the largest electronics companies in the world. Currently, they have shifted their focus to health care technology, resulting in the divesting of their other divisions [1].

Philips Domestic Appliances is one of the other divisions that got divested by Philips. In September 2021, the Domestic Appliances was sold off to Hill House Capital Group, an Asia-focused private equity firm. They were also a long-time investor for Philips Domestic Appliances. The total deal value was EUR 4.4 billion with a 15-year brand license agreement to use the Philips brand and certain of Philips' other Domestic Appliances brands for manufacturing, sales, and marketing of Domestic Appliances products globally. The domestic appliances division has around 7000 employees globally. They focus on kitchen, coffee, garment care, and home care appliances. Its successful products include the Airfryer, Fully Automatic Espresso Machine with LatteGo, Perfect Care Elite Steam Generator, Air Purifier, and Speed-Pro Max Vacuum Cleaner. In 2020, Philips Domestic Appliances recorded a sale of EUR 2.2 billion, making it one of the global leaders in domestic appliances [2].

2.2 Simplified Product Development Process

The current development process that Philips is using has many gates and milestones. It also includes several deliverables and documentation the employees are required to do at each of these gates and milestones. That required longer man-hours and was slowing the development process. Philips felt that the process could be more streamlined and simplified to make it more efficient, and for the process to develop better products at a faster pace. With the Domestic Appliances division divested from its parent company Philips, they saw an opportunity to simplify the product development process. The reasons being,

1. With the Domestic Appliances division divested, they would have fewer people to maintain their processes.
2. Lean product development has hardly been a driving principle for the processes.
3. The divesting from Philips, now a health care focused company, opened an opportunity to simplify the processes.

The simplified development process uses the same framework as the older development process. The new process has reduced the number of gates and deliverables, nothing more or nothing less than what is needed. There is minimal documentation that is much clearer and concise, it is easy to make and maintain. The process is logical and simple to follow, with a clear alignment of project goals. The new process will make sure that the work will be compliant with relevant norms and regulations, like ISO 9001 for example. The process overall will prove to be more efficient than the older process while being simple and less time-consuming. Once it is launched, Philips aims to push for continuous improvement of its processes based on the users' feedback.

The new process is built upon a few guiding principles for making it leaner. These principles form the base of each concept used in the new development process.

1. **Learn most when cost of change is low**
   - Push learning towards early stages of development process
   - Smooth low-risk realization
2. **Make decisions based on knowledge**
   - Narrow down options based on knowledge
   - Push decisions to the "last responsible moment"
3. **Create more alternatives**
   - Set-based: create alternatives at sub system level
   - Drop weaker alternatives, do not choose the strongest one
   - Ensure optimization at system level
4. **Work time-boxed in early stages of development process**
   - Agile ways of working, such as rapid learning cycles, to maximize the learning

In this thesis, we will be dealing with only a part of the whole development process. We will study in detail from the start of FFE to the end of S-AD. Also, the concepts from these will be discussed in detail.

2.2.1 FFE: Fuzzy Front End

The fuzzy front end is the first part of the simplified development process, it is a set of 'exploration' activities which are performed before starting the formal product development process. With this part of the process, the aim is to identify the direction for achieving the harmonious balance between the consumer need, technology options, and business requirements. FFE is to mature an idea through the exploration to find this harmonious balance between the three. Figure 2.1 shows the fuzzy

front end of the development process. ES- exploration start and EE- exploration end are the milestones in the process.

Figure 2.1: Fuzzy Front End

The process starts with project kick-off. In this initial stage, the organization forms a team based on the requirement of the project. The goal for the project is set, and an initial value proposition is carried out to answer the need for the project. Next, the team decides the scope and size of the exploration needed. That helps the team to understand the direction of the project. A decision logic for the project and a learning plan which lists the knowledge gaps that were identified based on priority are created.

Right after the 'ES'- exploration start milestone, the next stage of the FFE is exploration. Here, the team tries to identify a harmonious balance between the consumer needs, business requirements, and technology options. These explorations are carried out asynchronously. The team relies on learning cycles to gain the knowledge required for it and try to surface the unknowns through it. The knowledge gaps are the knowledge that the team requires to make the decisions. The learning cycle is a method of doing this learning in iteration to close the knowledge gaps. Then, this learning is integrated into the plan after each cycle to take the decisions. That gives way to obtaining multiple options for the project, and decisions on the selection are made based on the knowledge gained through the learning cycle. The team tries to mature the options for the project, and the decision on selecting an option is kept for later.

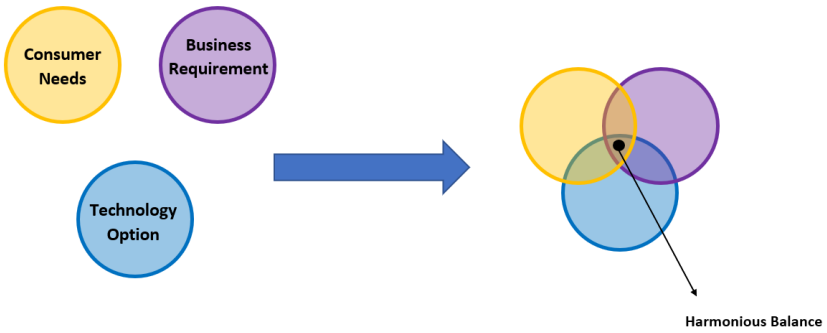


Figure 2.2: Harmonious balance between consumer need, business requirement, and technology option

With that, we reach EE- exploration end milestone. By then, the team should be ready for the project, and they have understood the direction to achieve the harmonious balance. At this stage, the team may be redefined to include critical competencies required for the project. The decision logic and learning plan are updated, and the initial requirements are understood. Also, after the exploration end milestone, the team creates a clear alignment with key stakeholders.

2.2.2 S-AD: Simplified- Advanced Development

The simplified- advanced development is the second part of the simplified product development process. It is a simplified version of the advanced development in their old process. At this stage, the team develops the product to move it from the concept phase to the embodiment phase. Figure 2.3 shows the simplified- advanced development part of the development process, where PI- project initiated, PP- principle proven, and FP- function proven are the milestones.

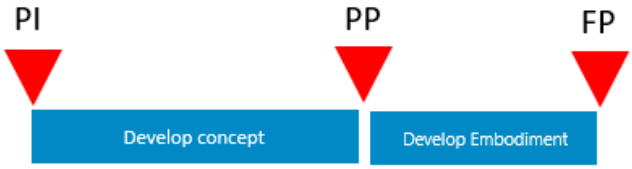


Figure 2.3: Simplified- Advanced Development

The first milestone of the S-AD process is the PI- project initiated, before which the team works to surface the known unknowns. A learning plan is also created based on the priority of the knowledge gaps. In S-AD, they try to further develop the options and look for feasible technologies.

After PI, in the 'develop concept' stage, the team develops the product concept from the knowledge and direction of the technology identified in the previous stages and proves it works. The team understands the parameter window where the principle works. This knowledge is used to complete the requirements list. The value proposition is also checked to support this. Then, the team identifies the alternate options and uses tools like morphological charts to understand the trade-offs. The decisions are made later based on the knowledge gained from these.

The next stage, i.e., from PP- principle proven to FP- function proven, is the 'develop embodiment' stage. Here, the team develops the product concept to embodiment level and proves the working. They define the embodiment and prove its robustness and the predictability of the function and module. The value proposition is updated at this stage, and a list of possible suppliers is made.

2.3 Process Breakdown

This section will explain each of the concepts in the simplified product development process. And the different mindsets required for it. Each of these concepts will be listed in the same order as it is used in Philips' simplified product development process.

2.3.1 Time-Box

In the Fuzzy Front End process, the team works in a time box, i.e., to learn as much as possible in a pre-defined budget and time period. 'Time Box' is a term that is not very commonly associated with lean product development, but it is more associated with agile product development. Time-boxing is allotting a fixed, maximum unit of time for an activity. That unit of time is called a time box. The goal of time-boxing is to define and limit the amount of time dedicated to an activity. Scrum, an agile methodology, uses time-boxing for all of its events and as a tool for concretely defining open-ended or ambiguous tasks. Scrum is a framework within which people can address complex adaptive problems, while productively and creatively delivering products of the highest possible value. Time-boxing is applied to some events in agile too, like sprint, daily scrum, etc. [3]

In the traditional product development processes, managers tend to lean towards the use of 'Schedule-boxing' or 'Scope-boxing'. In this method, the managers extend the size of the schedule to accommodate the completion of the task at hand. "That method might work if you can accurately size the scope of the requirements upfront and adjust the schedule to fit the scope of the items. But it has some significant disadvantages and is difficult to apply to a continuous flow-based model where the requirements are less-defined" [4]. Since we are dealing with a fuzzy front end process and the main objective is gaining knowledge, our case is a continuous flow-based model. The learning is done during the FEE has a requirement to gain maximum knowledge, the rest of the requirements are not well defined. With time-boxing, the team is forced to prioritize the knowledge gaps and take the decisions at the last responsible moment. This pulls the work forward.

That makes time boxing suitable for application in the simplified process. A few of the advantages that are listed in the book "The Project Manager's Guide to Mastering Agile" [4],

- **Focus:** The great advantage of time-boxing is that you learn how to focus your attention on the job at hand for the specified period of time
- **Increased productivity:** When you set a timer and work diligently, and in a focused manner on only the task you have identified, you work smarter and harder, and you get more done
- **Realization of time spent:** When you use time-blocking to get a job done, you realize how much time you might normally waste when working
- **Time available:** Time-boxing makes you consciously aware of something you previously were not consciously aware of—how much time you can give to a

particular project

Two additional advantages might not be immediately apparent. Time boxing addresses two common productivity issues,

- *Parkinson's law* says, "Work expands so as to fill the time available for its completion." Fixing the time allowed eliminates wasted slack time that might be built into a scope-boxing approach.
- *The student syndrome* refers to the phenomenon that many people will start to fully apply themselves to a task just at the last possible moment after a deadline. This leads to wasting any buffers built into individual task duration estimates.

2.3.2 Rapid Learning Cycles

In the exploration phase, the team works on closing the knowledge gaps. Philips DA deploys a learning pattern known as rapid learning cycles. It aims to make the team gain knowledge on unknowns and surface them, then later integrate this learning and plan for the next cycle. The rapid learning cycles are a synchronized set of experiments to remove uncertainty before key decisions need to be made in a product development program. They pull the learning earlier and push the decisions later [6].

First, the unknowns that are to be surfaced are identified using the direction of the project, as decided in the objective and the scope of the project. These unknowns are what make up the knowledge gaps. Then a document called a learning plan is created. In this, the knowledge gaps are listed in the decreasing rate of priority or criticality or the weighted shortest job first approach. The WSJF approach is used so that the knowledge gap that is of the highest criticality for making progress and is of the least duration to close is first in the list. This learning plan is consulted before each iteration of the learning cycle, and the learning cycle aims to close the knowledge gap of highest priority in the learning plan. This is iterated until enough knowledge is gained, and the unknowns are surfaced for the team to make decisions before the last responsible moment. That promotes the team to always look for knowledge actively. The validation of the knowledge gained is also followed after each learning cycle to make sure the project is moving towards the right direction asset in the objective and scope of the project [5].

2.3.3 Decisions at the Last Responsible Moment

Another mindset that lay hand in hand with the learning cycle is decision making at the last responsible moment. It promotes the employee to make use of the learning cycles to close the knowledge gaps and make the decisions based on the learning - "learn first, decide later". That is important because a decision made at the last responsible moment will be based on the maximum knowledge, and it keeps the solution space open longer. The more you can pull the learning forward and push the decisions later, the faster your ideas will get to the market [6].

The trade-offs must be recognized as well. The knowledge from the learning cycles is used for it, and the weaker options are dropped. This knowledge is not used to select the strongest option, but only to drop the weaker options through a set-based approach. That ensures that not only the best option remains. But also, the other usable options remain during the development process. The trade-offs are recognized from the weighting between two parameters: design and decisions.

3

Process Analysis

In this chapter, the process that was discussed in the previous chapter is further analyzed. The learning objectives and requirements list were formulated based on the analysis of this data and were later verified with the various leaders of the advanced development team at Philips Domestic Appliances through interviews. Both lists are explained in detail in this chapter.

3.1 Learning Objectives

The learning objectives for the simulation game were derived from the data analyzed in chapter 2. The learning objectives are the desired leanings that the user of the simulation game must gain. Upon analyzing, the mindsets for the FEE and S-AD phases were found and listed. Based on this, the learning objectives were found. An A3 sheet with the learning objectives, their justification, and ways to evaluate them can be found below. A total of five learning objectives with various sub-objectives were found and are discussed. The simulation game might not be able to teach all the learning objectives, some might have to be skipped to keep the complexity of the game low. So, the learning objectives were prioritized based on their importance in the simplified product development process and after discussion with leaders of the advanced development team at Philips DA. This prioritization will be considered if any of the learning objectives must be dropped while developing the simulation game.

The first learning objective is the learning cycle. The surface unknowns, plan in advance, and the weighted shortest job first are part of it. These are closely related to the learning cycle and support the way of working with learning cycles. These will be listed below the learning cycle. The rapid learning cycle is the core of the new development process. As it is used in FFE and S-AD to close the knowledge gaps, it is important to teach the player what a knowledge gap is first through the simulation game. Through the game, the player must understand how to effectively use a learning cycle and what its advantages are. The learning objective- surface the unknowns is to teach the players how to identify the knowledge gaps. Whereas, with the plan in advance the player must be taught how to create a learning plan with prioritized knowledge gaps. He or she must also understand when to create it and the benefits from it. A learning plan is a document that lists the complete plan of the learning cycle. It lists when each of the identified knowledge gaps will be closed, and when the decisions will be taken, and so on. With weighted short job

first, the approach to follow when prioritizing the knowledge gaps in the learning plan is taught, and the reason for it.

Learning Objectives	Justification	Evaluation / Verification
L1. Learning Cycle – Close knowledge gap & integrate	Multiple learning cycles and integration for gaining knowledge and surfacing the unknowns to plan next learning cycle. It must teach what a knowledge gap is. It must teach the player the advantages of learning cycle and how to effectively use it.	The simulation game excites the player to identify knowledge gaps and gain maximum knowledge at each iteration of the learning cycle.
L1.1. Surface Unknowns	Teach how knowledge gaps are to be actively identified.	
L1.2. Plan in Advance	Teach the needed for planning learning cycle, create learning plan with prioritized knowledge gaps.	
L1.3. WSJF	Teach to prioritize the knowledge gap based on Weighted Short Job First approach. Its importance must be showed as well.	
L2. Time Box - Constraint on time	High learning volume in a predefined time-period, stimulate maximum learning and understanding with the time bound. Teach when and where time boxing can be used, show its advantages to encourage the user to develop and adapt ways to learn faster with lesser efforts based on the scenario.	The simulation game stimulates the players' mind to take time as a constraint and do maximum learning
L3. Decision at last responsible moment	Learn first, decide later. Decisions made at last possible and responsible moment is taken based on the maximum learning.	The simulation game stimulates the players' mind to take time as a constraint and use the learning to take best possible decisions at the last possible moment.
L3.1 Alternative Options	Multiple options must be required to promote decisions making. Push the player to come up with multiple options.	The player comes up with multiple options after each learning cycle and understands the tradeoffs to take decisions.
L3.2 Recognize Tradeoffs	Tradeoffs are needed to be recognized through learning cycles for decision making and dropping weaker solutions. Teach importance of checking across all disciplines.	
L4. Validation of solution	Proving the performance of the solution finalized or validating the knowledge after each learning cycle is done.	The player feels the final solution or knowledge gained is the satisfactory.
L5. Robustness	Showing how learning cycles will ensure the robustness of the solution chosen.	The player at the end of the learning cycle/ game understands the need of learning cycle and its relation to robustness.

Figure 3.1: The Learning Objective list for the Simulation Game

The next learning objective based on priority is the time box. That is also an important part of the new development process, as all the learning cycles will be held in a time box. With this, the simulation game must teach the player how to plan a time box and how it can be used efficiently. With the game finished successfully, the player must be able to develop and adapt a way to learn faster with fewer efforts based on the scenario.

Next on the list is the decision at the last responsible moment. This learning objective highlights the 'learn first, decide later' approach. The player must understand the reason for making the decisions at the last possible and responsible moment. And must be able to recognize this moment. The learning objectives - alternate options and recognize trade-offs are part of the decision at the last responsible moment learning objective. With the learning objective alternate options included, the game must produce multiple options during its progress to support the decision at the last responsible moment. And with recognize trade-offs, the game must teach the player to recognize the trade-offs through the learning cycle. And the player also must be taught the importance of checking for the trade-offs across all the disciplines.

The last two learning objectives are the validation of the solution and robustness. With the validation of the solution, the player on finishing the game must understand the need to validate the leanings after each learning cycle and use this information to update the learning plan. And with robustness, the player, after playing the game, must be able to choose a robust solution.

3.2 Requirements

With the knowledge and limitations found through discussions with the leaders of the advanced development team at Philips Domestic Appliances and the findings explained in the previous chapter, a requirement list was created that applies to the simulation game. A total of 5 requirements (R) and 1 desire (D) are part of the list, where the requirements are a must, while the desire is not. The initial requirements set by Philips Domestic Appliances are also part of this list. The requirements are listed based on the priority, similar to the learning objectives.

The first requirement of the list is about the inclusion of learning objectives in the simulation game. This requirement is to ensure that the players playing the simulation game must be trained through all the learning objectives. Also, at the end of the game, the players must have the mindset and understand the way of working in the new development process.

The next requirement in the list specifies that the simulation game must be of the right duration. That was one of the requirements that were fixed at the early stages of the thesis by Philips Domestic Appliances. The game was decided to fit below the 3-hour mark with the justification: too little, it might not impart the whole required knowledge, and too much, it might result in losing the employee's interest. And as it is then easier to find a time slot in the agendas of the employees.

Requirements	Justification	Evaluation / Verification
R1. Simulation game must train players through all the learning objectives	After playing the simulation game, the player must have gone through all the listed learning objectives (refer learning objectives file). They must have the right direction and mindset needed for each gate or milestone.	Cross check with learning objectives tab
R2. Simulation game must be of the right duration	Too less, it might not impart the whole required knowledge, and too much, it might result in losing the employee's interest. It must be below a total time of 3 hours.	Verify with leaders of advanced development at Philips and other employees
R3. Simulation game must be simple and easy to follow	The simulation game must avoid any confusion due to its complexity, as it may impact the imparting of knowledge, and losing interest in the game.	Verify with leaders of advanced development at Philips and other employees
R4. Instructions must be straight-forward	Instructions must be easy to follow and must be in simple words for easy interpretation.	The player understands the instruction with first explanation
R5. Simulation game must be preferably online	Philips being a global organization, it is easier to train employees online	Verify with leaders of advanced development at Philips and other employees
D1. Simulation game should be able to run with minimal material	Materials needed for the simulation game should be easily available to the player (if the game is played online or away from office)	

Figure 3.2: The requirement list for the Simulation Game

The third requirement in the list is that the simulation game must be simple and easy to follow. That is, the simulation game must avoid any confusion due to its complexity, as it may impact the imparting of the knowledge, and losing the players' interest in the game.

The next requirement is on instructions. The instructions must be straightforward, must be easy to follow, and must be in simple words for easy interpretation.

And the final requirement, the simulation game must be preferably online. That was also a requirement that was agreed on at the early stages of the thesis. Since Philips is a global organization, it is easier for them to train employees away from the headquarters online.

That brings us to the only desire, the simulation game should be able to run with minimal materials. Since it is run online, the game must use materials that are easily available to the players.

4

Concept Generation and Evaluation

The result from the work carried out on concept generation and concept evaluation is presented in this chapter.

4.1 Concept Generation

A morphological matrix was used to generate the concepts. A morphological matrix was used as it covered all the important aspects. The criteria used for the matrix were derived from the learning objectives and requirements list presented in chapter 3. The criteria differ from the original learning objectives and requirements list, as some of them were not relevant, some combined, or could not be evaluated in any of the matrices at this stage.

A total of 8 sub-systems were considered for the morphological matrix, these sub-systems were decided through discussion. The sub-systems used were:

1. Surface unknowns / identify knowledge gaps before learning cycle
2. Learning plan using WSJF
3. Learning cycle within a time-box
4. Reconsider/update the learning plan
5. Alternative options
6. Recognize trade-offs
7. Decision at last responsible moment
8. Multiple rounds

All sub-systems are self-explanatory, as seen in *figure* 4.1. The concept generation was a huge part of this thesis, and emphasis was given to exploring as many ideas as possible. The morphological matrix had the possibility of producing a total of 10,368 concepts. As it is impossible to list and explain these concepts in this report, it would not be done so. These concepts needed to be evaluated, a Pugh matrix was deployed for this. The concepts that were most relevant to the thesis are explained in the next section.

Learning Objectives & Requirements	Options			
	A	B	C	D
1 Surface unknowns / Identify Knowledge Gaps before learning cycle	**S1.A** Teach to how and when to surface unknowns through an example.	**S1.B** The player is given a list of unknowns that is be part of the learning cycle, the player can add any unknowns that might be relevant.	**S1.C** Push the player to surface the unknows through tips, like by guiding them by telling 1 or 2 of the unknowns.	**S1.D** Push the player to surface the unknows by reminding him the objective of the learning cycle, to help them understand what needs to be done & what they do not know to accomplish it.
2 Learning Plan using WSJF	**S2.A** Teach what is a learning plan and how to prioritize the unknows based on WSJF, teach when to deploy them. All this through an example.	**S2.B** Teach what is a learning plan and how the unknowns are prioritized based on WSJF. Provide the player with a learning plan that is already contain the prioritized unknowns for the game.	**S2.C** Teach what is WSJF through theory, provide the players with a template to help them prioritize the unknowns based on WSJF.	**S2.D** Push the player to prepare the learning plan based on his vision on the direction to attain the objection. Check it and if needed point out to use WSJF, this helps the player to remember it better.
3 Learning Cycle within a Time-box	**S3.A** Teach what is knowledge gap and learning cycle through an example. Show how time-boxing the learning cycle is advantageous.	**S3.B** The player is guided to use the learning cycle within a time-box without teaching what it is. The player is explained at the end of the game what a learning cycle and knowledge gap using the exercise as the example. And how using a time-box advantageous.	**S3.C** Teach what is knowledge gap and player understand learning cycle by playing a pre-defined learning scenario with time constraint.	
4 Reconsider/Update the Learning Plan	**S4.A** Teach importance of updating the learning plan after each learning cycle, through an example show how to cross-check the knowledge from learning cycle with the learning plan and how to update it.	**S4.B** The player is taught the importance of updating the learning plan after each learning cycle. The player is guided to cross-check his learning plan with the knowledge gained in the last learning cycle. The learning plan is not updated, the player continues to use the provided learning plan without any changes.	**S4.C** The player to cross-check the knowledge he gained in the last learning cycle against the learning plan. Remind the player to update the learning plan accordingly to help him understand its importance	
5 Alternative Options	**S5.A** The game does not produce any alternatives.	**S5.B** Use an example that deals with multiple options or where multiple decisions are taken.	**S5.C** Present the player with pre-defined alternatives.	**S5.D** Use an exercise which will spawn multiple options or decisions to be taken.
6 Recognize Tradeoffs	**S6.A** The game does not require recognizing the tradeoffs due to lack of alternative options or due to other reasons.	**S6.B** The example used teaches the player to study the different alternatives using the knowledge from after completing learning cycles and recognizing the tradeoffs.	**S6.C** The player is pushed to compare the different options using the knowledge from the learning cycle. Hints can be given to recognize the tradeoff; player is reminded of the objective of the project, or it is done for them in the first iteration.	
7 Decision at last possible moment	**S7.A** Taking decision at last possible moment is not taught	**S7.B** Teach when to take the decisions and why so through the example.	**S7.C** Guide the player not to decide on solutions until the knowledge gaps listed in the learning plan are closed. Doing this through explanation of its importance.	
8 Multiple Rounds	**S8.A** Game will have a single round, where the player plays the game using the learning objectives from the beginning itself.	**S8.B** The game has 2 or more rounds, where in the first round the player plays the game without using the learning objectives and later in the coming round uses them.		

Figure 4.1: Morphological Matrix for Core High-level Concepts

4.2 Concept Evaluation

The concepts that were generated in the morphological matrix got evaluated in a *Pugh matrix*, seen in *figure* 4.2 and 4.3. The concepts were evaluated with respect to 10 criteria, which along with the criteria used for the *Morphological matrix* in section *4.2*, cover the relevant aspects of the simulation game. These criteria are again derived from the requirements table. A few requirements were further expanded with the help of the learning objectives table to make the evaluation process accurate. These criteria cover the effectiveness of teaching the learning objectives. This matrix compares how each of the concepts performs with a datum. In the comparison, criteria that are equally good as the datum are given an 's'. If it is not as good as the datum, then it is given a '-', and if it is better, then a '+'. The total of these scores for the criteria is the total score of the game concept. The ten criteria used for the *Pugh matrix* were:

1. Effectiveness of teaching how and when to surface unknowns
2. Understanding of learning plan and prioritizing based on WSJF
3. Understanding of learning cycle with time-box and its application
4. Effectiveness of teaching to update the learning plan
5. Effectiveness of teaching to recognize trade-offs
6. Effectiveness of teaching concept of decision at last possible moment
7. Does the game fit below 3 hours
8. Complexity of the game concept
9. Trigger player interest/ attentiveness
10. Possibility of running it online

Each subsystem in the Pugh matrix was weighted based on its importance with thesis, it was decided based on the prioritization done in the *learning objective list* and the *requirements list*, and the discussion with Philips Domestic Appliances. As explained in the previous section, the morphological matrix generated 10,368 concepts. The evaluation of all these concepts cannot be depicted in the Pugh matrix seen in the report. But, its evaluation will be explained in this section.

4.2.1 0th iteration

Out of the all the concepts generated, only a few concepts could create a meaningful link between the subsystems. As discussed earlier, the subsystems used in the morphological matrix were based on the requirements and learning objectives list found in chapter 3. All the subsystems are closely related to others in one way or another. This can be understood from how the learning objectives were listed in the learning objectives table. For example, the criteria, *Learning plan using WSJF* and *Reconsider/ Update the learning plan* are closely related, as they are sub-learning objectives that come under a single learning objective. And so, the same option can sometimes address both the subsystems. Hence, the same option has to be picked for the subsystem whenever the other subsystem chooses a particular option. Picking a different subsystem is not an option, as the game concept will not make

sense logically. This can be also seen with the subsystems *Alternate Options* and *Recognize Tradeoffs*. So, many of the concepts were overly complicated. They failed to effectively teach the learning objectives listed as subsystems in the Pugh matrix. These concepts were eliminated in the initial 0th iteration of the Pugh matrix.

Out of the remaining concepts, many did not score well in the last 2 subsystems. Many did not perform well in all or few of the subsystem: *Trigger player interest/ attentiveness*, *Possibility of running it online*, and *Does the game fit below 3 hours*. These were important criteria for the evaluation process and laid foundation of the game concepts. So, these concepts too were eliminated in the initial 0th iteration of the Pugh matrix.

4.2.2 Game Concepts

With the 0th iteration of the Pugh matrix executed, only six of the game concepts remained. Each of these concepts is explained in detail below.

4.2.2.1 Not The Same Old Monopoly Game

This game concept is simple. The team must design a Monopoly game from scratch. But as the name suggests, this is not like the original monopoly game. This game is built to tackle a specific problem in a fun and creative way. For example, a monopoly game for dogs. So, the team must think about multiple aspects like a dog cannot roll dice or a dog cannot deal with the money, and so on. The game is designed for multiple teams of 4 to 6 members to play together. And the teams compete. The team with the best design wins. The working of the game is explained in detail below.

First, the teams are created. Considering the game will be held online, it is held in such a way to create space for teams to discuss and develop ideas away from other teams. Maybe through breakout rooms.

The game start-off with one player from each team comes forward to form a panel of stakeholders. They collect theme ideas, like a monopoly game for dogs, from the different players. Then, the panel of stakeholders discusses and takes a collective decision on which theme to go forward with. Then the panel breaks out and goes back to their original teams.

Next, the game organizer hands over the pre-defined requirements list to the stakeholder present in each team. The requirements will be basic. Like, the total number of squares in the game, the number of properties for purchase in the game, etc.

Next, the game organizer explains what a learning plan is, and how to work in a time box. Then the teams are pushed to plan the learning cycles. The organizer provides hints on what decisions can be included in the learning cycle. Things like the dice design, the layout of the board, cash, etc., are hinted at as decisions. The tasks required to take each decision are also brainstormed and placed in the learning plan. This is done using the weighted shortest job first approach. The time for each

time-box and the number of learning cycles are fixed for every team by the organizer.

The teams are guided through the first learning cycle, and they are helped with updating the learning plan through hints. The team, if necessary, adds new tasks, reprioritizes the existing task, and so on. As each learning cycle is finished and the decisions are taken, the team works side by side on creating the monopoly game on a virtual platform.

Once all the learning cycles are finished, and the monopoly game is created, the team explains to each of the teams how the game works and how it can be implemented to tackle the decided theme.

4.2.2.2 The Skyscraper Game

The mission of this game is to develop a skyscraper for a construction company, it will be the company's flagship project. The game involves only pre-development activities to keep the complexity of the game low. The game will be designed to train a team of product developers in the new product development process. The company provides the team with a few decisions that need to be taken while they develop the skyscraper. The company will also provide the data required for learning to make these decisions.

The game starts with the trainer explaining how the game works and the different steps involved. Next, the trainer presents the players with the decisions to be taken as the game progresses. The decisions will be on the different aspects like the location of the skyscraper, its purpose, and so on. The players discuss between themself to create a logical order in which the decisions will be made.

Then the team starts to plan for the learning. They start by brainstorming the knowledge gaps that must be closed to make the decisions. These are then prioritized based on the weighted shortest job approach. Then, the team creates the learning plans and places the decisions and the knowledge gaps based on the logical order and prioritization.

Next, the team starts running the learning cycle based on the plan. Each of the learning cycles will be run in a time-box fixed by the trainer. The players are also given access to the data from the company. The data will be in the form of cards. They can be mapped with the knowledge gaps that were brainstormed earlier.

Each iteration of the learning cycle will be followed by reviewing the learning. During this phase, the team can add new knowledge gaps or reprioritize the existing ones. As the iterations of the learning cycle progress, each of the decisions is made. Finally, the team develops the skyscraper, and it is presented to the company.

4.2.2.3 Logic Puzzle

As the title suggests, the objective of the game is to solve a puzzle. The puzzle used in the game is a series of cryptograms, a short piece of encrypted text. The game requires the teams to coordinate with each other and find the right set of ciphers to solve their cryptograms. The game is designed to accommodate multiple teams with 2 to 3 players each. The game will have two rounds. The first one lets the teams play the game according to their wish. They can decide how to coordinate with the other teams, and no particular concept needs to be used. In the second round, the organizer guides the team to play the game using concepts like learning cycle and time boxing. This approach was chosen intentionally to show how the process can be bettered using the concepts, and the teams can compare the results of each round.

In the first round of the game, each team is given a sheet, filled with say 10 cryptograms and 10 ciphers. These ciphers may not be the right ones to solve the cryptograms in the sheet. Each cryptogram is of different difficulty and solving each of them will get the team a pre-defined point. The points are not set based on their difficulty. Each of the sheets given is unique to each team. Initially, each team is given a few minutes to look at their sheets and check if any of the ciphers with them can be used to solve their cryptograms. The game will be designed in a way that one of the cryptograms can be solved with the existing cipher. That is to ensure that the team gets an idea of how to solve a cryptogram.

Next, the teams must prepare a plan on how they can coordinate with each other and find the ciphers they need. The teams are not allowed to multitask. But they check for the cipher for only one cryptogram at a time. That is, once they decide which cryptogram they are going to solve next, they search the cipher for only that. Only after finishing that particular cryptogram, they are allowed to move to the next one. In the permitted time, the teams cannot finish all the cryptograms. So, planning and time management are important to get the maximum points.

Then the learning cycle iterations start. As per the learning plan, each team coordinates with another team in the set time. When two teams are co-coordinating, the first team checks for the cipher they need in the other team's collection of ciphers. And once it is done, the vice-versa happens. The first round is bound to be confusing. Finally, points scored by each team are calculated and recorded.

The second round works similarly to the first round. A new set of sheets containing 10 cryptograms and 10 ciphers are distributed. Now, the teams are asked to arrange the cryptograms based on their difficulty and points, i.e., based on the weighted shortest job first prioritization. That is part of the learning plan, and the ciphers required for solving each of the cryptograms are the knowledge gaps.

Next, the teams are asked to plan to seek alignment with each of the teams. This is added to the learning plan. A fixed time is allotted for this. Once this is finalized, the learning cycles are run similarly to the previous round. Once all the iterations of the learning cycle are completed, the points based on the number of cryptograms

solved are calculated. It is then compared with the points scored in the first round. The teams would have scored more points in the second round. Next, the teams discuss the reason for this and what they have learned from the game. Finally, the organizer or the trainer explains in detail each of the concepts involved and how they helped the teams.

4.2.2.4 The Mini Project

This game setup is like a case study, but it involves a lot more player interaction. The game is to develop a small product or part of a product within a set of requirements. The game will be designed to use most of the learning objectives in the development process. But also, to be simple and easy to follow at the same time. The game is suitable for multiple teams playing at the same time.

The game starts with the teams being handed the requirements of the product to be developed. The players are explained how the game works by taking them through a mock example. Then, the team makes a list of the key decisions to be taken, which are required for the development of the product.

Next, the team is instructed to plan for the learning cycle. First, they prepare a learning plan with all the knowledge gaps, i.e., problems that are needed to be investigated, to take the product to the concept level. These are listed based on the weighted shortest job first approach. Then the iteration of the learning cycle is run in a pre-defined time-box. At the end of each learning cycle, the learning is used to close the knowledge gaps listed in the learning plan. It is made sure the team has sufficient knowledge to close the knowledge gaps. And it is made sure they are moving in the right direction. Also, the team is hinted to update the learning plan accordingly.

With the iterations of the learning cycle progressing, the team takes the decisions, and along with it, they continue to integrate the knowledge and develop the product. The teams will be given hints on the process, like taking the decision at the last responsible moment, as they progress with it. Once all the decisions are made and the product developed, the final product is presented to everyone. The product that serves the purpose the best, wins.

4.2.2.5 The Flying Machines

This game concept requires the players to better their playing strategy as the game progresses to succeed. The game concept runs in multiple iterations. Each iteration includes a learning cycle in which the players build and test paper aeroplanes. Between each iteration of the game, there is a planning event. Here, the team gives an estimate of the number of paper aeroplanes they can build and test. They also plan for the approach to make the plane during this time.

Once the learning cycle starts, each player can fold the paper only once. Then, he or she passes it to the next player in the team. Once the plane is finished, the plane

is flown. Only if covers a pre-defined distance it is considered complete. At the end of the learning cycle, the number of completed planes is counted and compared with the estimated number of planes stated in the learning plan.

Next, the planning event is run. Here, the team discusses the learning from the last learning cycle and plans to better their approach. They work on improving their strategy to build and test the paper aeroplanes faster. Again, an estimate of the number of planes made is noted.

This is done for 3 to 4 iterations. Then the teams are put forward with questions like,

1. What would have happened if there was no time-box applied?

2. What made them improve over the iteration?

3. Was validation of improvement in each planning cycle useful?

4. How can the learning from this exercise can be made useful when dealing with FEE and S-AD?

Finally, the advantages of the learning cycle, time-box, decision at the last possible moment, validation are explained by highlighting the experiment and the actual FEE, and S-AD process.

4.2.2.6 The Boring Case Study

The boring case study is based on how a case study works. It is the most commonly used solution to training employees. A case study of a product is shown through its development phases to explain the different concepts in this game. A small and simple product or part of a product will be used in the case study, mostly a product from Philips Domestic Appliance's line-up. The product is taken through the different stages of the FEE and S-AD. It is shown how the product gets developed and how the different learning objectives are used throughout the process.

First, the trainer explains what a knowledge gap is and what the knowledge gaps are in the case they are discussing. Then, as in the example, what a learning cycle is explained, and how it will be used within a time-box will be shown. The example will show how each of the unknowns was surfaced through the time-constrained learning cycle. Along with working on the learning cycle, the example will include the use of a learning plan. It will explain the advantages of a learning plan and how the knowledge gaps are prioritized based on the weighted shortest job first. The case study example will show multiple learning cycles. And, after each learning cycle, the learning plan will be updated based on the knowledge gained or the knowledge gaps closed.

As the product is shown through the different phases, it will be explained the way of the decision-making process- *Decision at last possible moment.* The example will

teach the player its importance. It will also teach when the right possible moment is. The case study example will be having multiple solutions or options to be selected. That is, to show the decision-making process clearly. With the decision-making process, the way of recognizing trade-offs is also taught.

4.2.3 1st iteration

Game Concepts		The Boring Case Study	Not the same old Monopoly Game	The Skyscraper Game	Logic Puzzle	The Flying Machines	Mini Project
Criteria		Weightage (1-5)	DATUM	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
1.	Effectiveness of teaching how and when to surface unknowns	5	D	+	S	S	S	+
2.	Understanding of learning plan & prioritizing based on WSJF	4		S	S	S	S	S
3.	Understanding of learning cycle with time-box and its application	5	A	S	+	+	+	S
4.	Effectiveness of teaching to update the learning plan	3		S	+	S	S	S
5.	Effectiveness of teaching to recognize tradeoffs	3	T	S	S	-	+	S
6.	Effectiveness of teaching concept of decision at last responsible moment	3		S	-	-	-	S
7.	Does the game fit below 3 hours	4	U	S	S	S	S	S
8.	Complexity of the game concept	4		S	+	+	+	S
9.	Trigger player interest/ attentiveness	5	M	+	+	+	+	S
10.	Possibility of running it online	4		S	+	+	-	S
	Sum of Positives			2	5	5	4	1
	Sum of Negatives			0	1	2	2	0
	Sum of s			8	4	3	4	9
	Weighted sum of Positives			10	21	18	17	5
	Weighted sum of Negatives			0	-3	-6	-7	0
	Total		0	10	**18**	12	10	5

Figure 4.2: 1st iteration of *Pugh matrix* evaluating the six concepts

The remaining six concepts needed to be evaluated further to drop the weaker ones. *The Boring Case Study* was decided as the datum, since it the most common and widely used tool for training currently. The concept generation was done and cross-checked with representatives of Philips Domestic Appliances. The possibility of using these core high-level concepts as the base for the game was also ensured.
All the concepts compared with the datum scored greater than it, showing simulation games are a better way of training than conventional training in our case. The *"Effectiveness of teaching how and when to surface unknowns"*, *"Understanding of learning cycle with time-box and its application"*, and *"Trigger player interest/ attentiveness"* carried the highest weightage out of all the criteria. The reason for it is that the first two of these criteria are the fundamental learning objectives of the simulation game. And the third is an important aspect of a simulation game, as without triggering the players' interest and attentiveness, the game will not be a success.

The *Mini Project* scored an 's', same as the datum in most criteria, with getting a '+' only in one criterion. It is a little better over *The boring case study*, as there is more player interaction involved in the game concept. Otherwise, it is same as *The Case Study* concept. That is not surprising, as the *Mini Project* is a blend of both the *Develop and Improve* and *The Case Study* concept.

So, with first iteration of Pugh matrix, *The Boring Case Study*, the datum and the *Mini Project* were eliminated. Both the concepts were clearly the weaker options as they did not effectively teach most of the learning objectives mentioned in the criteria. With that the 1st iteration of the Pugh matrix was done

Multiple rounds of evaluation using the Pugh matrix as to be done till the results converge. This ensures the accuracy of the evaluation process.

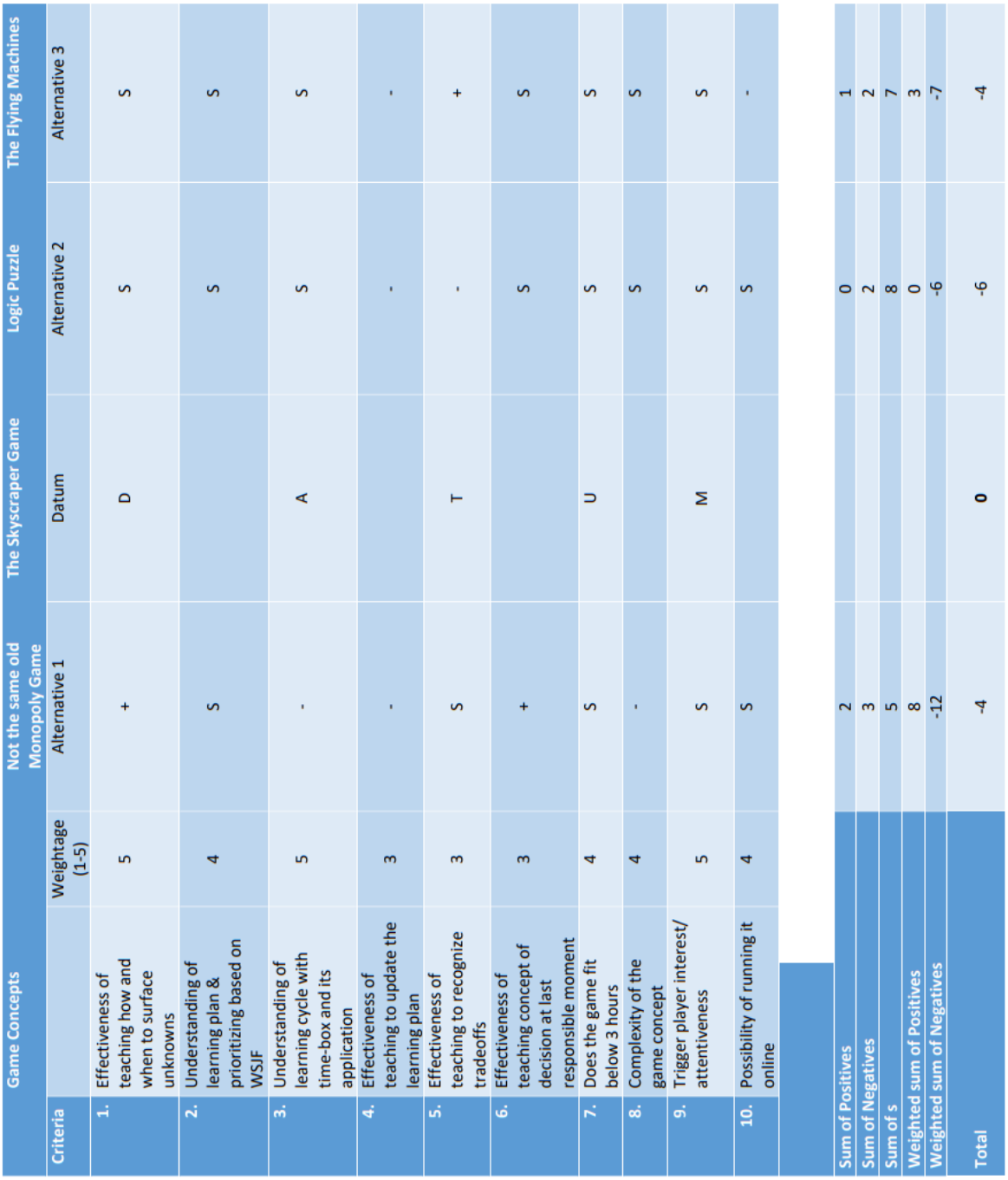
4.2.4 2nd Iteration

In the second iteration of the Pugh matrix evaluation, the remaining three concepts were evaluated against the datum. *The Skyscraper Game* was made the datum, as it highest ranked concept.

The *Logic Puzzle* did not perform well in *"Effectiveness of teaching to recognize trade-offs"*, and *"Effectiveness of teaching to update the learning plan"*. The reason for this is that this concept involves solving the logic puzzle to finish the game, so it did include the updating of the learning plan. The game concept also makes it harder to recognize the trade-offs, as it is hard to compare the different puzzles and realize the trade-offs without solving them first. With these criteria being a few of the most important learning objectives, and the *Logic Puzzle* failing to teach it led to the concept's elimination.

The *Not the same old Monopoly Game* was a promising game concept in the early stages of development. It was a game that involved a lot of player interaction and

could have been the most fun simulation game out of all the final concepts. This concept was eliminated as it was complex, and the chances of players straying of the desired game path were high. Even with the complexity kept low, the game concept will not necessarily succeed in teaching the learning objectives such as *"Understanding of learning cycle with time-box and its application"*, and *"Effectiveness of teaching to update the learning plan"*.



Game Concepts			Not the same old Monopoly Game	The Skyscraper Game	Logic Puzzle	The Flying Machines
Criteria		Weightage (1-5)	Alternative 1	Datum	Alternative 2	Alternative 3
1.	Effectiveness of teaching how and when to surface unknowns	5	+	D	S	S
2.	Understanding of learning plan & prioritizing based on WSJF	4	S		S	S
3.	Understanding of learning cycle with time-box and its application	5	-	A	S	S
4.	Effectiveness of teaching to update the learning plan	3	-		-	-
5.	Effectiveness of teaching to recognize tradeoffs	3	S	T	-	+
6.	Effectiveness of teaching concept of decision at last responsible moment	3	+		S	S
7.	Does the game fit below 3 hours	4	S	U	S	S
8.	Complexity of the game concept	4	-		S	S
9.	Trigger player interest/ attentiveness	5	S	M	S	S
10.	Possibility of running it online	4	S		S	-
Sum of Positives			2		0	1
Sum of Negatives			3		2	2
Sum of s			5		8	7
Weighted sum of Positives			8		0	3
Weighted sum of Negatives			-12		-6	-7
Total			-4	**0**	-6	-4

Figure 4.3: 2nd iteration of *Pugh matrix* evaluating the remaining four concepts

Also, *The Flying Machines* concept was eliminated. It failed to teach *"Effectiveness*

of teaching to update the learning plan" criteria. Another reason for the elimination of *The Flying Machines* concept was its inability to run online.

The Skyscraper Game ranked the highest again. This meant the results converged in the second iteration of the Pugh matrix. So, only *The Skyscraper Game* will be further developed, as it is the only concept that remained after the elimination process.

5
Detailed Design

This chapter presents the activities that were performed to develop *The Skyscraper Game* concept further and create a working prototype of the game. The concept was refined further in this phase of the thesis. The different aspects of the simulation game that were developed are discussed in this section.

5.1 Game Platform

A platform in which the game will be developed and run needed to be found. The platform had to be easily available to the employees globally, and that can be used without much training. Several online platforms were considered. The Miro board was finally selected, as it is widely used and provides good support to its users. Miro board also provides features that are useful for the development and running of the game. The platform also supports multiple numbers of users playing the game at the same time. The platform also provides a lot of space around the developed game space for the players to use while playing the game.

5.2 Game Setup Layout

It was decided the game setup will have five main parts: an instructions tab, the main game body, the data cards tab, the concepts tab, and the summary sheet. The instructions tab will explain to the players how the game works through an example citing the different steps. The main game body will house the game along with its steps. The data provided by the company will be presented in the form of cards in the repository cards tab. The different concepts associated with the game will be described in the concepts tab. The trainer can use this to explain in detail the concepts used in the game. The summary sheet is the results tab, which the team will fill in as they progress with the game. It will be presented at the end of the game. Each of these parts of the game setup is explained in detail in the coming sections.

5.3 Instructions Tab

The instructions tab is the first part of the game which the players will be viewing. The players need to be briefed on the working of the game. They need to get familiar with the five different steps of the game, and other aspects of the game.

Also, the players are given a background of what the game presents and the results they are expected to obtain at the end of the game. Not all information is available in the instruction slides. Some are explained orally by the trainer for the ease of understanding and avoiding confusion.

The instructions tab has a total of 8 slides, including the title slide. The title slide is the first of the instructions tab. It provides direct links to the main game body and the first slide of the instructions. The players can click on these links while playing to go to the respective slides.

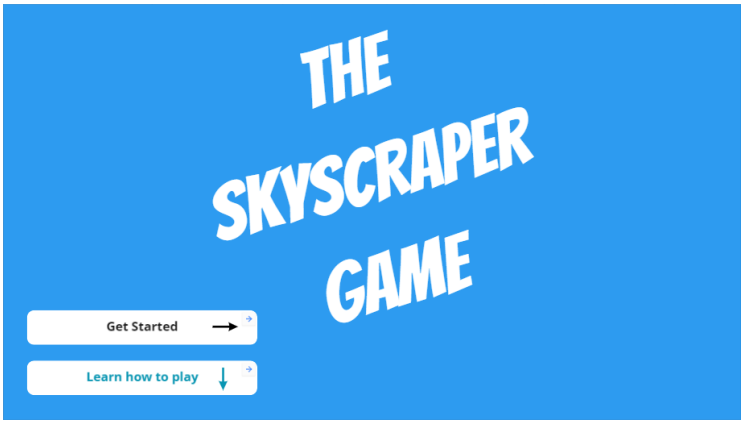


Figure 5.1: The title slide

The next slide is the background slide. This slide introduces the player to the game. The slide explains that the players will work as a team of real-estate developers working for a mock-up construction company named Skylight Construction Company. It further explains that the team will do pre-development activities to help the construction company develop a flagship Skyscraper in the United States of America. The team will work in a short time to extract the knowledge from the data given by the company to take the key decisions related to the skyscraper project. As mentioned before, the instructions tab will explain the five steps in the game. The background slide will also provide a direct link to each of the steps explained in the instruction tab. The background tab is showed in the *Figure* 5.2.

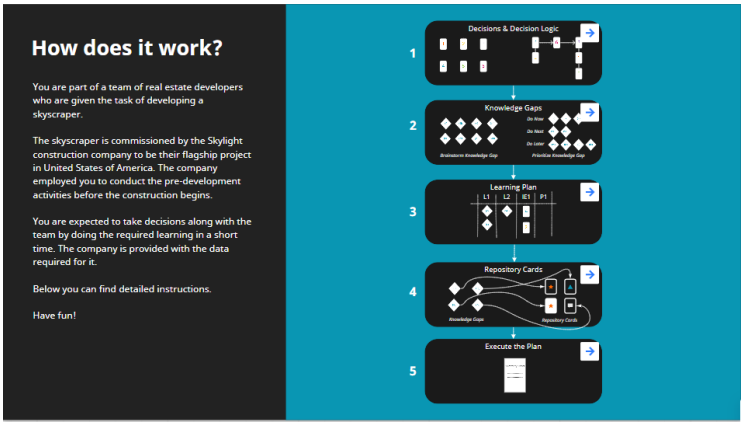


Figure 5.2: The background slide with the direct links to various steps

The instructions for the game and the steps are presented in the rest of the 6 slides. Each of the steps is titled based on the task they must do in the respective steps. The steps are the following:

1. Decision and decision logic
2. Knowledge gaps
3. Repository cards
4. Learning plan
5. Execute plan

5.3.1 Decision and Decision Logic

This slide explains the first step of the game. As the name suggests, in this step, the team of players is presented with the decisions that must be made as they progress in the game. The instructions tab instruct the team to have a brief discussion to understand each of them.

Next, the team is instructed to create a decision logic. The instruction slide explain that the decision logic is a plan containing how the decisions will be executed. That is, it is a logical order that is created by the team. It explains in what order the decisions must be executed. This is done to make the decision-making process as smooth as possible and avoid any confusion in the later stages of the game.

The instruction slide, using an example, explains in detail how the decision logic can be created. The right side of the slide, as seen in figure 5.3, presents the team with a pictorial example of it for easy understanding. In the example, six decisions are presented. Each of these is numbered. Once the team studies these decisions, they get a vague logical order of how they can be executed. Some decisions are needed to be taken before the rest, so they come first in the logical order. While some can be taken together, so they are clubbed together. Within the allotted time, the team creates the decision logic, as shown in the example. Here, as seen in the example decisions, '4' and '2' are to be executed together. It is followed by decision '2', then finally decisions '1', '5', and '6' are to be executed together.

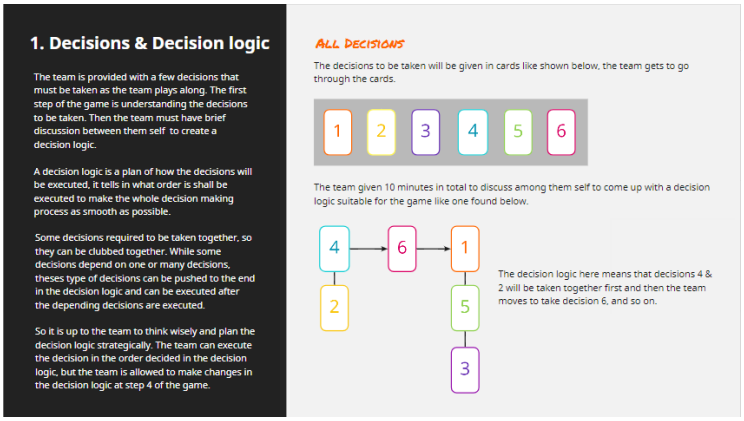


Figure 5.3: The decision and decision logic instruction slide

The instruction further hints the players to think wisely and plan the decision logic strategically. As this directly influences the success of the game. Also, it hints that changes can be made to the decision logic in later stages of the game if needed.

5.3.2 Knowledge Gaps

The second step in the game is about brainstorming the knowledge gaps and prioritizing them. This instruction slide explains that the knowledge gaps are unknowns that must be surfaced and closed to gain the knowledge to make the decisions in the decision logic. As shown in figure 5.5, the instructions explain that the knowledge gaps need to be brainstormed by the players and listed next to the related decisions. The knowledge gaps are brainstormed based on the decisions to be taken. One must answer the question, *what are the unknowns related to the decision?*

Once all the relevant knowledge gaps are brainstormed, the player starts to prioritize them. The instruction explains how the player must prioritize and arrange the knowledge gaps into three lists: *"Do now"*, *"Do next"*, and *"Do later"*. The player revisits the decision logic created in the previous step before prioritizing. The weighted shortest job first approach is considered for the prioritization. The WSJF approach results in more critical gaps prioritized above the less critical ones, and the shorter ones are prioritized above the longer ones. The knowledge gaps that need to be closed first and are of highest priority are listed under *"Do now"*. The knowledge gaps that are next in priority are listed in, *"Do next"*, and those of the least priority in *"Do later"*.

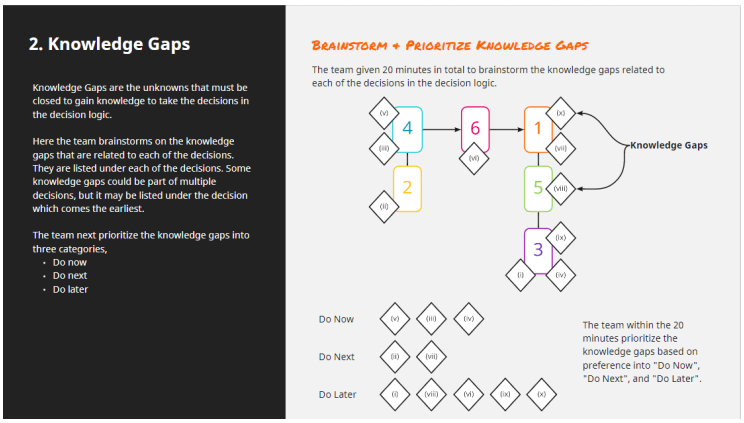


Figure 5.4: The knowledge gap instruction slide

5.3.3 Repository Cards

The repository cards instruction slide explains how the knowledge gaps will be matched with the data given by the company. After the knowledge gaps are brainstormed and prioritized, the team is given access to the repository cards. The team is not allowed to study the data in the cards, but they are allowed to read the titles of the cards and match them with their knowledge gaps. They can drag the repository cards from the tab to place them next to the matching knowledge gaps. The

team need not necessarily use all the repository cards. They can skip any if they do not require them.

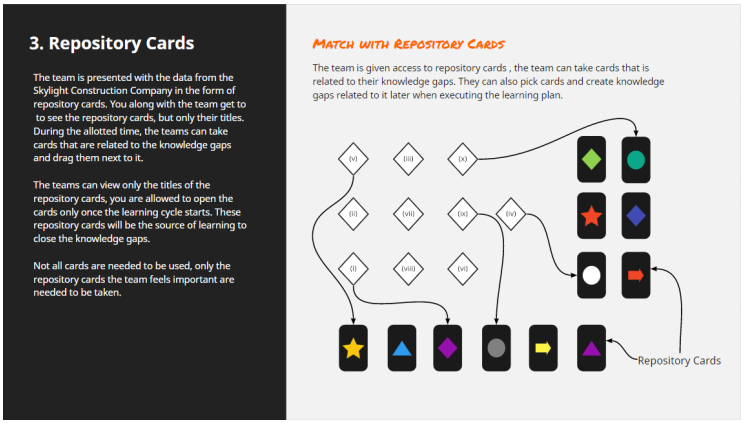


Figure 5.5: The repository cards instruction slide

5.3.4 Learning Plan

The learning plan is explained through two slides. The slide explains to the players how to create a learning plan. As seen in figure 5.9, the slide explains how basic boxes are already provided to the players to combine and create the learning plan. Four basic boxes will be provided in this step: *Learning cycle*, *Learning event*, *Integration Event*, and *Planning*. *Learning cycle* and *Learning event* boxes are divided into several smaller boxes for each of the players to share the space in the box. Each of the boxes and how they will be used is explained in detail.

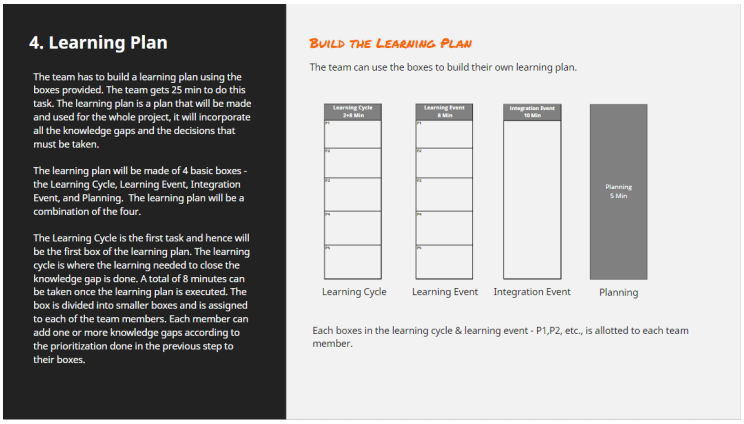


Figure 5.6: The learning plan instruction slide

The learning plan always starts with the learning cycle box, since it is the first task. It is explained first in the learning plan instruction slide. The learning cycle is where the learning needed to close the knowledge gaps are done. The repository cards that were matched in the previous steps are moved into the learning cycles based on the prioritization of the knowledge gaps. Each player is assigned repository cards for which they are responsible.

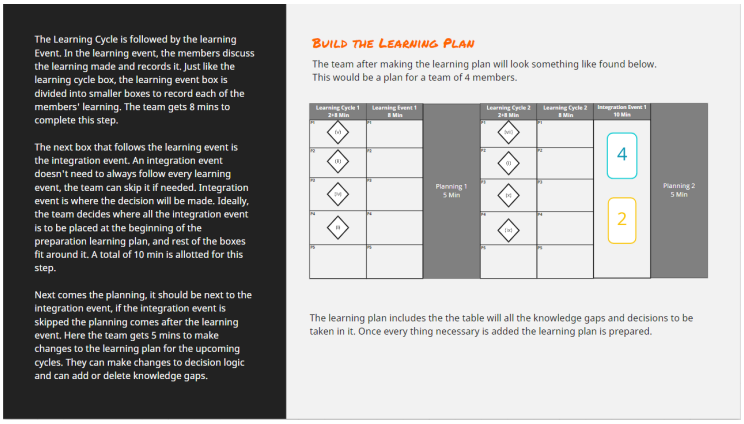


Figure 5.7: The learning plan instruction slide

The next box that follows the learning cycle box is the learning event box. It always follows after every learning cycle box. The players fill in the key knowledge which they gained during the learning cycle into the learning event box. Each player has a space assigned to them in the learning event box.

The Integration box follows the learning event box. An integration event box does not always have to follow the learning event box. The players can choose to skip it if not needed. These events are where the decisions given by the company will be made. Ideally, the team must place the integration event boxes first in the learning plan and then place the rest of the boxes around it. That is, the last responsible moment when the decisions will be taken is decided first, and then the learning cycles are planned to fit between them. The number of integration event boxes directly depends on the decision logic which was made earlier. If the decision logic has three sets of the decision-making process, then there will be three integration events as well. The decisions to be made are moved into these boxes.

The planning box follows this. If the integration event box is skipped, the planning box follows after the learning event box. This box does not require filling in any information. This box depicts that a planning phase has to be run. How the planning has to be done is explained in *Execute the plan* instruction slide.

With all the boxes assembled and all the knowledge gaps assigned, the learning plan would look as seen in figure 5.7. The next instruction slide explains how to use the learning plan to run the learning cycles and make the decisions.

5.3.5 Execute the Plan

Execute the plan is the last slide in the instructions tab. It explains how the learning plan has to be executed. Once the team creates the learning plan, the team starts with the first learning cycle. In the set time, each player starts studying the repository cards that they are assigned. They extract knowledge from the cards and write down the key information relevant to the knowledge gaps in their learning event box. Once the learning cycle is done, the learning event starts right away.

Here, the players explain the knowledge they have gained to the other players in the team in the allotted time. If an integration event follows next according to the learning plan, the team takes the decisions assigned to that integration event based on the knowledge from the past learning cycles. If it is planning next, the team makes necessary changes to the learning plan, the decision logic, or the knowledge gaps if required. The execution of the learning plan will be further explained in the main game body.

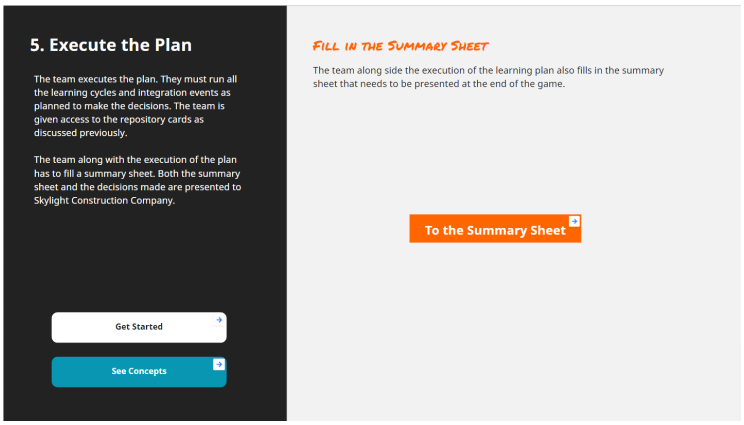


Figure 5.8: The execute the plan instruction slide

This slide provides direct links to the main game body and the concepts tab. The players can click the links to directly view them. A link to the summary sheet is provided as well. The team has to fill in the required information in the summary sheet as they progress with the learning cycle or after completing the execution of the learning plan. The team can use the allotted time in the learning event to fill in the summary sheet.

5.4 Concept Tab

The concept tab is the slide which the trainer can use to explain the concepts in the game. Links to each of the concepts are provided in the main body of the game. Also, the trainer uses this tab to provide hints to the player to help them achieve the right mindset while playing the game. The concept tab pushes the players to ask themself relevant questions to use the game process in the right way. Not all concepts needed to be explained separately. Only a few concepts are listed and explained in the concept tab. The concepts listed in the concept tab are explained below.

5.4.1 Surface Knowledge Gaps

With the decision logic created, the players have to brainstorm the knowledge gaps. The concept tab hints the players to ask themself, *"What knowledge is required to take this decision?"*. Answering this question while brainstorming the knowledge gaps helps the players surface the ones relevant to the decision. Only with the relevant knowledge gaps closed, the players can take the right decisions.

Figure 5.9: The concepts tab

5.4.2 Weighted Shortest Job First

The WSJF approach used for prioritizing the knowledge gaps is an important concept. The players might not easily understand it. The trainer can use the concept tab to explain how the knowledge gaps are prioritized by considering their criticality. It hints the player to answer questions like, *"When we do not close it, what might happen to the project?"*, *"Will the project fall over?"*. If the impact on the project is not visible when answering these questions, then the criticality is low. The WSJF results in the more critical gaps prioritized above the less critical ones, and the shorter ones prioritized above the longer ones.

5.4.3 Learning Cycle with Time-Box

Even though the learning cycle and its usage are well explained in the instructions tab, the right mindset required to perform it might not be passed on to the players. So, the concept tab further explains this concept. It explains, *"Pull learning forward to identify and remove obstacles, push decisions later to preserve flexibility"* is what learning cycles follow. The time-boxes are deployed to ensure the team focuses on the most important tasks. And they are done one at a time.

5.4.4 Decision at the Last Responsible Moment

The concepts remind the players to *"learn first, decide later"*. A decision has to be pushed to the last responsible moment. The last moment is the moment before which there is no adverse effect on the downstream activities or decisions.

5.5 The Game Body

This is the heart of the simulation game. It is where the team plays the game. After running through the instructions tab, the trainer gives a walk-through of the complete game body. The game body has been designed to make the work easier for the players as they progress through the multiple steps. Pre-defined tables and structures are already presented in the game for the team to make use of. This section will explain each step in the game body again, but in much detail, along with the different structures, time for each step, and the data that will be used in the game.

5.5.1 Decision and Decision Logic

As discussed in section 5.3.1, the game starts with the team being presented with the decision to be made. As seen in figure 5.10, the team will be presented 6 decisions. The team is given 10 minutes to study the decisions to be made and then discuss among themself to create a decision logic. The decisions to be made are:

1. In which city will the skyscraper be build?
2. Where will the skyscraper be build- in the industrial park or the residential park?
3. Will the city be build for easy accessibility to the highway/ city or closer to nature/ less busy area?
4. Will the foundation of the skyscraper use friction piles or end-bearing piles?
5. Will the apartment be taller than the current tallest apartment?
6. Which structural system will the skyscraper adopt?

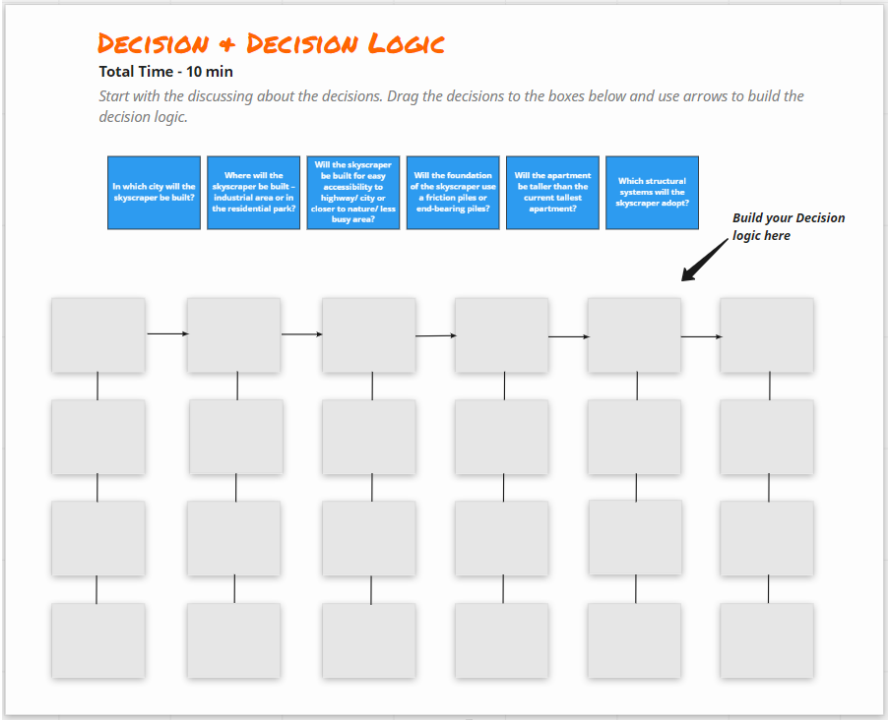


Figure 5.10: The decision and decision logic

There are multiple sequences that the decision logic can have. There is no fixed ideal decision logic for these sets of decisions. It is up to the team to discuss and bring up the different factors, and create the decision logic that is apt. To make it easier for the players to create the decision logic, the game has already laid out a series of boxes that are connected using arrows. The players need to drag down the decision into these boxes to create the decision logic they desire.

5.5.2 Brainstorm and Prioritize Knowledge Gaps

This step is divided into two parts, the players get a total time of 20 minutes to complete both the parts. The first part deals with the brainstorming of knowledge gaps. The step 2 tab has the decisions listed again for the players to review while brainstorming the knowledge gaps. Each decision has three blank boxes below them for the players to fill in the knowledge gaps. The team can fill in only a maximum of three knowledge gaps for each decision. A link to the concept tab is also provided for the trainer to explain the concept of surfacing knowledge gaps in detail.

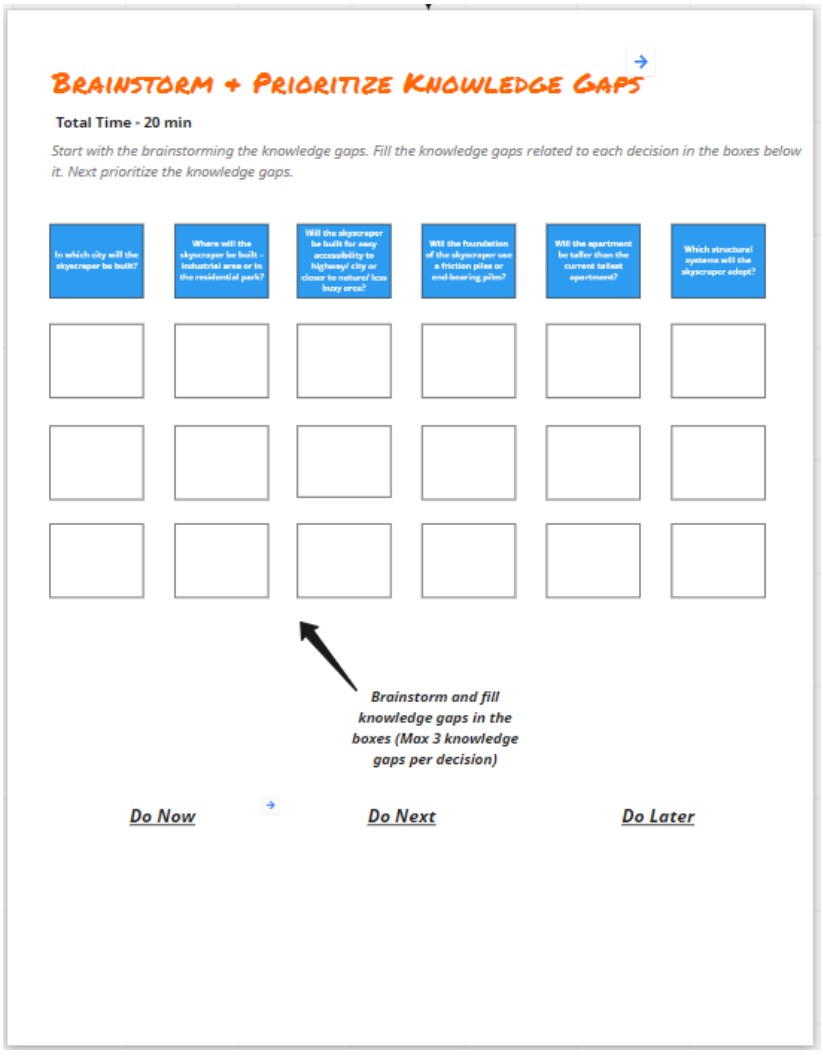


Figure 5.11: Brainstorming and prioritizing the knowledge gaps

The player on finishing the brainstorming moves on to the second part. Here, three titles are listed, one next to the other. They are *Do now*, *Do next*, and *Do later*. The players have to copy the brainstormed knowledge gaps from the previous part and list them under these titles after discussing. The trainer can use the link provided to navigate to the concepts tab to explain how to prioritize the knowledge gaps based on the weighted shortest job first approach.

5.5.3 Match with Repository Cards

The step 3 in the game body features a tab that contains a link to the repository cards. The players in the allotted time of 10 minutes have to complete this step. They can use the link to navigate to the collection of repository cards and study them without opening them. They then try to match the repository cards with the knowledge gaps they have prioritized in the previous step. They drag the cards and place them next to the related knowledge gaps. The players need not use all the repository cards, they can skip any if not needed.

Figure 5.12: Matching knowledge gaps with repository cards

The repository cards and its contents will be discussed in the later sections.

5.5.4 Learning Plan and Learning Cycle

As explained in the instructions, this step pushes the players to create the learning plan using the provided basic boxes. With the instructions learned earlier, the players in 10 minutes use the four basic boxes as seen in the figure 5.13 to create their learning plan. A link to the concepts tab is provided to teach the players more about the learning cycles and time boxes.

The players make use of the tab named *your learning plan* to assemble the learning plan. *Your learning plan* tab can be seen in figure 5.14. The players copy the basic boxes from the tab above and place them here. Then they copy the decisions from the decision logic and place them in the integration event boxes. The knowledge gaps are also placed in the learning cycle boxes based on the prioritizing done earlier.

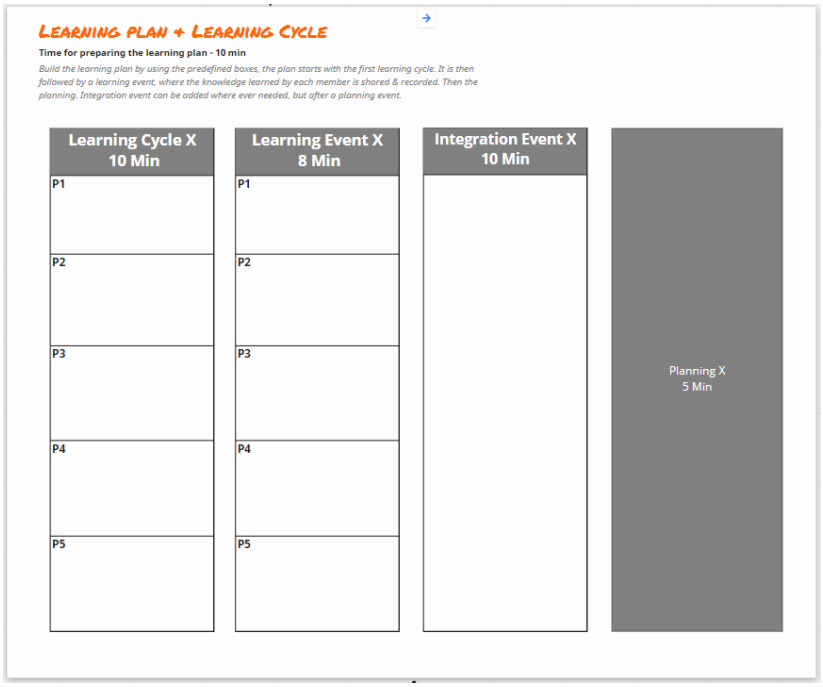


Figure 5.13: The basic learning plan boxes

5.5.5 Execute the Learning Plan

For executing the learning plan, there is no separate step. Once the team has created the knowledge gaps, the team has to execute the learning plan in the same *your learning plan* tab. The team executes this as they learned earlier from the instructions in the time allotted.

Figure 5.14: The learning plan

The team also fills the summary slide along with completion of execution of the learning plan.

5.6 Repository Cards

The repository cards contain the data provided by the Skylight construction company to the players. These data cards are an important factor in the success of the game. If the players are asked to research the data, the game can have a countless number of outcomes and endings that may not be predictable. Also, if the team focuses on researching their data to make the decisions, there are chances that they will focus less on the actual learning from the game and more on researching irrelevant data. The repository cards are also used by the game to guide the players to stick with the relevant data and focus more on the process. The cards create a narrow path through the vast possibilities in the game. Also, the employees playing the game may not have relevant knowledge about skyscraper construction to completely understand the actual data, calculation, formulas, and so on. And, the game is not about teaching skyscraper construction, but the product development process along with the required mindsets. Hence, the cards were made out of fictional data to keep the game as less complex as possible. So, some of the data may not be valid in real life, and things such as units, formulas, and calculations may not be accurate.

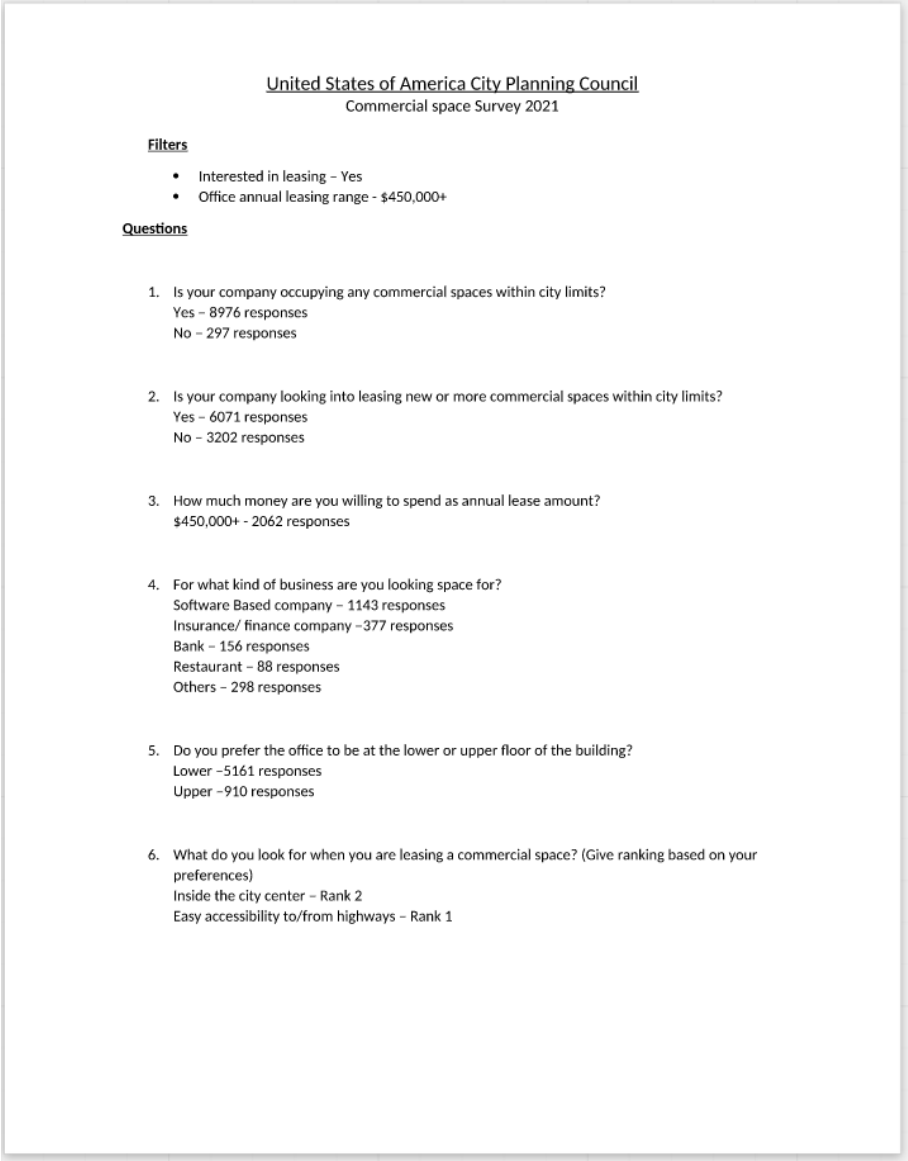
The game features 21 cards in total. More cards can be added by the trainer later, to make the game more interesting and fun. The number of cards can be also adjusted to change the game time and its complexity. The game is designed in a way that trainers can make changes to the game based on their liking and satisfaction without changing the learning outcome of the game. These cards will be explained in this section. They are listed here based on the data they present. The cards are categorized into surveys and graphs, newspaper articles, general information, tests and calculation, and government notices. Not all cards will be explained in detail, as some of them are similar to the other with only minor changes.

5.6.1 Surveys and Graphs

A total of 6 cards will be categorized under surveys and graphs. These cards present data that will be relevant to the players in the form of surveys and graphs. As the aim of the game is to develop a skyscraper, the game has data in the form of repository cards to cover most of the knowledge gaps that the team would surface. With skyscrapers, a common knowledge gap that could arise would be: 'what is the purpose of the skyscraper?' The team will conclude it to be for residential and commercial purposes after seeing the decisions to be made. But the team would not know which must be given a higher preference, whether commercial or residential. As the team has to decide the location of the skyscraper and so on, they have to check which has more demand. Therefore, few of the cards listed in this category cover data for the team to analyze the demand.

Two surveys were added in the form of cards representing the public's opinion on both commercial spaces and high-end apartment sales. Both the surveys present data that is relevant to the high-value properties found in a skyscraper. The cards may contain data that is not important to the players. The players have to constantly

cross-check with the decisions to be made and the summary sheet to extract the data they need. A single question in the survey may not give a direct answer to the decision to be made. A collection of data from multiple cards might be needed for this.



United States of America City Planning Council
Commercial space Survey 2021

Filters

- Interested in leasing – Yes
- Office annual leasing range - $450,000+

Questions

1. Is your company occupying any commercial spaces within city limits?
   Yes – 8976 responses
   No – 297 responses

2. Is your company looking into leasing new or more commercial spaces within city limits?
   Yes – 6071 responses
   No – 3202 responses

3. How much money are you willing to spend as annual lease amount?
   $450,000+ - 2062 responses

4. For what kind of business are you looking space for?
   Software Based company – 1143 responses
   Insurance/ finance company –377 responses
   Bank – 156 responses
   Restaurant – 88 responses
   Others – 298 responses

5. Do you prefer the office to be at the lower or upper floor of the building?
   Lower –5161 responses
   Upper –910 responses

6. What do you look for when you are leasing a commercial space? (Give ranking based on your preferences)
   Inside the city center – Rank 2
   Easy accessibility to/from highways – Rank 1

Figure 5.15: The repository card on commercial space survey

Figure 5.15 represents the survey on commercial spaces. It contains information like buyers' preference on skyscraper location, preference of level, and so on. These data might seem irrelevant but might be needed in the later stages of the game. So, the team must study the cards properly. A similar strategy is applied to the high-end apartment buyers survey. This card can be found in the appendix A.1.

The skyscraper is depicted to be built in the United States of America, so repository cards presenting data on the country was also been added. One such card is on the predicted GDP growth of the United States of America, seen in appendix A.4. This

card can be used by the team to check the potential success of the skyscraper. The rest of the repository cards in this category present the sales and demand for the commercial spaces and high-end apartments. The construction company has two planned locations in mind: New York City and Los Angeles, so the cards contain data related to these two cities.

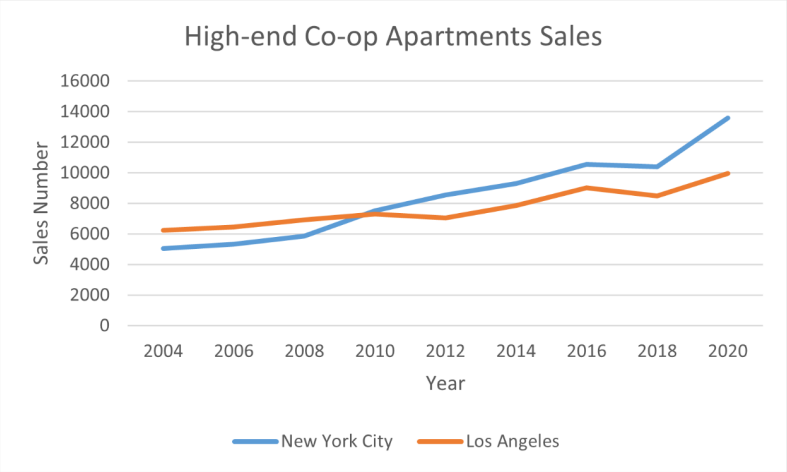


Figure 5.16: The repository card showing the graph on high-end apartment sales

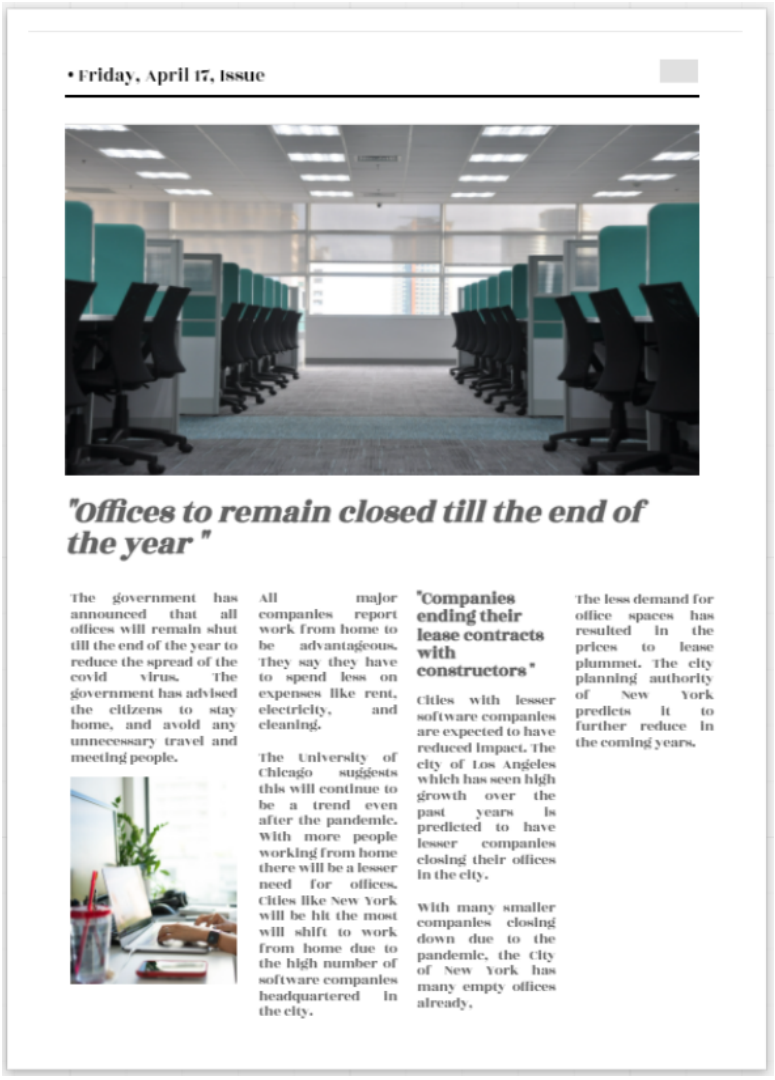
Shown in figure 5.16 is one of the repository cards providing the data in the form of a graph presenting the high-end apartment sales in the two cities. They give hints to the players about the demand for high-end apartments in the two cities. Similarly, the rest of the graphs provide players relevant information to fill in the summary slide and close the relevant knowledge gaps to make the right decisions. These cards are found in appendix B.

5.6.2 Newspaper Articles

Three newspaper articles were made for use as repository cards. These are articles with one page each containing fictional facts that would help support the decision-making process. One of the articles, seen in figure 5.17, refers to the facts that affect office leasing. It explains how the covid19 virus has forced people to work from home. The offices have remained shut for the past year and will continue to remain so. The government has advised the citizens to stay home, avoid necessary travel, and meeting people. The article further provides hints that the demand for office spaces will reduce over the coming years due to covid19. And companies are planning to let their employees work from home even after the global pandemic ends. It says, currently many office spaces in major cities around the United States of America are empty with no takers for them.

Another newspaper article similar to the demand for offices is on apartment prices, which can be found in appendix A.5. It explains how apartment prices have skyrocketed during the pandemic due to the demand and how it will stay on the higher side over the next few years. It says how the government is not able to build apartments

to keep up with the ever-increasing demand for apartments. The newspaper article blames it on covid19, more and more people are forced to work from home, and the people prefer moving to bigger spaces. New York and surrounding areas, including Manhattan Staten island, have reported the highest increase in apartment prices. Cities like Seattle, San Francisco, and Los Angeles have also reported increasing apartment prices, but only by a small margin.



• Friday, April 17, Issue

"Offices to remain closed till the end of the year"

The government has announced that all offices will remain shut till the end of the year to reduce the spread of the covid virus. The government has advised the citizens to stay home, and avoid any unnecessary travel and meeting people.

All major companies report work from home to be advantageous. They say they have to spend less on expenses like rent, electricity, and cleaning.

The University of Chicago suggests this will continue to be a trend even after the pandemic. With more people working from home there will be a lesser need for offices. Cities like New York will be hit the most will shift to work from home due to the high number of software companies headquartered in the city.

"Companies ending their lease contracts with constructors"

Cities with lesser software companies are expected to have reduced impact. The city of Los Angeles which has seen high growth over the past years is predicted to have lesser companies closing their offices in the city.

With many smaller companies closing down due to the pandemic, the City of New York has many empty offices already.

The less demand for office spaces has resulted in the prices to lease plummet. The city planning authority of New York predicts it to further reduce in the coming years.

Figure 5.17: The repository card on impact on office leasing

The third and final repository card with newspaper articles explains the skyscrapers' influence on cities. It supports skyscrapers by mentioning how it brings in huge revenue to the cities. They have been the core of tourism, attracting millions of people each year. Several examples of this are listed in the article. It says how Burj Khalifa, the current tallest skyscraper, has accomplished this by bringing big revenue to the UAE. It also says the trend of building tall skyscrapers continues, with many new skyscrapers in plans around the world, aiming to secure the title of the tallest building. This card, along with others, supports the decision of building the tallest skyscraper. But the players might also find other learnings or facts that

are against this. This repository card can be seen in appendix A.6.

5.6.3 General Information

The two cards under this category contain data that is not directly related to the decision to be made. These cards provide general information that is required to understand the skyscraper project better. The first card describes to the players about the plots' characteristics. It gives a background of the plots. Things like the locality, places of interest around the plot, accessibility, and so on are described in this card. The Skylight construction company has shortlisted 4 locations in the United States of America that are potentially suitable for the skyscraper. Two each in New York City and Los Angeles. These fictional plots are described as one in the residential and another in the industrial area for each city. The team, with the description, gets an idea of what each location is suitable for, whether a skyscraper with preference to residential spaces or commercial spaces. The repository card describing these plots is shown in figure 5.18.

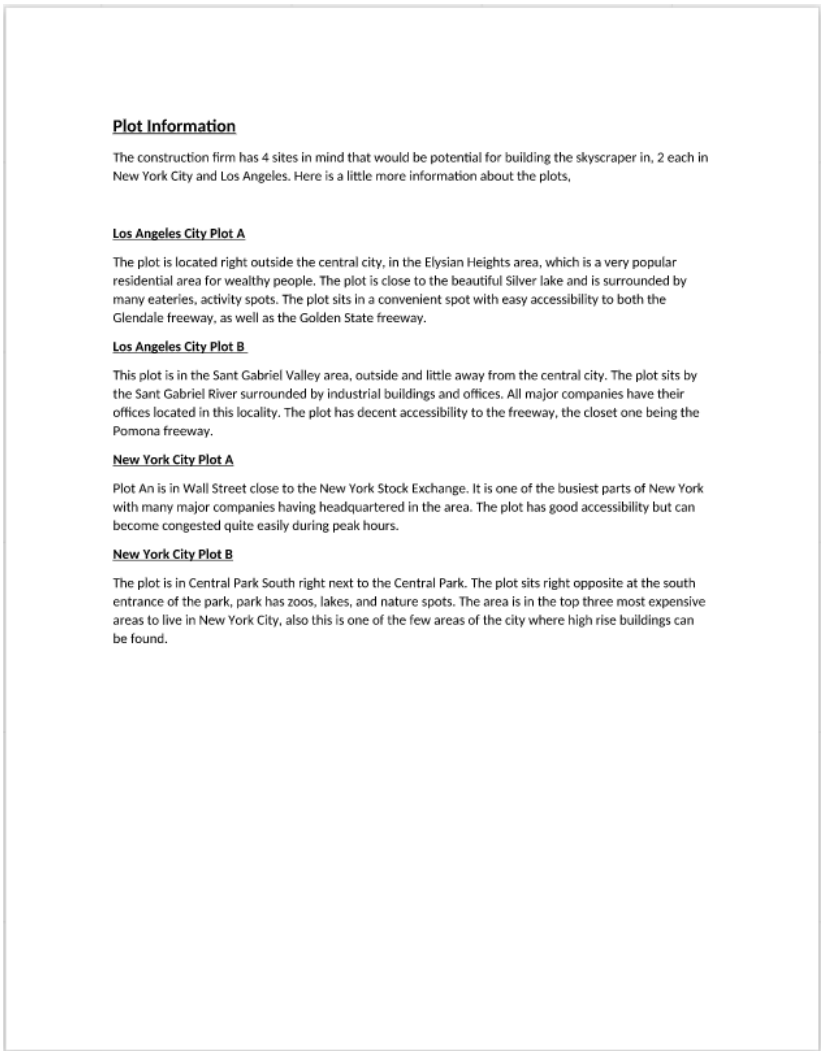


Figure 5.18: The repository card describing the plots

The second repository card is for the team to help collect facts on the current tallest skyscraper, the Burj Khalifa. It contains relevant facts such as the height of this skyscraper, along with other non-relevant facts which are not required for the simulation game. This repository card can be viewed in the appendix A.7.

5.6.4 Tests and Calculations

Nine cards were made for this category. It included cards related to soil tests, wind tests, and structural systems. Both soil test and wind test have four cards each. One each for the four plots. All the cards that are not shown here, can be found in Appendix B. In the soil test calculation, the players analyze the data provided by the company on the soil to decide which plot is suitable for the skyscraper construction and decide the type of piling system. The repository card with soil test calculation for Los Angeles plot A is shown in, figure 5.19 and figure 5.20.

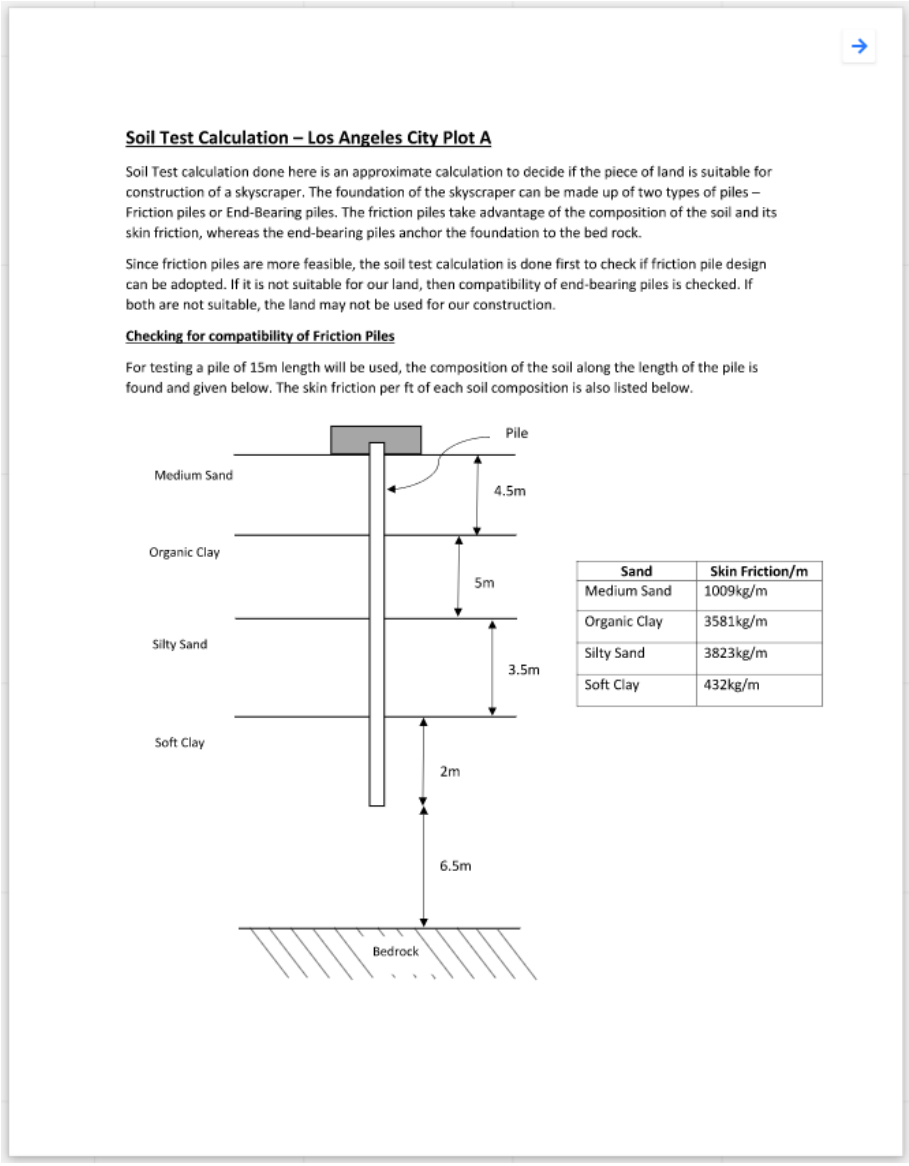
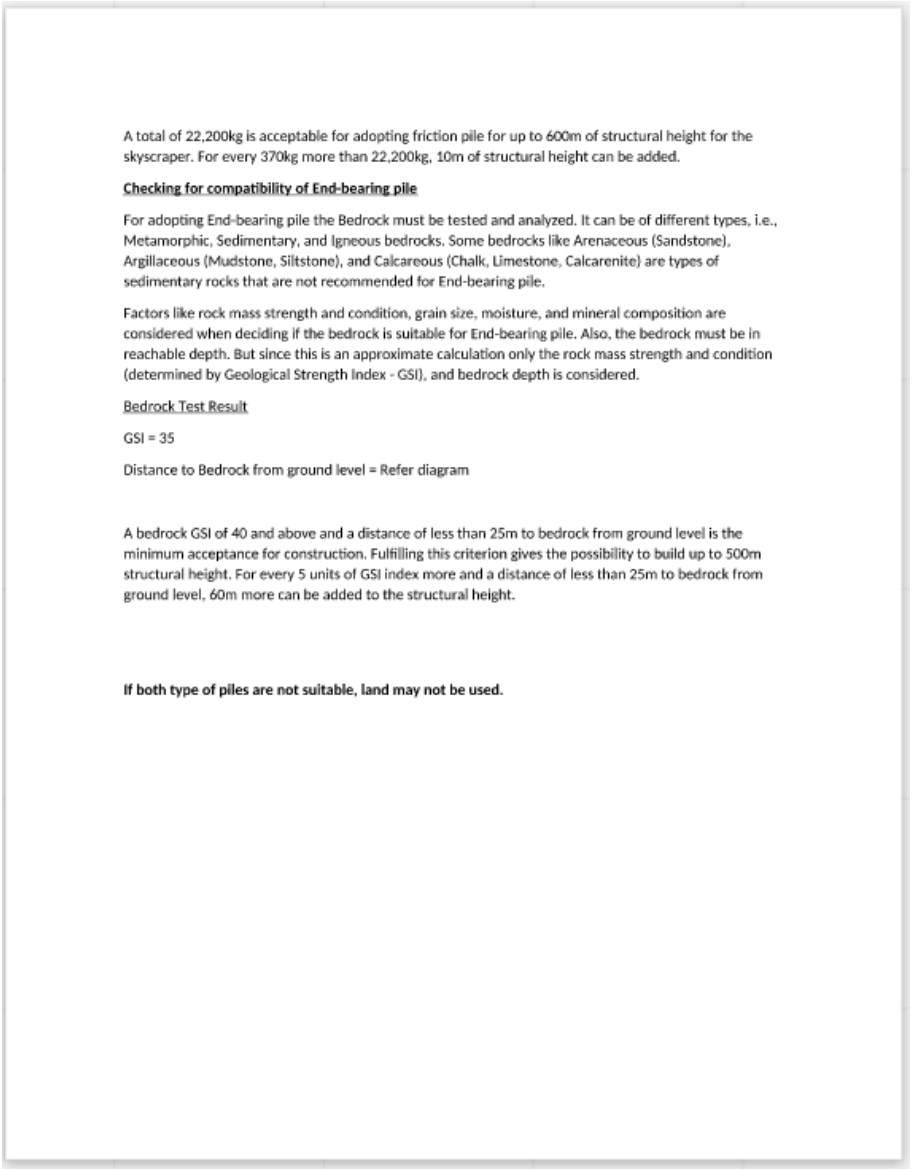


Figure 5.19: The repository card with soil test calculation for Los Angeles plot A



A total of 22,200kg is acceptable for adopting friction pile for up to 600m of structural height for the skyscraper. For every 370kg more than 22,200kg, 10m of structural height can be added.

Checking for compatibility of End-bearing pile

For adopting End-bearing pile the Bedrock must be tested and analyzed. It can be of different types, i.e., Metamorphic, Sedimentary, and Igneous bedrocks. Some bedrocks like Arenaceous (Sandstone), Argillaceous (Mudstone, Siltstone), and Calcareous (Chalk, Limestone, Calcarenite) are types of sedimentary rocks that are not recommended for End-bearing pile.

Factors like rock mass strength and condition, grain size, moisture, and mineral composition are considered when deciding if the bedrock is suitable for End-bearing pile. Also, the bedrock must be in reachable depth. But since this is an approximate calculation only the rock mass strength and condition (determined by Geological Strength Index - GSI), and bedrock depth is considered.

Bedrock Test Result

GSI = 35

Distance to Bedrock from ground level = Refer diagram

A bedrock GSI of 40 and above and a distance of less than 25m to bedrock from ground level is the minimum acceptance for construction. Fulfilling this criterion gives the possibility to build up to 500m structural height. For every 5 units of GSI index more and a distance of less than 25m to bedrock from ground level, 60m more can be added to the structural height.

If both type of piles are not suitable, land may not be used.

Figure 5.20: The repository card with soil test calculation for Los Angeles plot A

These repository cards on solving tell the players if the particular plot is suitable for building a skyscraper. And if so, what piling system can be used. The skyscraper can use either friction piles or end-bearing piles as its foundation. These repository cards on solving will also provide information on what is the maximum height possible for the skyscraper if it to be built in that plot. This information is needed to be filled in the summary slide.

The next set of cards on wind test calculation is similar to the ones on the soil. The results from these cards will also be considered to decide the type of piling system that will be used. They also provide important learning required to decide the type of structural system the skyscraper will have. Also, information for filling the summary slide can be found in these cards. The repository card on wind test calculation for Los Angeles Plot A can be found in figure 5.21.

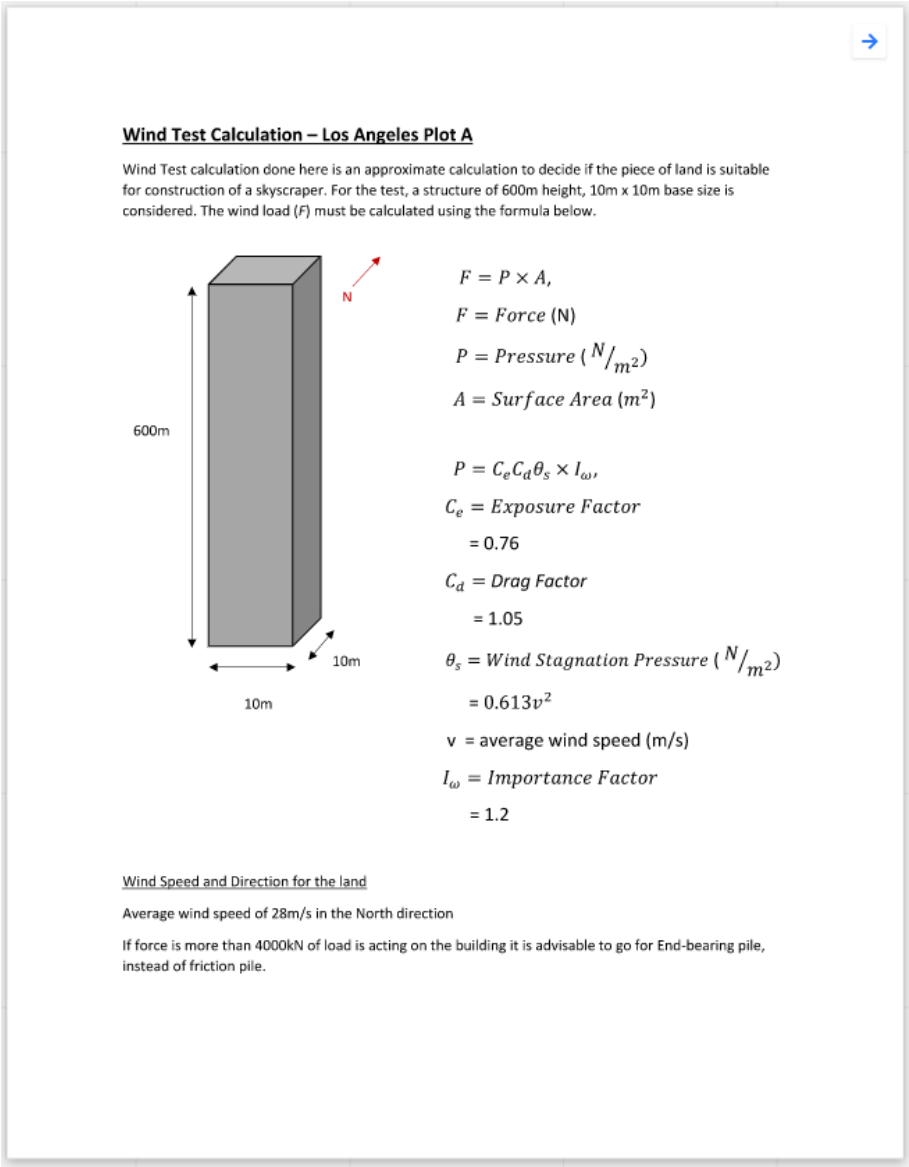


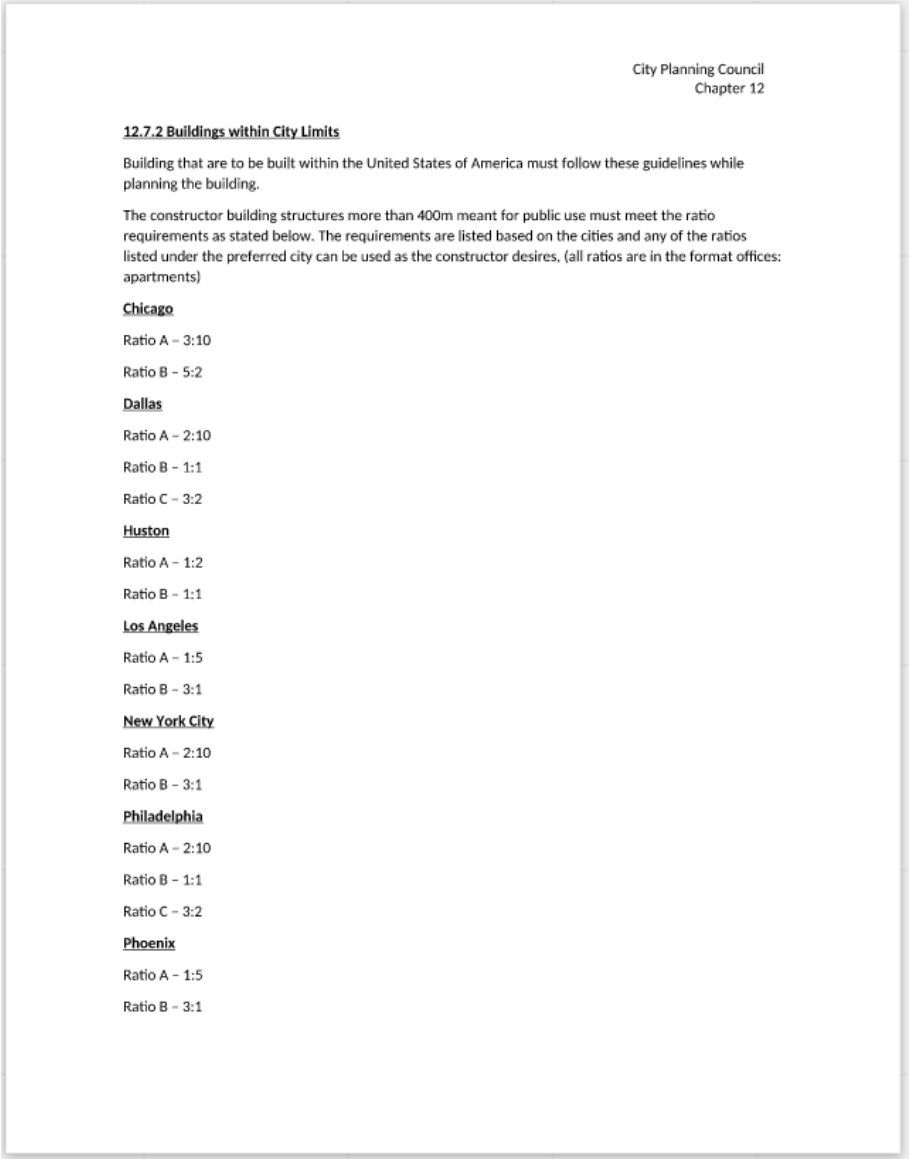
Figure 5.21: The repository card with wind test calculation for Los Angeles plot A

The final card in this category helps the players choose the structural system suitable for the skyscraper. From the hints that have been collected from other repository cards like soil test calculation and wind test calculation cards, the team can make the decision on which structural system to choose. The team has to decide between 5 different structural systems that are listed in the repository card, based on the height of the planned skyscraper and the wind load. This card can be viewed in the appendix A.17 and A.18.

5.6.5 Government Notices

The offices to apartments ratio rule is the only repository card under this category. It contains the information from the government regarding the offices to apartments ratios in the buildings constructed in the major cities around the United States of

America. This card was added to the collection of repository cards to ensure that the players do not plan all the skyscraper spaces with either only apartments or offices. A mix of both needed to be maintained. The players get to choose between 2 ratios in each city depending on their preference to have more apartments or more offices. Also, the players have to mention the offices to apartment ratio in the summary slide. Figure 5.22 shows the repository card containing this notice.



City Planning Council
Chapter 12

12.7.2 Buildings within City Limits

Building that are to be built within the United States of America must follow these guidelines while planning the building.

The constructor building structures more than 400m meant for public use must meet the ratio requirements as stated below. The requirements are listed based on the cities and any of the ratios listed under the preferred city can be used as the constructor desires, (all ratios are in the format offices: apartments)

Chicago

Ratio A – 3:10

Ratio B – 5:2

Dallas

Ratio A – 2:10

Ratio B – 1:1

Ratio C – 3:2

Huston

Ratio A – 1:2

Ratio B – 1:1

Los Angeles

Ratio A – 1:5

Ratio B – 3:1

New York City

Ratio A – 2:10

Ratio B – 3:1

Philadelphia

Ratio A – 2:10

Ratio B – 1:1

Ratio C – 3:2

Phoenix

Ratio A – 1:5

Ratio B – 3:1

Figure 5.22: The repository card with ratios on offices to apartments in major cities

All the repository cards discussed in this section were created so that the players put less effort into extracting the learning, but more on understanding and taking in the whole development process. Hence, some of the cards may have test and calculation that is not valid in reality.

5.7 Summary Slide

The summary slide on filling will give a complete summary of the results from the development process. It contains information other than the decisions made, those that are important for the construction company. It gives a brief idea about the plot selected, the height of the planned skyscraper, the office to apartment ratio, and so on. The summary slide is presented by the team to the company so that they can make use of it while working on the detailed plan and the design of the skyscraper.

The trainer can also review the summary sheet to understand how successful the team was in developing the skyscraper. The team is given an additional 10 minutes at the end of the game to finalize the information in the summary sheet before submitting it.

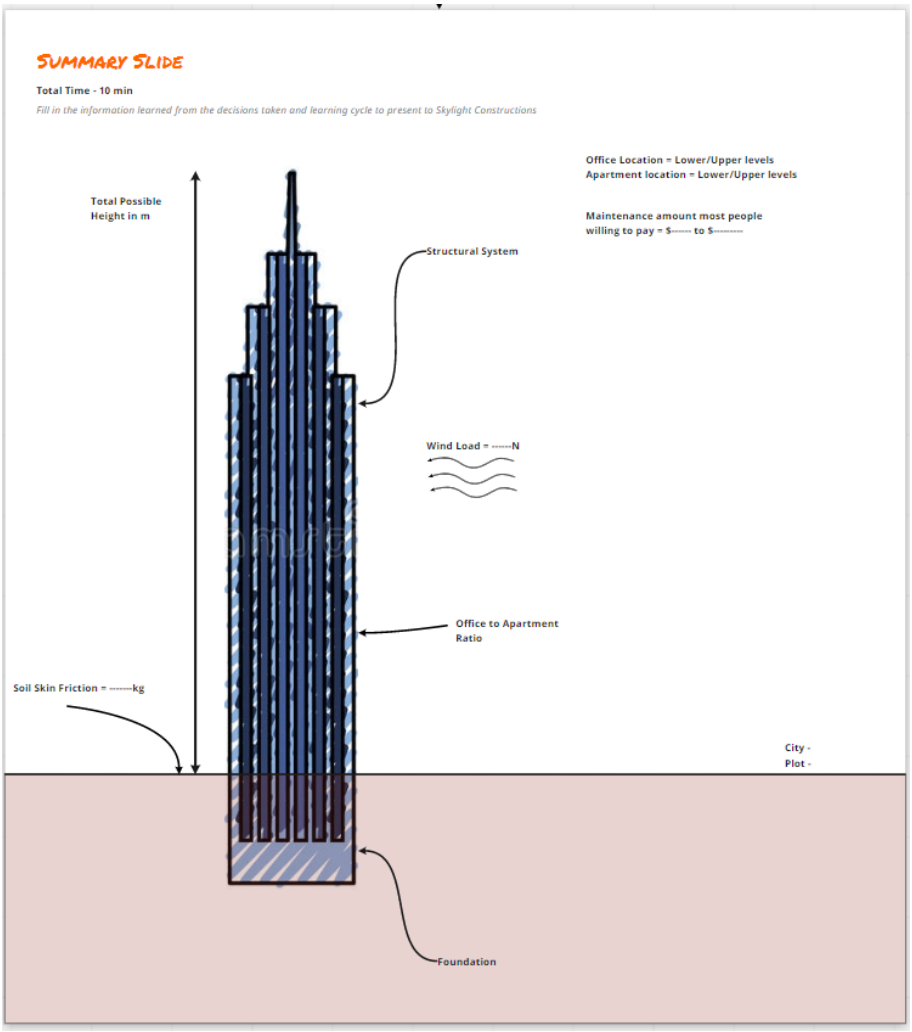


Figure 5.23: The summary slide the team needs to fill

The trainer can make changes to the summary sheet to push the players to add more information to the summary slide. It can be personalized and made sure that the players focus on specific parts of the learning or closing specific knowledge gaps.

6
Testing

This chapter describes the performed tests or game trials, what insight they gave, what conclusions could be drawn, and what changes could be made to improve the game's performance. The trial runs were limited to two due to the shortage of time. The objective of the trials was to prove the concept and get input for further improving the game performance.

6.1 Initial Test and its Findings

The initial test was run with the help of students from the Chalmers University of Technology. A group of four students volunteered to help run the game. The students had a background in product development and had good knowledge about the development processes. That made it possible to relate them to actual product developers in Philips Domestic Appliances and expect similar performance and knowledge as them. The group was new to the concepts that were involved in the game. They have never worked with learning cycles and time boxing. They were much more familiar with the traditional product development processes, similar to the employees at Philips Domestic Appliances.

The initial game test trial was successful. The players were happy about the results from the game and did manage to learn the concepts. But the game still required few improvements. The players' feedback was noted. Time management was the biggest improvement to be made. Since the game had several steps, when the team overshot the time in some of the steps by a few minutes each, the game time increased a lot. The required total game time was set at 3 hours, as decided earlier with Philips domestic appliances. But the initial test trial took close to 3 hours and forty minutes. Explaining the instructions was also another task that consumed a lot of time.

The team, when brainstorming the knowledge gaps, brought up ones on design, shape, and materials even though they were hinted the game will only include pre-development activities. They also had trouble formulating the knowledge gaps. The team listed the knowledge gaps as single words and found it hard when prioritizing and using them in the learning cycle. Another feedback from the players was on working with the Miro board. It sometimes did not work as predicted. The links in the slides and cards did not work as they should when they have moved. And navigating between steps was at times hard. The team also pointed out some of the

repository cards contained calculations that seemed a bit confusing. The team could not fill in the summary slide completely, as they did not do it from the beginning of the game. The team kept it aside, to do it at the end of the game. They missed out on collecting the learning for it from the repository cards.

Overall, it was a good trial run for the first try, and the concept was proven. A lot of time was wasted, as it was the first-ever trial. And the Miro board had shown some problems as well. Even still, time management needed to be improved. These problems have to be fixed before the game can be used for running the final testing.

6.1.1 Improvements and Changes

The improvements and changes made to the game were decided based on the feedback from the players and after discussion with Philips Domestic Appliances. Based on it, to tackle the time management, it was decided that it is best to send the instruction for the game beforehand to the players. This will give the players a background of the game, and also an idea about the different steps and their working. Also, the players should be instructed beforehand to try out the Miro board and learn the basics of operating it. The trainer can give just a walkthrough of the game body to help the players understand better. That saves a lot of time. It was also decided to adjust the time allotted currently based on the initial trial run.

Another change was to add a bit more detailed explanation on what it means by pre-development activities. That they do not include aspects like design, shape, and material. And these must not be considered as knowledge gaps. It was also decided the knowledge gaps will be listed in the form of questions for easier understanding and usage in the learning cycles. A change requested by Philips Domestic Appliances was on how the players use the repository cards. It was seen, in the initial game trial, the team picked all the repository cards even though they have not brainstormed knowledge gaps related to it. And they used repository cards to derive most of the knowledge gaps. To stop that from happening, the game step was changed a bit. The players will be allowed to access the repository cards only at the beginning of the learning cycles. That is, after the team creates the learning plan, they execute them. Then they get an additional 2 minutes to view the repository cards and pick the ones that are related to the knowledge gaps they will close in that specific learning cycle. This way, they are limited to pick only cards that they need. It was also decided to push the players a bit more to fill in the summary slide, along with the execution of the learning plan.

No changes were made to the layout of the game. It was decided to run another trial to check if the layout of the game needs to be changed. And, if the game can be made any easier and smoother for the players to operate. With these changes made, the game should perform better and should meet the time requirement.

6.2 Final Test and its Findings

The final test was held with the employees of Philips Domestic Appliances. A group of five employees played the game. And it was attended by leaders of advanced development. Most of the players had no prior knowledge of the concepts involved in the game. They were new to it. As per the changes made earlier, the instructions were prepared as slides and were sent to the players a day before the game. The players had a decent understanding of the game before starting the session. The game went well, with lesser troubles than the previous iteration of the trial. It was still not perfect. The team struggled to finish the whole game at the decided 3-hour mark. But the game trial gave some comprehensive feedback from the players and the leaders of advanced development at Philips.

The team and other attendees agreed the time management was not bad even though the team could not finish the game. It was mainly down to the struggle that had getting used to interface in Miro board. Time was also lost while executing the learning cycles. The team overshot the fixed time in the most iteration of the learning cycle. Another problem was that the players often strayed away from the desired game path. While prioritizing the knowledge gaps, the team found it was hard to do it based on the weighted shortest job first approach. Some of the knowledge gaps were categorized into *Do now*, *Do next*, and *Do later* based on the players' intuition.

The team had trouble creating the learning plan. They found it hard and time-consuming to drag the basic boxes and create the learning plan. They also did not place the decisions first in the learning plan, even though it was hinted at in the instructions. That is important because the decisions must be made in the last responsible moment and should not be pushed beyond that time frame. They must be placed first, and then the players must push to close the knowledge gaps related to the decision before that last responsible moment.

6.2.1 Improvements and Changes

The biggest change was made in how the learning plan is created. It was completely changed to make it easier for the players. Since the players found it hard to copy and drag the basic boxes to create their learning plan, a learning plan structure was made. As seen in the figure 6.1, this step requires the players to fill in the boxes with the knowledge gaps and the decisions.

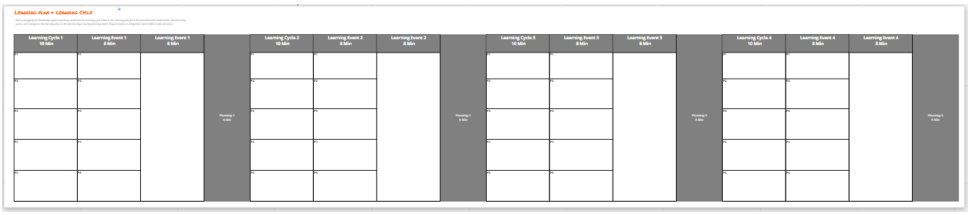


Figure 6.1: The new learning plan slide

The trainer will also push the players to place the decisions first, then the knowledge gaps. The knowledge gaps must be placed based on the prioritization, i.e., knowledge gaps under *Do now* are placed first, then ones under *Do later*, and so on.

It was clear that the game was complicated. And the players could often stray away from the game path. It was, therefore, decided the players must be guided and given hints wherever necessary to stop this from happening. The time constraint for each step must be forced strictly to prevent players from overshooting. The trainer must introduce the players to the Miro board to make it easier for them to work on it. More links were added, especially to the repository cards for the players to navigate back to the game body faster and easier.

A criticality matrix, as seen in figure 6.2, was added to the game to make it easier for the players to prioritize the knowledge gaps based on the weighted shortest job first. The matrix shows clearly how each of the knowledge gaps has to be prioritized into *Do now*, *Do next*, and *Do later*.

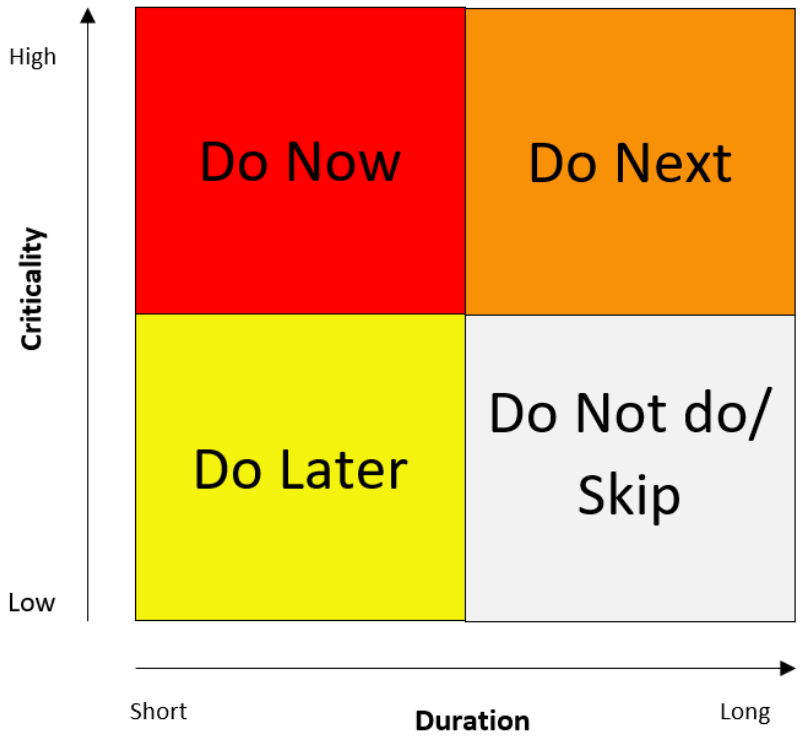


Figure 6.2: The criticality matrix for prioritizing based on WSJF

7
Discussion

The results from the development of the game and the iteration of its testing are discussed in this session. A few factors limiting the performance of the game are also discussed.

7.1 Results

From the game trial results, it was seen that the game was nowhere close to perfect. There are more improvements to be made to the game to get the maximum results out of it. The game also struggles to run under the fixed 3-hour time period. The game has succeeded in meeting most of the requirements set by Philips Domestic Appliances. The game managed to train the players well in most of the concepts in the learning objectives. The game, as intended, works well online except for a few niggles from the game platform- Miro board. That could be potentially fixed over a few test iterations. The game, but as required, is not the simplest and easy to follow. With a handful of concepts to teach, the game is a bit complicated.

The instruction was clear and concise. The players, along with the walkthrough of the game body, understood the game instructions very well. The time allotted for all the sections was adequate for the players to finish the step, but the trainer had to keep a strict check of the time and push the players to continue to the next step. With the game a bit complex, it was noticed the players sometimes stray away from the game path. They have to be guided wherever required, through hints and explanations to avoid this.

The game was overall a success. But it has to go further to be perfect. More improvements have to be made, the feedback from the players will help achieve it. Each time the game is run, its performance directly depends on the trainer. Only a good trainer can guide the players through the game and help them learn the concepts. Another factor is the ease with which the player can operate in the game platform. The layout and the general mechanism of the game affect its performance. These have to be bettered over time with the player feedback.

7.2 Limitations

The whole thesis was conducted from home due to covid19. That limited the interaction with the company. More inputs and feedback on the game could have been

received if it was conducted at the site along with the team at Philips Domestic Appliances. Another limiting factor was time. With the allotted time, only two iterations of the game trial were possible. The game would have seen major improvements and could have met all the requirements if a few more iterations were run.

Most employees are not used to the interface and controls on the Miro board. That was a drawback. They struggled to with the functions, like dragging boxes and scrolling through the board. They often managed to accidentally move around content in the game, which they are not supposed to, altering the whole structure of the game. Players with prior knowledge of operating the Miro board would potentially perform better.

Even though the game was designed to run online, the game would perform significantly better if run offline. More player-to-player and player-to-trainer interactions would take place offline. And some problems faced from the game platform could be removed completely. Also, players when playing the game from the same location can connect much efficiently and the game could produce better results.

8

Recommendation

This chapter explains the recommendation to Philips Domestics Appliances regarding further development, in which direction Philips takes the simulation game.

8.1 Further Development

Further development can take place only with continuous game trials. The players' feedback has to be collected, and improvements have to be made based on that. The players can let the trainer know what steps they struggled with and the concepts they found hard to follow. Changes to these parts of the game have to be made. Only with these consistent improvements, the game can be bettered. The feedback from the players on the layout is relevant too. Changes can be made to the game layout to make it easier and smoother for future users. Discussion with the players after finishing the game has to be conducted. It will give a clear idea of how well the game is performing. It will let the trainer understand if the players have successfully learned the concepts or not.

Guiding the players through the game is a huge factor in the success of the game. Only a person who has adequate knowledge of the concepts can push the players in the right direction to help them learn the process and the mindsets involved. Hints and explanations have to be given at the right stages to players. They have to be pulled back to the game path if they stray away from it. The person guiding the players must be trained well in the concepts. They should understand the mindsets before conducting the game. They should also be able to keep a good check of time in each step and should be able to push the players to the next step before the time ends.

Philips has to try running the game offline. As discussed in the previous chapter, the game will show better results. The game slides and repository cards can be made with paper for this. The game can be used as it is on the Miro board, using the same steps and instructions. That could accommodate better interaction between the players, and they would perform better. It would be easier for the trainer to interact and guide the players. Also, the players will have less trouble and time wasted on learning to navigate and interact with the Miro board.

The game has to be strictly constrained to use for a single team of 4 to 5 members. As designed, the skyscraper game is meant for a team of product developers. The

team will perform better if the players have experience working with each other. If so, they would interact with each other more, and the discussions would be healthier. Also, the concepts they learn from the game will be used by the players together in developing products in the new simplified development process.

9
Conclusion

The thesis project did succeed in delivering a concept with a working prototype of the simulation game. But the game has not met all the requirements and desires of the requirement list in chapter 3. Even though these have not fully been fulfilled, they have been taken into consideration throughout the whole project. The result is the game should potentially achieve these requirements and desires with further development and testing.

9.1 The Simulation Game

The developed simulation game on testing proved the concept, but it is far from being a finished product. It needs further development through testing and feedback. In the game trial tests, the players enjoyed the game. They managed to learn the concepts, but not to a complete extend. The game has many learning objectives, as listed in chapter 3, that it is trying to teach the players. Along with problems faced with the game platform, these have made the game complex than anticipated initially. These need to be rectified by running more game trials with the employees in the company.

The project failed to fulfill the requirement of running below the 3-hour mark. This can be met with the improvements made in the game through the feedback from the players. Other requirements, like the simulation game must be simple and easy to follow, can be met too through this.

9.2 The Company

By optimizing the game through running game trials, Philips Domestic Appliances can achieve the goal of training the employees using this simulation game. It would be a fun and interesting way of training that a company can opt for to reap the maximum results. With the simulation game, the company can facilitate the smooth transition from the old development process to the new. The employees would also learn the new development process and the concepts in it faster and more efficiently with this simulation game. The simulation game from this project could be one of the many steps that Philips would take towards the successful transition to the new process and develop market-leading products using innovative ideas.

Bibliography

[1] Wikimedia Foundation. (2021, October 30). *Philips*. Wikipedia. Retrieved August 20, 2021, from https://en.wikipedia.org/wiki/Philips.

[2] *Philips. (n.d.). 2021.* Philips News Center. Retrieved August 14, 2021, from https://www.philips.com/a-w/about/news/archive/standard/news/press/2021.

[3] *What is Timeboxing?: How is Timeboxing used in Scrum?: Scrum Inc.*. Scrum Inc. (2020, November 16). Retrieved July 4, 2021, from https://www.scruminc.com/what-is-timeboxing/.

[4] Cobb, C. G. (2015). *The Project Manager's Guide to Mastering Agile: Principles and practices for an adaptive approach*. John Wiley Sons.

[5] Dixon, N. M. (1994). *The Organizational Learning Cycle: How We Can Learn collectively*. McGraw-Hill Book Co.

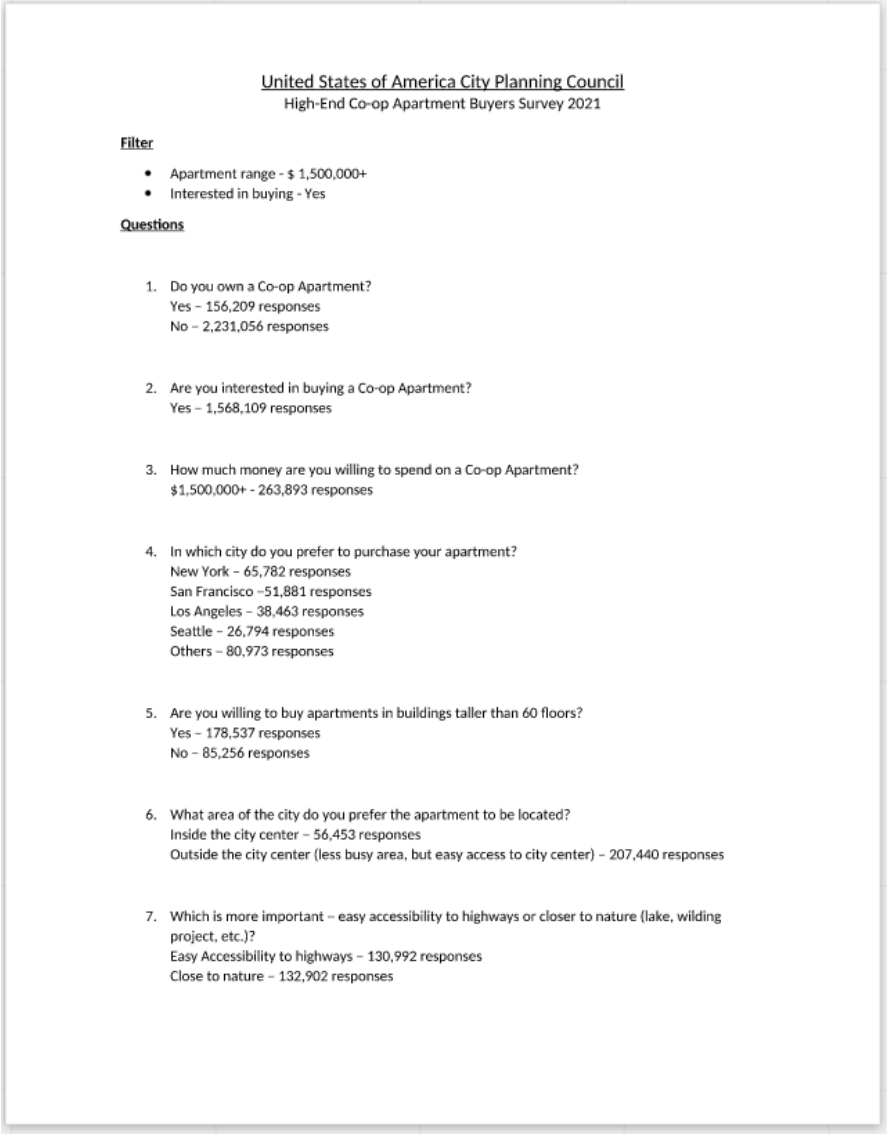
[6] Radeka, K. (2017). *The shortest distance between you and your new product: How innovators use rapid learning cycles to get their best ideas to market faster*. Chesapeake Research Press.

[7] Rajapakse, R. (2016). Chapter 13 - Pile settlement. In *Pile design and construction rules of thumb*. essay, Butterworth-Heinemann.

[8] WikiHow. (2020, May 25). *How to calculate wind load*. WikiHow. Retrieved July 2, 2021, from https://www.wikihow.com/Calculate-Wind-Load.

A

Repository Cards



United States of America City Planning Council
High-End Co-op Apartment Buyers Survey 2021

Filter

- Apartment range - $ 1,500,000+
- Interested in buying - Yes

Questions

1. Do you own a Co-op Apartment?
   Yes – 156,209 responses
   No – 2,231,056 responses

2. Are you interested in buying a Co-op Apartment?
   Yes – 1,568,109 responses

3. How much money are you willing to spend on a Co-op Apartment?
   $1,500,000+ - 263,893 responses

4. In which city do you prefer to purchase your apartment?
   New York – 65,782 responses
   San Francisco –51,881 responses
   Los Angeles – 38,463 responses
   Seattle – 26,794 responses
   Others – 80,973 responses

5. Are you willing to buy apartments in buildings taller than 60 floors?
   Yes – 178,537 responses
   No – 85,256 responses

6. What area of the city do you prefer the apartment to be located?
   Inside the city center – 56,453 responses
   Outside the city center (less busy area, but easy access to city center) – 207,440 responses

7. Which is more important – easy accessibility to highways or closer to nature (lake, wilding project, etc.)?
   Easy Accessibility to highways – 130,992 responses
   Close to nature – 132,902 responses

Figure A.1: The repository card on High-end apartment buyers survey

Figure A.2: The repository card on the graph showing the predicted GDP growth of USA

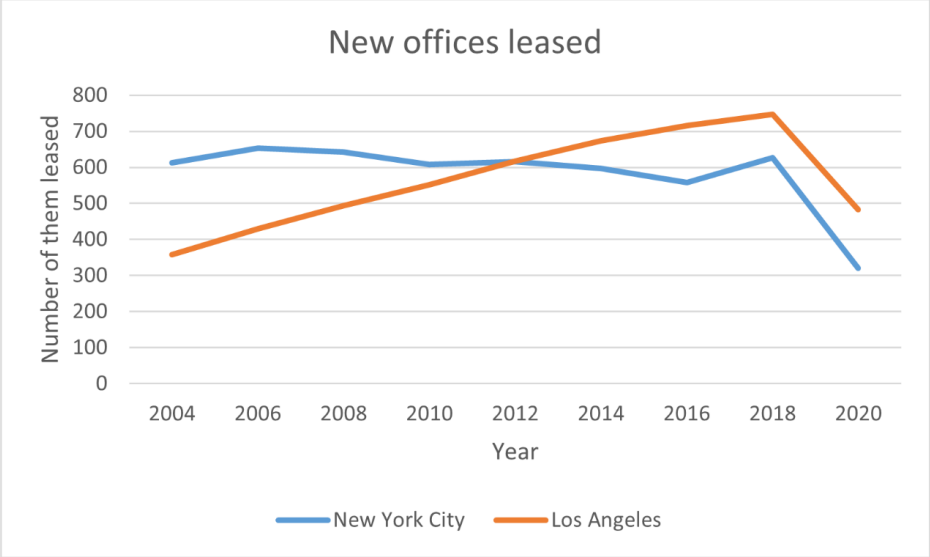


Figure A.3: The repository card showing the graph on new offices leased

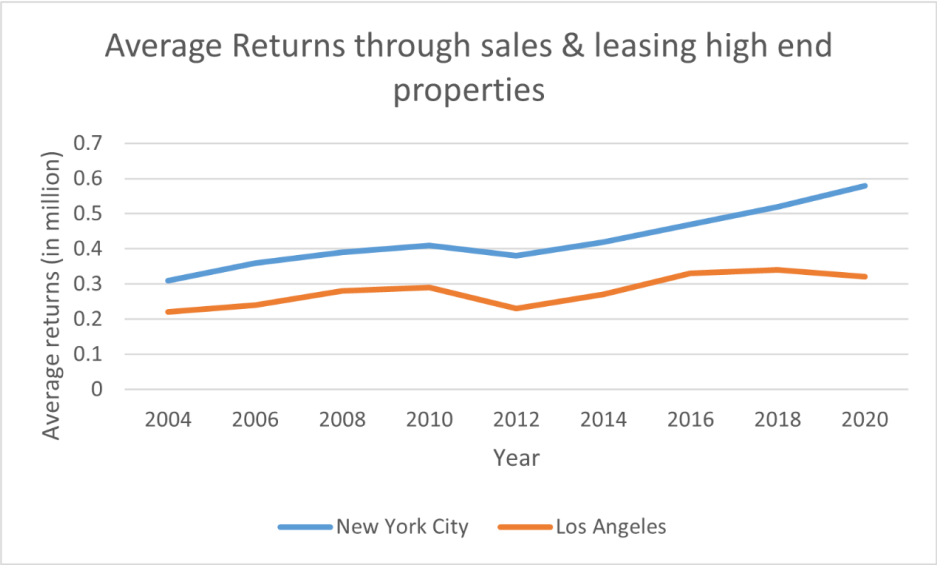


Figure A.4: The repository card showing the graph on Average returns through sales

New York City Newspaper • Monday, March 15, Issue

CITY NEWS

Economic Times

"Apartment prices skyrocket as demand increases."

Following COVID19 restrictions coming into place in February of last year, all nonessential workers were instructed to work from home. With millions of people working from home, the demand for houses has gone up drastically. This has shot up the value of properties by almost 150%. The US housing society suggests this could be because of multiple individuals from each household working from home. This brings in the need for more space for each family, and most of them are looking to upgrade to bigger apartments. People currently staying in rented apartments are also trying to secure their own houses.

"The demand for houses and apartments are gone keep increasing during the coming years"

As working from home has been happening for more than a year, major software companies are reporting it to be successful. Companies have also been saving a lot of money on electricity, rent, and other expenses. Most major companies are suggesting the idea to continue with work from home even after the pandemic and running only the important departments from offices.

"City-wise surveys report an increase in property prices in every major city, city planning not able deliver with demand."

New York City and the surrounding areas including Manhattan and Staten Island have reported the highest increase in property prices. Closely followed by Chicago. Cities like Seattle, San Francisco, and Los Angeles have reported price increase, but only by a smaller margin.

Figure A.5: The repository card on impact on apartment demand

ISSUE 15, JUNE 2021 DAILY AMERICA

Skyscrapers' influence on cities' roles as a tourist destination

8 June 2021

Skyscrapers are nowadays a major point of attraction in major cities. Tall buildings have been the base of tourism for big cities over the past decade. The current tallest skyscraper - The Burj Khalifa, has over 1.87 million visitors every year.

Countries such as UAE have become huge tourist attractions and make a lot of revenue from this. Tall skyscrapers which are part of the country play a big role in contributing towards it.

Emaar Properties, the owners of Burj Khalifa recorded a net profit of $1.55B in 2017, part of which is from their high-rise buildings in the UAE.

It is seen that just from holding the record for the tallest building in the world, Burj Khalifa has been the center of attraction welcoming millions of tourists from every part of the world each year. With this other rich countries are in plans to build tall skyscrapers and snatch the tallest building crown from Burj Khalifa. The Burj Mubarak in Kuwait, The Jeddah Tower in Saudi Arabia, Dubai Creek Tower in Dubai, and The Sky Mile Tower in Tokyo are the upcoming skyscrapers in the near future. It is to be seen how many projects make it into reality, but with the added benefits of building one, every project looks promising.

Thousands of people can be employed in these tall skyscrapers. A variety of jobs in maintenance, security, etc., opens up.

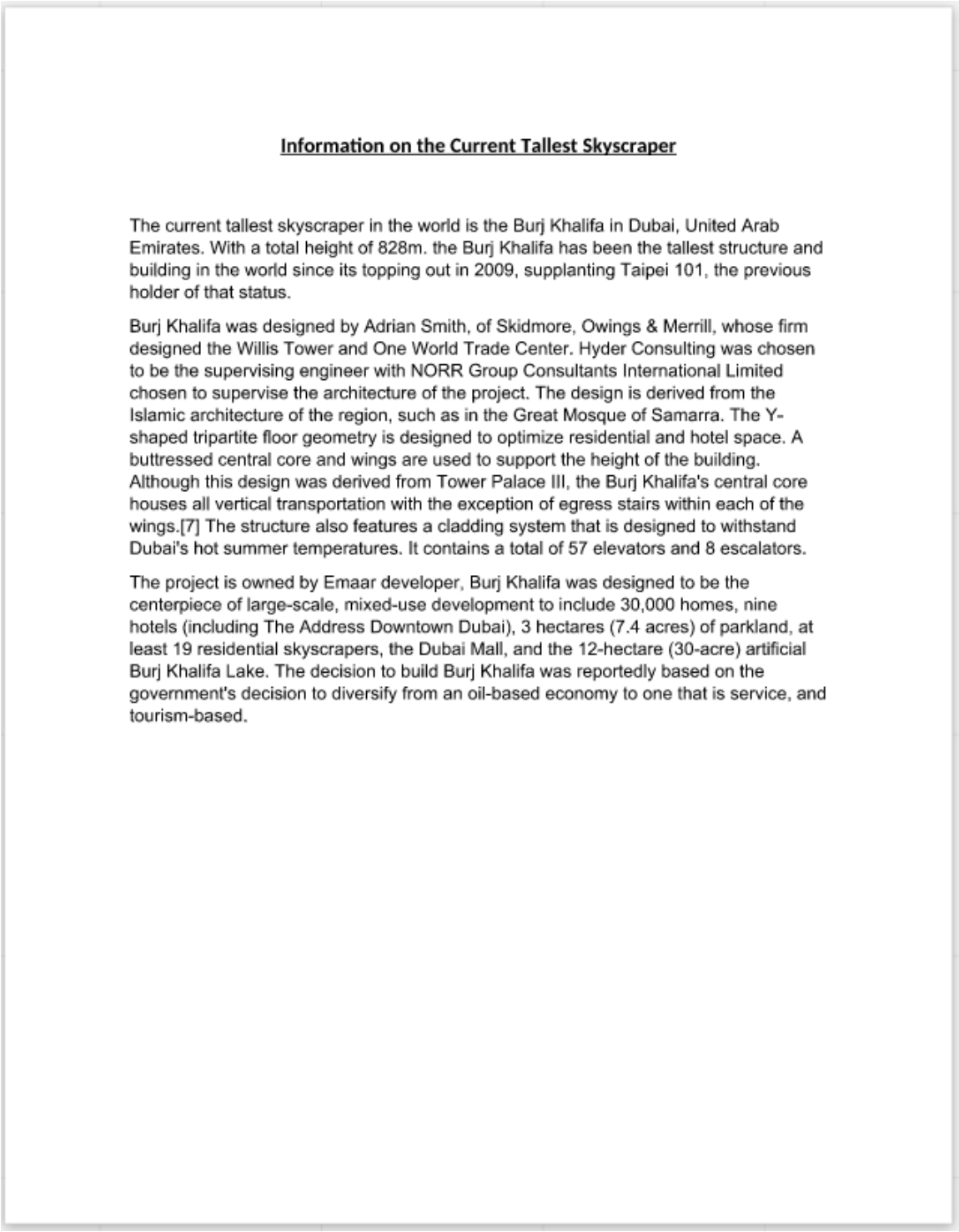
The Burj Khalifa every year collects 15 million gallons of water sustainably. The water is used for irrigation to water the landscaping and plants, for the cooling system, and to supply the Dubai Fountain.

Specialists predict a huge economic boom coming, market values will go up rapidly, and tourism will be better than ever.

The local government hence forth supports projects like these, more over it will help the local government generate a lot of revenue from it. These new buildings are also moving towards sustainability, which is a win-win for everyone.

Suddenly, it seems to be a good idea to build a skyscraper! All the plus seems to add up and most countries doing well with the economy even amidst corona. Global economy specialists are reporting to see a huge boom in the economy

Figure A.6: The repository card on skyscrapers' influence on cities



Information on the Current Tallest Skyscraper

The current tallest skyscraper in the world is the Burj Khalifa in Dubai, United Arab Emirates. With a total height of 828m. the Burj Khalifa has been the tallest structure and building in the world since its topping out in 2009, supplanting Taipei 101, the previous holder of that status.

Burj Khalifa was designed by Adrian Smith, of Skidmore, Owings & Merrill, whose firm designed the Willis Tower and One World Trade Center. Hyder Consulting was chosen to be the supervising engineer with NORR Group Consultants International Limited chosen to supervise the architecture of the project. The design is derived from the Islamic architecture of the region, such as in the Great Mosque of Samarra. The Y-shaped tripartite floor geometry is designed to optimize residential and hotel space. A buttressed central core and wings are used to support the height of the building. Although this design was derived from Tower Palace III, the Burj Khalifa's central core houses all vertical transportation with the exception of egress stairs within each of the wings.[7] The structure also features a cladding system that is designed to withstand Dubai's hot summer temperatures. It contains a total of 57 elevators and 8 escalators.

The project is owned by Emaar developer, Burj Khalifa was designed to be the centerpiece of large-scale, mixed-use development to include 30,000 homes, nine hotels (including The Address Downtown Dubai), 3 hectares (7.4 acres) of parkland, at least 19 residential skyscrapers, the Dubai Mall, and the 12-hectare (30-acre) artificial Burj Khalifa Lake. The decision to build Burj Khalifa was reportedly based on the government's decision to diversify from an oil-based economy to one that is service, and tourism-based.

Figure A.7: The repository card with information of the current tallest building

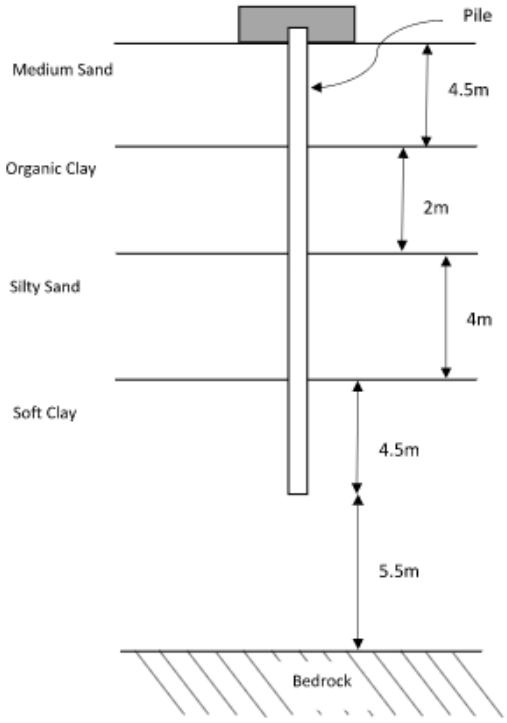
Soil Test Calculation – Los Angeles City Plot B

Soil Test calculation done here is an approximate calculation to decide if the piece of land is suitable for construction of a skyscraper. The foundation of the skyscraper can be made up of two types of piles – Friction piles or End-Bearing piles. The friction piles take advantage of the composition of the soil and its skin friction, whereas the end-bearing piles anchor the foundation to the bed rock.

Since friction piles are more feasible, the soil test calculation is done first to check if friction pile design can be adopted. If it is not suitable for our land, then compatibility of end-bearing piles is checked. If both are not suitable, the land may not be used for our construction.

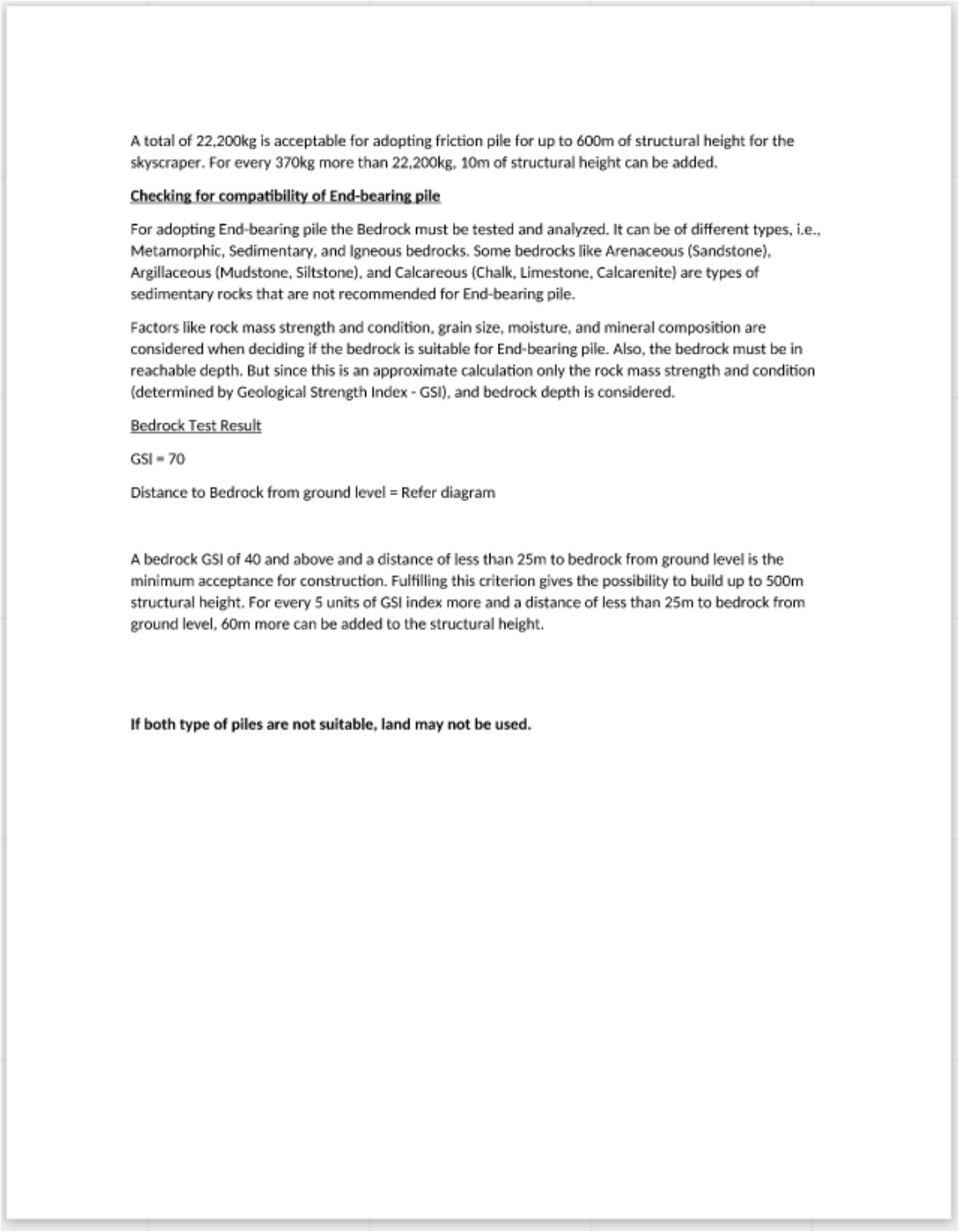
Checking for compatibility of Friction Piles

For testing a pile of 15m length will be used, the composition of the soil along the length of the pile is found and given below. The skin friction per ft of each soil composition is also listed below.



Sand	Skin Friction/m
Medium Sand	601kg/m
Organic Clay	1935kg/m
Silty Sand	3473kg/m
Soft Clay	242kg/m

Figure A.8: The repository card with soil test calculation for Los Angeles plot B



A total of 22,200kg is acceptable for adopting friction pile for up to 600m of structural height for the skyscraper. For every 370kg more than 22,200kg, 10m of structural height can be added.

Checking for compatibility of End-bearing pile

For adopting End-bearing pile the Bedrock must be tested and analyzed. It can be of different types, i.e., Metamorphic, Sedimentary, and Igneous bedrocks. Some bedrocks like Arenaceous (Sandstone), Argillaceous (Mudstone, Siltstone), and Calcareous (Chalk, Limestone, Calcarenite) are types of sedimentary rocks that are not recommended for End-bearing pile.

Factors like rock mass strength and condition, grain size, moisture, and mineral composition are considered when deciding if the bedrock is suitable for End-bearing pile. Also, the bedrock must be in reachable depth. But since this is an approximate calculation only the rock mass strength and condition (determined by Geological Strength Index - GSI), and bedrock depth is considered.

Bedrock Test Result

GSI = 70

Distance to Bedrock from ground level = Refer diagram

A bedrock GSI of 40 and above and a distance of less than 25m to bedrock from ground level is the minimum acceptance for construction. Fulfilling this criterion gives the possibility to build up to 500m structural height. For every 5 units of GSI index more and a distance of less than 25m to bedrock from ground level, 60m more can be added to the structural height.

If both type of piles are not suitable, land may not be used.

Figure A.9: The repository card with soil test calculation for Los Angeles plot B

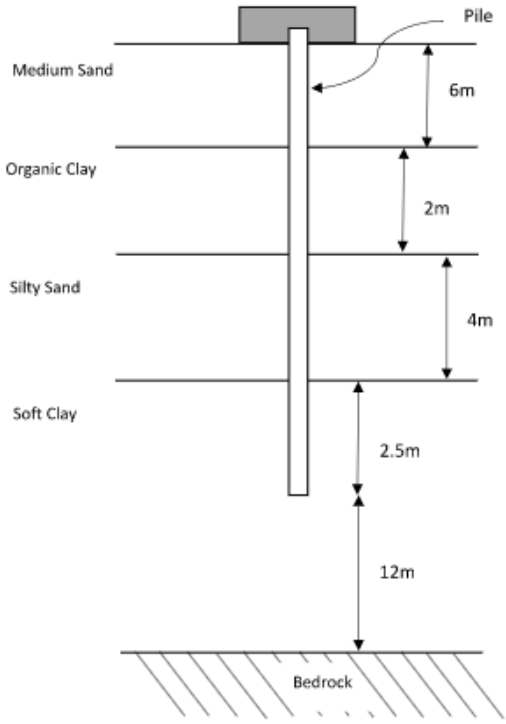
Soil Test Calculation - New York City Plot A

Soil Test calculation done here is an approximate calculation to decide if the piece of land is suitable for construction of a skyscraper. The foundation of the skyscraper can be made up of two types of piles – Friction piles or End-Bearing piles. The friction piles take advantage of the composition of the soil and its skin friction, whereas the end-bearing piles anchor the foundation to the bed rock.

Since friction piles are more feasible, the soil test calculation is done first to check if friction pile design can be adopted. If it is not suitable for our land, then compatibility of end-bearing piles is checked. If both are not suitable, the land may not be used for our construction.

Checking for compatibility of Friction Piles

For testing a pile of 15m length will be used, the composition of the soil along the length of the pile is found and given below. The skin friction per ft of each soil composition is also listed below.



Sand	Skin Friction/m
Medium Sand	765kg/m
Organic Clay	2012kg/m
Silty Sand	3064kg/m
Soft Clay	317kg/m

Figure A.10: The repository card with soil test calculation for New York plot A

A total of 22,200kg is acceptable for adopting friction pile for up to 600m of structural height for the skyscraper. For every 370kg more than 22,200kg, 10m of structural height can be added.

Checking for compatibility of End-bearing pile

For adopting End-bearing pile the Bedrock must be tested and analyzed. It can be of different types, i.e., Metamorphic, Sedimentary, and Igneous bedrocks. Some bedrocks like Arenaceous (Sandstone), Argillaceous (Mudstone, Siltstone), and Calcareous (Chalk, Limestone, Calcarenite) are types of sedimentary rocks that are not recommended for End-bearing pile.

Factors like rock mass strength and condition, grain size, moisture, and mineral composition are considered when deciding if the bedrock is suitable for End-bearing pile. Also, the bedrock must be in reachable depth. But since this is an approximate calculation only the rock mass strength and condition (determined by Geological Strength Index - GSI), and bedrock depth is considered.

Bedrock Test Result

GSI = 65

Distance to Bedrock from ground level = Refer diagram

A bedrock GSI of 40 and above and a distance of less than 25m to bedrock from ground level is the minimum acceptance for construction. Fulfilling this criterion gives the possibility to build up to 500m structural height. For every 5 units of GSI index more and a distance of less than 25m to bedrock from ground level, 60m more can be added to the structural height.

If both type of piles are not suitable, land may not be used.

Figure A.11: The repository card with soil test calculation for New York plot A

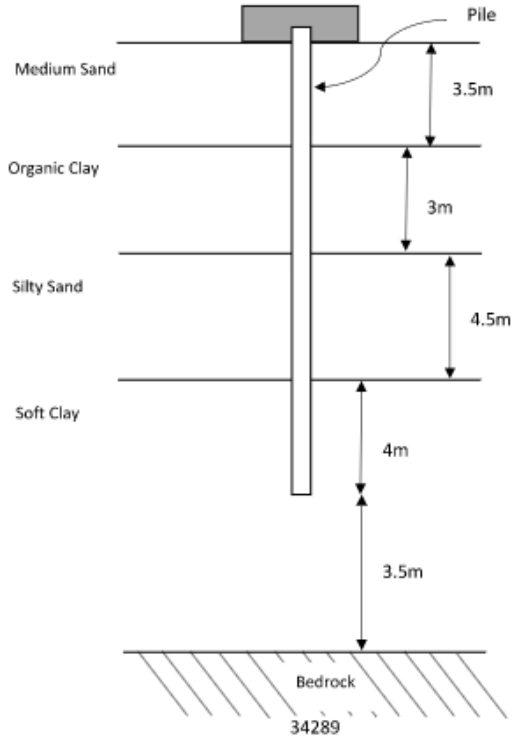
Soil Test Calculation - New York City Plot B

Soil Test calculation done here is an approximate calculation to decide if the piece of land is suitable for construction of a skyscraper. The foundation of the skyscraper can be made up of two types of piles – Friction piles or End-Bearing piles. The friction piles take advantage of the composition of the soil and its skin friction, whereas the end-bearing piles anchor the foundation to the bed rock.

Since friction piles are more feasible, the soil test calculation is done first to check if friction pile design can be adopted. If it is not suitable for our land, then compatibility of end-bearing piles is checked. If both are not suitable, the land may not be used for our construction.

Checking for compatibility of Friction Piles

For testing a pile of 15m length will be used, the composition of the soil along the length of the pile is found and given below. The skin friction per ft of each soil composition is also listed below.



Sand	Skin Friction/m
Medium Sand	910kg/m
Organic Clay	2338kg/m
Silty Sand	5029kg/m
Soft Clay	365kg/m

Figure A.12: The repository card with soil test calculation for New York plot B

A total of 22,200kg is acceptable for adopting friction pile for up to 600m of structural height for the skyscraper. For every 370kg more than 22,200kg, 10m of structural height can be added.

Checking for compatibility of End-bearing pile

For adopting End-bearing pile the Bedrock must be tested and analyzed. It can be of different types, i.e., Metamorphic, Sedimentary, and Igneous bedrocks. Some bedrocks like Arenaceous (Sandstone), Argillaceous (Mudstone, Siltstone), and Calcareous (Chalk, Limestone, Calcarenite) are types of sedimentary rocks that are not recommended for End-bearing pile.

Factors like rock mass strength and condition, grain size, moisture, and mineral composition are considered when deciding if the bedrock is suitable for End-bearing pile. Also, the bedrock must be in reachable depth. But since this is an approximate calculation only the rock mass strength and condition (determined by Geological Strength Index - GSI), and bedrock depth is considered.

Bedrock Test Result

GSI = 55

Distance to Bedrock from ground level = Refer diagram

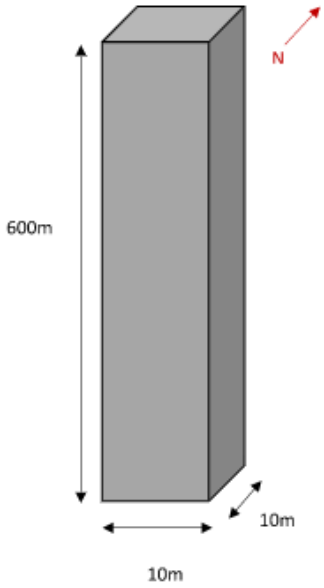
A bedrock GSI of 40 and above and a distance of less than 25m to bedrock from ground level is the minimum acceptance for construction. Fulfilling this criterion gives the possibility to build up to 500m structural height. For every 5 units of GSI index more and a distance of less than 25m to bedrock from ground level, 60m more can be added to the structural height.

If both type of piles are not suitable, land may not be used.

Figure A.13: The repository card with soil test calculation for New York plot B

Wind Test Calculation – Los Angeles Plot B

Wind Test calculation done here is an approximate calculation to decide if the piece of land is suitable for construction of a skyscraper. For the test, a structure of 600m height, 10m x 10m base size is considered. The wind load (*F*) must be calculated using the formula below.



$F = P \times A,$

$F = Force$ (N)

$P = Pressure\ (^{N}/_{m^2})$

$A = Surface\ Area\ (m^2)$

$P = C_e C_d \theta_s \times I_\omega,$

$C_e = Exposure\ Factor$

= 0.83

$C_d = Drag\ Factor$

= 1.05

$\theta_s = Wind\ Stagnation\ Pressure\ (^{N}/_{m^2})$

$= 0.613v^2$

v = average wind speed (m/s)

$I_\omega = Importance\ Factor$

= 1.2

Wind Speed and Direction for the land

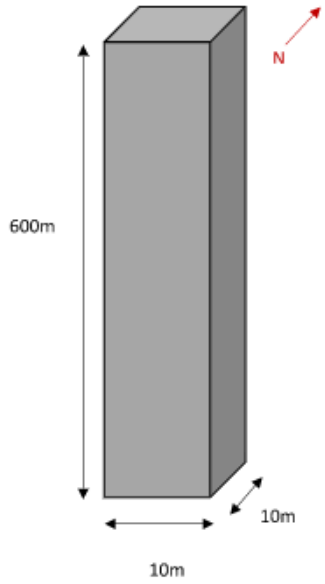
Average wind speed of 19m/s in the East direction

If force is more than 4000kN of load is acting on the building it is advisable to go for End-bearing pile, instead of friction pile.

Figure A.14: The repository card with Wind test calculation for Los Angeles plot B

Wind Test Calculation – New York City Plot A

Wind Test calculation done here is an approximate calculation to decide if the piece of land is suitable for construction of a skyscraper. For the test, a structure of 600m height, 10m x 10m base size is considered. The wind load (F) must be calculated using the formula below.



$$F = P \times A,$$

$F = Force$ (N)

$P = Pressure\ (^{N}/_{m^2})$

$A = Surface\ Area\ (m^2)$

$$P = C_e C_d \theta_s \times I_\omega,$$

$C_e = Exposure\ Factor$

= 0.92

$C_d = Drag\ Factor$

= 1.05

$\theta_s = Wind\ Stagnation\ Pressure\ (^{N}/_{m^2})$

$= 0.613v^2$

v = average wind speed (m/s)

$I_\omega = Importance\ Factor$

= 1.2

Wind Speed and Direction for the land

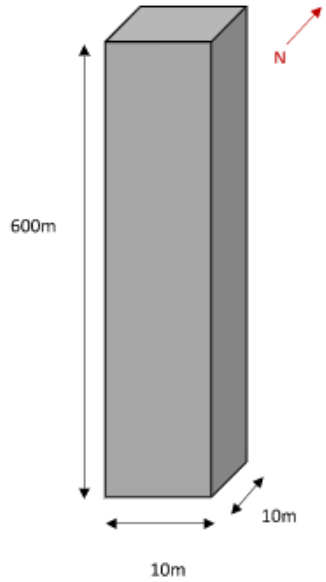
Average wind speed of 32m/s in the South direction

If force is more than 4000kN of load is acting on the building it is advisable to go for End-bearing pile, instead of friction pile.

Figure A.15: The repository card with wind test calculation for New York plot A

Wind Test Calculation – New York City Plot B

Wind Test calculation done here is an approximate calculation to decide if the piece of land is suitable for construction of a skyscraper. For the test, a structure of 600m height, 10m x 10m base size is considered. The wind load (*F*) must be calculated using the formula below.



$F = P \times A,$

$F = Force$ (N)

$P = Pressure\ (^{N}/_{m^2})$

$A = Surface\ Area\ (m^2)$

$P = C_e C_d \theta_s \times I_\omega,$

$C_e = Exposure\ Factor$

= 0.84

$C_d = Drag\ Factor$

= 1.05

$\theta_s = Wind\ Stagnation\ Pressure\ (^{N}/_{m^2})$

$= 0.613v^2$

v = average wind speed (m/s)

$I_\omega = Importance\ Factor$

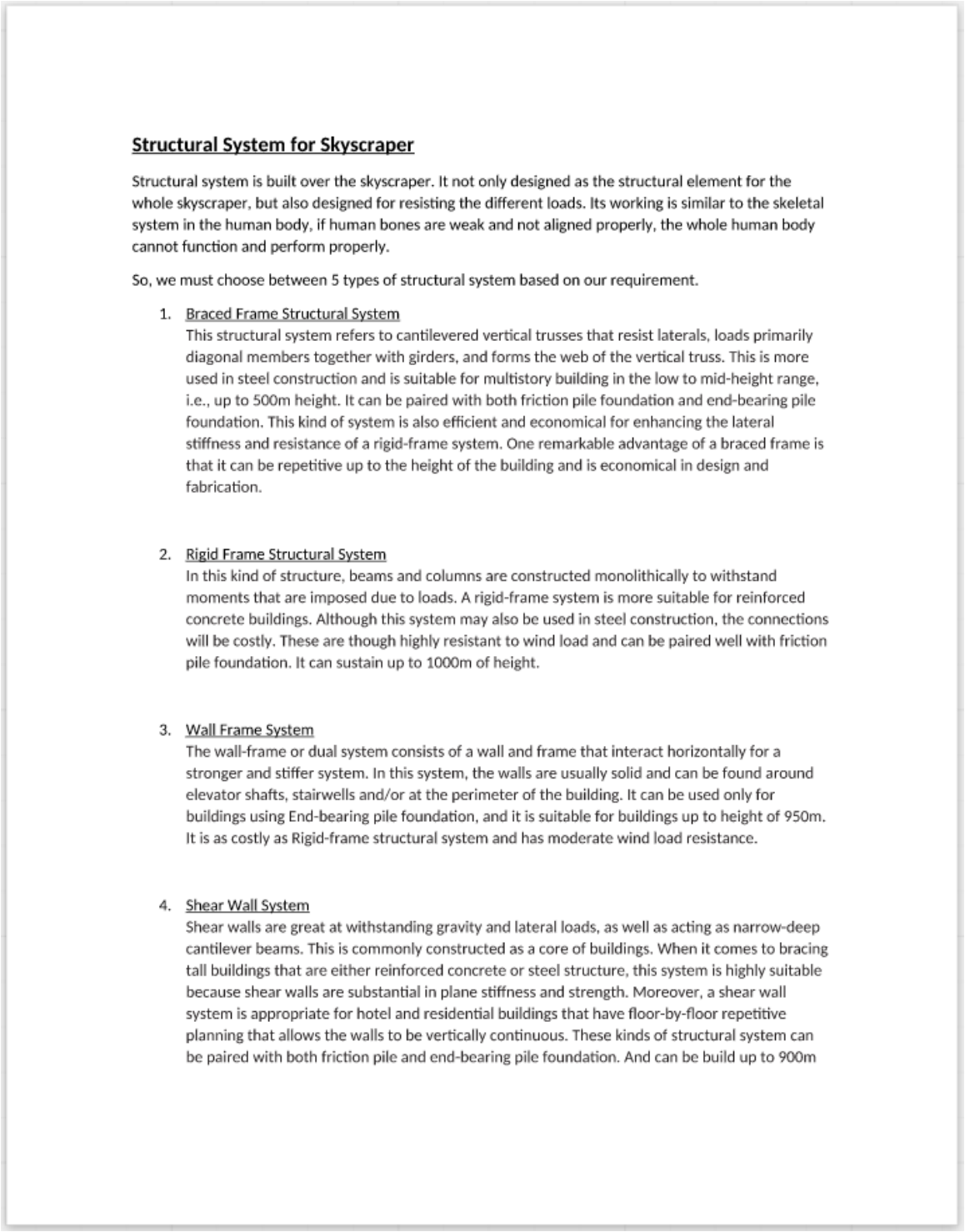
= 1.2

Wind Speed and Direction for the land

Average wind speed of 25m/s in the North direction

If force is more than 4000kN of load is acting on the building it is advisable to go for End-bearing pile, instead of friction pile.

Figure A.16: The repository card with wind test calculation for New York plot B



Structural System for Skyscraper

Structural system is built over the skyscraper. It not only designed as the structural element for the whole skyscraper, but also designed for resisting the different loads. Its working is similar to the skeletal system in the human body, if human bones are weak and not aligned properly, the whole human body cannot function and perform properly.

So, we must choose between 5 types of structural system based on our requirement.

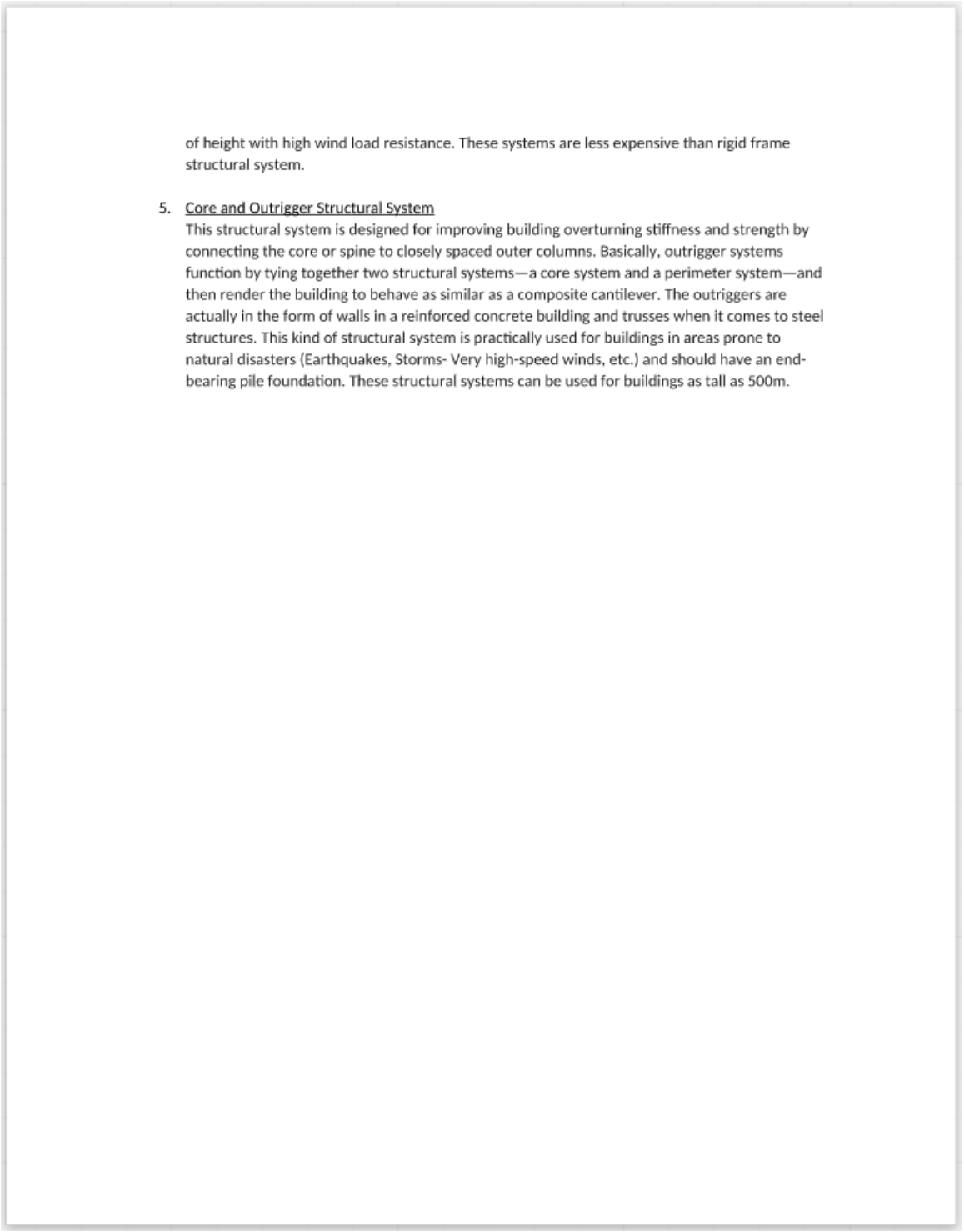
1. Braced Frame Structural System
   This structural system refers to cantilevered vertical trusses that resist laterals, loads primarily diagonal members together with girders, and forms the web of the vertical truss. This is more used in steel construction and is suitable for multistory building in the low to mid-height range, i.e., up to 500m height. It can be paired with both friction pile foundation and end-bearing pile foundation. This kind of system is also efficient and economical for enhancing the lateral stiffness and resistance of a rigid-frame system. One remarkable advantage of a braced frame is that it can be repetitive up to the height of the building and is economical in design and fabrication.

2. Rigid Frame Structural System
   In this kind of structure, beams and columns are constructed monolithically to withstand moments that are imposed due to loads. A rigid-frame system is more suitable for reinforced concrete buildings. Although this system may also be used in steel construction, the connections will be costly. These are though highly resistant to wind load and can be paired well with friction pile foundation. It can sustain up to 1000m of height.

3. Wall Frame System
   The wall-frame or dual system consists of a wall and frame that interact horizontally for a stronger and stiffer system. In this system, the walls are usually solid and can be found around elevator shafts, stairwells and/or at the perimeter of the building. It can be used only for buildings using End-bearing pile foundation, and it is suitable for buildings up to height of 950m. It is as costly as Rigid-frame structural system and has moderate wind load resistance.

4. Shear Wall System
   Shear walls are great at withstanding gravity and lateral loads, as well as acting as narrow-deep cantilever beams. This is commonly constructed as a core of buildings. When it comes to bracing tall buildings that are either reinforced concrete or steel structure, this system is highly suitable because shear walls are substantial in plane stiffness and strength. Moreover, a shear wall system is appropriate for hotel and residential buildings that have floor-by-floor repetitive planning that allows the walls to be vertically continuous. These kinds of structural system can be paired with both friction pile and end-bearing pile foundation. And can be build up to 900m

Figure A.17: The repository card on structural systems



of height with high wind load resistance. These systems are less expensive than rigid frame structural system.

5. Core and Outrigger Structural System
This structural system is designed for improving building overturning stiffness and strength by connecting the core or spine to closely spaced outer columns. Basically, outrigger systems function by tying together two structural systems—a core system and a perimeter system—and then render the building to behave as similar as a composite cantilever. The outriggers are actually in the form of walls in a reinforced concrete building and trusses when it comes to steel structures. This kind of structural system is practically used for buildings in areas prone to natural disasters (Earthquakes, Storms- Very high-speed winds, etc.) and should have an end-bearing pile foundation. These structural systems can be used for buildings as tall as 500m.

Figure A.18: The repository card on structural systems

DEPARTMENT OF INDUSTRIAL AND MATERIAL SCIENCE
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden
www.chalmers.se

CHALMERS
UNIVERSITY OF TECHNOLOGY