Enhancing Indoor Wayfinding at the University of Waterloo: Designing a Tailored, Adaptive Navigation System

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SYDE 600

Dr. Munteanu

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SYDE600 Team Contract

SYDE600 Team Name: UWPilot	**Date: Sep 13th. 2024**

Team Member	Student ID	Specialization
Junyan Chen	21111709	Human Factors
Zhanfei Gu	20873704	AI and Machine Learning
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Zhiyao Yu	20835121	Human Factors

Roles, Responsibility:

- Junyan - Project Manager: Host the meetings, manage the project progress, and distribute the works
- Zhenfei - Document Controller: Track the DDL, manage the documents, and upload the deliverables
- Yifei - Record Keeper: Record the key points and the decision process during the meetings
- Zhiyao - Progress Coordinator: Control the discussion time and track the individual contributions

Deliverables:

- Strive to complete all assigned tasks before or by deadlines
- Complete all tasks to the best of your ability

Work Process, Conflict Resolutions:

- Files will be shared via Google Drives Decisions need to be agreed upon by everyone
- Meetings should be paused and rescheduled within 3 days if the conflict is too bad

Team Meeting Time: 1:30 - 2:00 pm Wed & 10:00 - 11:00 am Fri

Abstract

*The project aims to address the **navigational challenges** faced by students and visitors within the University of Waterloo's complex building layout and inter-connected facilities. Based on preliminary observations, many buildings have numerous rooms and are sometimes interconnected, making it **difficult for users to switch between classrooms efficiently** or **utilize shortcuts**. Additionally, the large size of these buildings often leads to **unfamiliarity with essential facilities** like convenience stores, public office areas, and rest spaces. In shared environments such as libraries, crowded areas, and obstructed views can make it challenging for **groups to meet at designated spots**, further highlighting the need for a more straightforward and user-friendly navigation system on campus.*

***The primary users** include current **UW students**, while university staff may also benefit from this design but they are considered more familiar with the campus. The proposed solution is an indoor **navigation app** that helps users find optimal routes to classrooms or facilities, clearly identifying internal building shortcuts. The system would also provide an indoor positioning function, enabling users to locate friends or shared locations in complex spaces. Implementing this system involves 3D modeling, an indoor navigation algorithm, and the integration of building maps and facility information into a user-friendly interface.*

Executive Conclusion

Initially, when we were doing the observation, problems were found in the process of navigating UW Indoor Campus Spaces, some significant problems were the following. Firstly, **multiple buildings interconnected** via hallways, sky bridges, and tunnels, **without a clear unified guide**. Users must guess how structures align vertically and horizontally. Secondly, **floor numbering inconsistencies** (e.g., "3rd floor" in one building linking directly to the "4th floor" of another) force students into trial-and-error wayfinding. Thirdly, **static wall-mounted floor maps and signs lack practical route instructions**. They only show room numbers or building names instead of step-by-step guidance. In addition, **hidden shortcuts** (unmarked doors, unlisted indoor paths) remain undiscovered. Newcomers and even experienced students **rely on outdoor routes** that may be inefficient. Last but not least, **some environmental uncertainties** such as closed corridors due to maintenance, locked internal doors, and unpredictable elevator wait times.

In order to design a solution that formally addresses those problems in on campus navigation, we have concluded the following solutions to Design. Those solutions were developed in an iteration cycle of contextual inquiry method, multiple participatory design sessions, and data clustering and analysis for those data, which all methods will be addressed within this report later. The developed solutions are considered both effective and adaptive for the particular use case - UW Indoor Navigation. Firstly, develop a **unified digital platform** that integrates all building layouts. The platform presents each **floor as a layered, as a scrollable map**, so users can clearly see how halls, elevators, and stairs connect to other floors and buildings. Secondly, **Highlight shortcuts** (e.g., label "Sky Bridge to E3 on 3rd Floor" or "Connector Hallway to RCH behind E5-312") to ensure efficient paths are as visible as main entrances. Thirdly, **Provide precise directions instructions with recognizable landmarks** ("Turn right at the vending machine after room E5-310") rather than generic arrows, so users can confirm they're on the correct path. Fourthly, **incorporate real-time status updates**, such as indicating a certain elevator is currently out of service, a building is under renovation, or a particular indoor route is temporarily blocked—so users don't waste time on dead ends. Furthermore, **include user-friendly visuals**, such as photographs of tricky intersections or unique hallway features, so users can match what they see on their device with the actual environment.

In addition, **apply intuitive design principles**. The primary screen should feature a clear, layered map, with a minimal bottom search bar, concise weather and floor buttons at the top, and discreet street-view or repositioning icons on the sides. Reduce button count and text labels so that users remain focused on the map itself. Moreover, **mitigate the gap between the virtual map and the real environment by offering street-view images and user-shared photographs** at critical turns and confusing hallways. Also, **enable users to input precise start and end points—down to specific rooms—and incorporate real-time conditions** like weather, personal preferences, and efficiency factors into route calculations. Users can save frequently visited locations for instant navigation in the future. The second last solution is to **allow rapid mode switching** (e.g., priority on efficiency, walking-only paths, or outdoor routes) directly on the route screen without requiring a new search, so users can adapt their choices on the go. Lastly, **implement automatic floor-level map transitions**: as users follow the directions and move up or down floors, the system intelligently switches to the corresponding floor plan. This ensures a seamless multi-floor navigation experience.

Aside Notes for Improvement:

- **Allow students and staff to add helpful notes or tips directly on the map** (e.g., "Elevator E5-2 is slow after 10 AM" or "This door is locked on weekends") to ensure that the navigation system remains up-to-date.
- **Encourage users to share images of hidden passageways or lesser-known corridors**.
- **Regularly update route data based on real-time conditions**—such as weather forecasts, event schedules that cause crowding, or temporary re-routes.
- Continuously **gather feedback** on unclear instructions, confusing signage, and missing shortcuts, **then refine the digital maps accordingly**.
- **Before official launch, conduct multiple testing and iteration cycles**. Utilize participatory design feedback to refine elements such as icon clarity, floor-switching accuracy, system responsiveness, and data update frequency, to deliver a reliable, simple, and practical indoor navigation solution at release.

Important aside note for reading this report:

- *You will see a lot of colors within this report; that is because we'd like to show our thought process on how did we come to those solutions. But there are essentially four colors:*
    - *Red: coloring content related to objective factors affecting route choices*
    - *Yellow: coloring content related to efficiency in users' route choice*
    - *Green: coloring content related external personal preference*
    - *Purple: coloring content related to individual situations on route choice*
    - *Orange: coloring content related to Intrinsic personal preference on route choice*

Objective: From low level data to develop high level themes - for design solutions!

1. Preliminary Observations

1.1 Executive Summary

- **Objective**: Identify difficulties in navigation on campus and propose a solution to help students find ways on campus.
- **Methodology**: Conducted three observations focusing on pedestrian movement and their behaviors.
- **Insights from this section**:
    1. Many pedestrians prefer ground routes over indoor shortcuts.
    2. Lack of awareness of most shortcuts.
    3. High usage of floor maps in the MC building.
    4. Difficulties with indoor navigation in complex layouts.
    5. Numerous shortcuts (sky bridges, joints, underground passages) exist but can be overwhelming for students to use subconsciously.
    6. A variety of pathways leads to confusion.
- **Conclusions**:
    1. A comprehensive indoor navigation system is needed for UW.
    2. A user-friendly, real-time solution would improve both navigation efficiency and user experience.

Navigating the extensive campus of the University of Waterloo can be a complex task for students, visitors unfamiliar with the campus, and even staff members. To better understand the challenges and behaviors associated with campus navigation, we conducted three preliminary observations focusing on different aspects of pedestrian movement and wayfinding. The first observation by Zhanfei Gu and Junyan Chen focuses on a few samples of shortcuts between buildings and their alternative ground routes (Observation 1). The second observation by Zhiyao Yu applies the Goetz and LeCompte framework to assess how frequently students consult floor maps within the Mathematics and Computer (MC) building (Observation 2). The third observation by Yifei Liu explores the connectivity of campus buildings through indoor pathways and the prevalence of shortcuts (Observation 3). By analyzing these observations, we aim to

identify key navigation issues on campus and lay the groundwork for proposing solutions to enhance the commuting experience for the university community.

1.2 Observation: Sample Observation

Key Takeaway: More students use the regular route to get to their destination instead of using efficient shortcuts; Students lack awareness of the existence of campus shortcuts.

We observed people crossing 2 shortcuts and their alternative ground route, focused on the pedestrians taking different routes with the same travel purpose. The following map and pictures present the location we observed more clearly. One shortcut is between E6 and E7, marked in red. It has 1 alternative ground route, marked in green. Another shortcut is between E3 and E5, marked in red. It has 2 alternative ground routes, marked in green.

Figure 1.2.1

Shortcut between E6 and E7

We first observed people crossing the shortcut between E6 and E7, since there is only 1 alternative ground route which means it is easy to observe. The picture below was marked in the same fashion as the map.

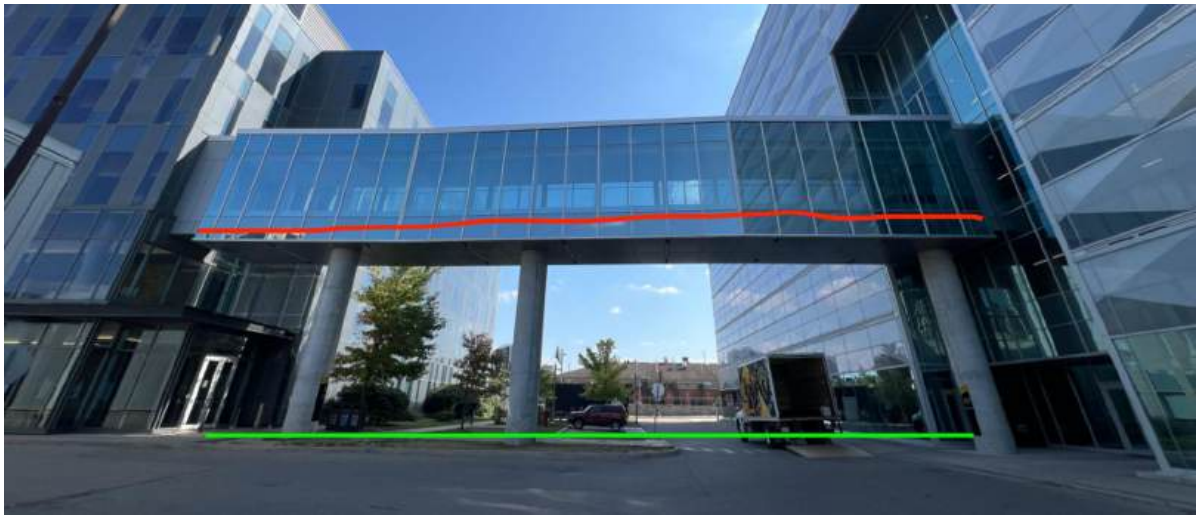


Figure 1.2.1

The following table shows the results of our first observation.

Time	Sep. 19th. 2024 14:50-15:00			
Route	Shortcut E6-E7	Shortcut E7-E6	Ground E6-E7	Ground E7-E6
Number	4	9	5	6

First of all, we can easily tell from the map that the shortcut and the ground route almost share the same origin, destination, and distance in 2D. The only difference is that the shortcut connects 2 buildings on the 3rd floor, while the ground route connects 2 buildings on the ground. This implies there will not be a huge difference between those 2 routes, which matches our result that 13 people took the shortcut and 11 took the ground route.

Both routes share the same result: more people go to E7 from E6, and fewer go in another direction. Based on our observation and discussion, this might be caused by the time we chose to

observe. Other than purely commuting between 2 buildings, people passing there could have other purposes. The direction from E6 to E7 is to the main campus, while another direction is to leave the campus. We observed in the afternoon when most people go home after studying or working. This assumption could be proven by observing at a different time.
We were expecting more people to take the ground route than the shortcut. To our surprise, the result proved we were wrong. We supposed that this shortcut is clear, so those who pass there every day can easily know how to take the shortcut.

Shortcut between E3 and E5

To prove our assumption, we immediately decided to observe another shortcut, where people have more route options and more people need to commute between. This decision brought out our second observation, the shortcut between E3 and E5 and its 2 alternative ground routes. The pictures below were marked in the same fashion as the map.

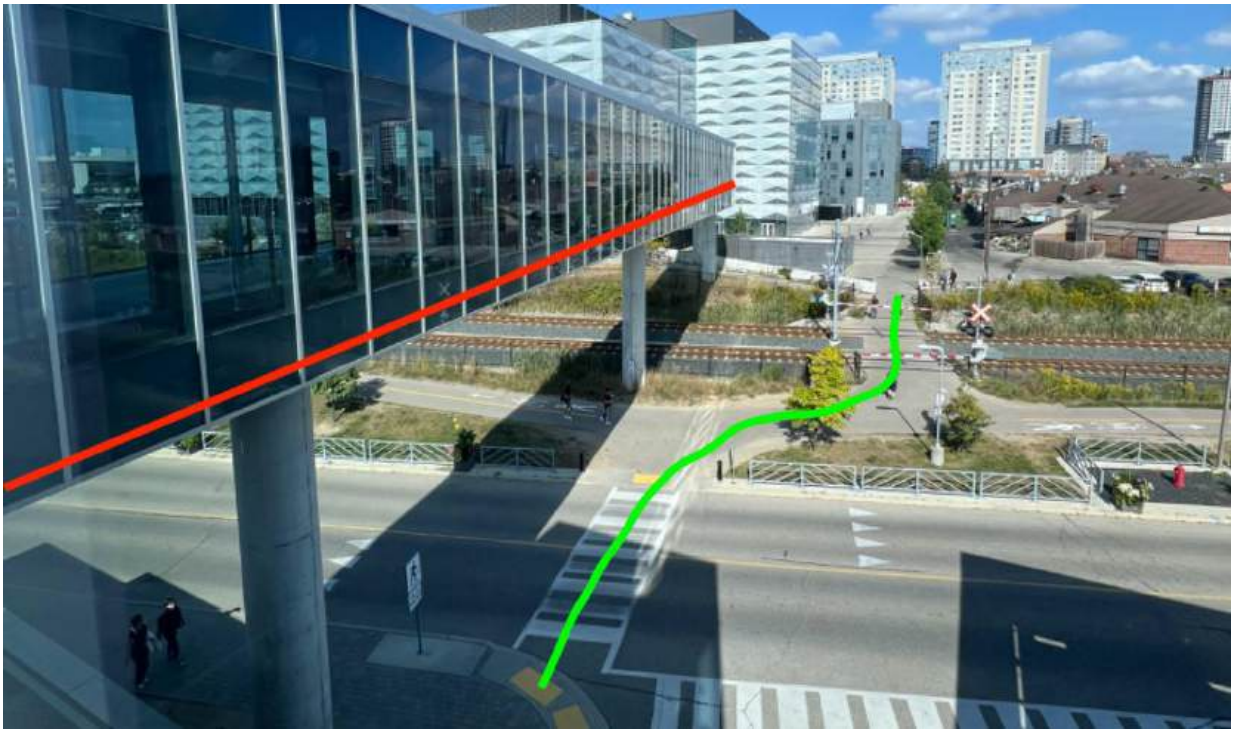


Figure 1.2.3

Figure 1.2.4

Figure 1.2.5

The following table shows the results of our second observation.

Time	Sep. 19th. 2024 15:20-15:30					
Route	Shortcut E3-E5	Shortcut E5-E3	G. North E3-E5	G. North E5-E3	G. South E3-E5	G. South E5-E3
Number	8	12	45	38	37	56

The second observation focused on the shortcut between E3 and E5, its first alternative ground route connecting a crossing between DC and E3 with the west door of E5, where people need to take stairs before entering E5, and its second alternative ground route connecting E3 and a point between E5 and the University Plaza. We name the first alternative ground route as ground route north (G. North in the table), and the second alternative ground route as ground route south (G.

South in the table). Both ground routes require pedestrians to cross a railway and a busy vehicle road.

Simply summarize the data recorded in the table, 20 people took the shortcut, 83 people took the ground route north, and 93 people took the ground route south. Even under the circumstance that the shortcut provides a safer, cozier, more straightforward option, more people choose to walk on the ground. It persuades us to think that they do not want to take the shortcut, or they just do not know.

In total, 90 people went from E3 to E5, while 106 people went from E5 to E3. There exists a minor difference between those 2 directions, but we could not conclude on a persuasive reason. Looking deeper, the population taking the shortcut in 2 directions shares the same tendency as the total population in 2 directions. 2 ground routes appear to be different in the number of people going in 2 directions. On the north one, more people were going from E3 to E5, while on the south one, more people were going from E5 to E3. We realized though people on both routes seemed to take their way to cross the vehicle road and railway, their real origin and destination for this little trip could be different. By observing the campus map, people taking the ground route north from E3 to E5 are most likely coming from DC and the middle part of the campus, which contains a larger population than their destination, the east side of the campus. People taking the ground route south from E5 to E3 are most likely from the east campus plus the University Plaza to the southwest part of the main campus. Though the population from the origin was not great, the population to the specific destination on the ground route south is smaller. However, most of the analysis above was based on our assumption. In our next field research, we hope to interview the users about their real origins and destinations to see if our assumptions hold.

1.3 Observation: Map Observers

Key Takeaway: Students get more confused when navigating within a more complex structured building floor layout; they heavily rely on floor maps to find routes to destinations.

By applying the Goetz and LeCompte framework which was covered in lecture 2, this time we have shifted our focus on our primary stakeholders: students at the University of Waterloo who go to classes on a daily basis. We would like to understand their needs and verify our initial proposed user pain point that there are students who will get lost and are unaware of possible shortcuts. We conducted an observation of students who interact with the building floor maps in the Mathematics and Computer (MC) building on different floors at the University of Waterloo. We conducted the observation in MC because the MC building contains both straightforward large-size lecture halls, and also complex distribution of smaller units, such as the instructors' office. By using the given framework, we can make observation notes on who, what, when, where, why, and how on the observed objects. Analysis of such behavior of students interacting with the floor map enables understanding the extent to which the students are confused about finding the correct path to destinations.

Who is Present: The students from different years of study, having classes in the MC building, are the main subjects of observation. These are students who are actively navigating within the MC building before their scheduled classes. The observation targeted students who might require assistance in locating classrooms or navigating the building's layout, as these students would demonstrate this characteristic by checking the building floor maps.
What is Their Role: The students observed are taking the role of the primary users of our design since a percentage of them are confused about finding the correct path to their destination.
What is Happening: The observer will be checking three floors before the class begins, the duration of the observer staying at each floor is roughly 5 minutes. The observer will observe the floor map near the entrance (main door, elevator, or stairs) and count how many students pass by in total, as well as how many students interact with the floor map. This activity was documented to investigate under how many times and what conditions the students felt the need to refer to floor maps.
When Does the Activity Happen: The observation was done within fifteen minutes from 9:45 AM to 10:00 AM on the 19th day of September 2024. This time range was selected as it is right before a typical class period, which is a busy period as most students would want to get directions. In addition, Thursday is also a busy workday, relatively in a week.

Where is it Happening: The observation was carried out in the MC building on three different floors:

- First Floor: Open plan style with a large lecture room with many students within it.

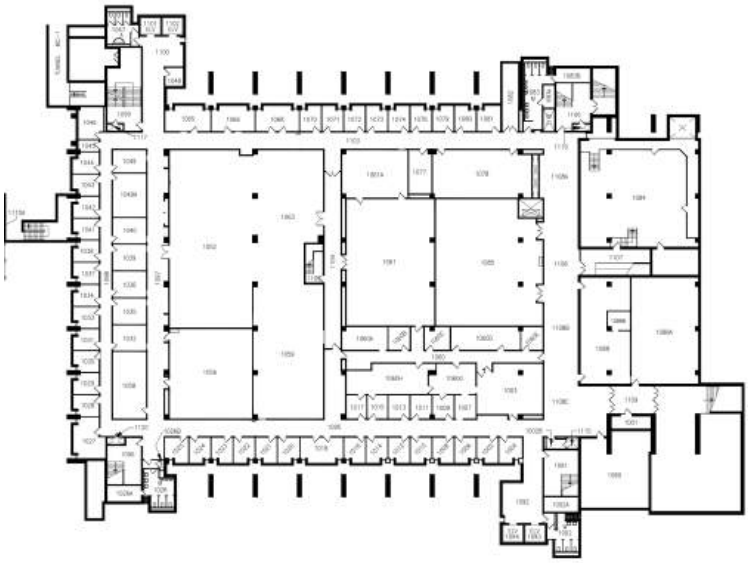


Figure 1.3.1: First Floor Layout

- The second Floor: contains mostly medium-size classrooms, fitting fewer students compared to the first floor.

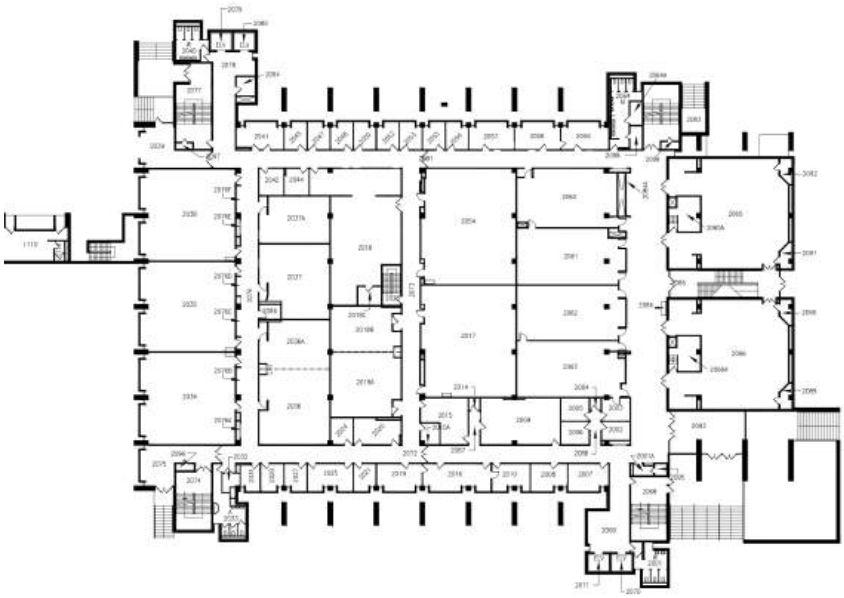


Figure 1.3.2: Second Floor Layout

- Third Floor: Features lots of small-sized classrooms and offices.

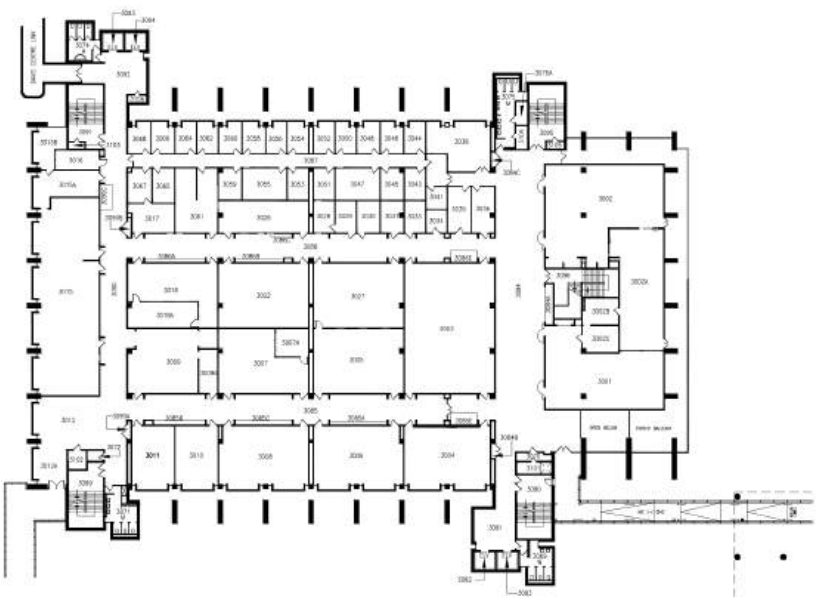


Figure 1.3.3: Third Floor Layout

In addition, we have selected the MC building since each floor has a very similar architectural style. This style is somehow considered confusing for first-time visitors since the lighting is dark and lacks significant landmarks on each floor.

Why is it Happening: The observation aims to find out how often students use floor maps and how these patterns vary depending on floor orientation and the complexity of the layout. The first floor has a relatively easy layout since large-scale lecture halls take up most of the space. The second floor has medium complexity since it has more classrooms. The third floor has the most complex layout and students are often confused about the path since they may be the first time visiting the instructor's office on the third floor. The assumption was that students on such floors with small and many unknown classrooms would rely on the maps more than those on simpler floors. In addition, we conducted this observation in mid-September, before the Add/Drop period, as students are still switching classes and therefore looking for new ones.

How is the Activity Organized: The observer will count and record the number of students passing by and the number who stopped to consult the map. Conducting observation on different

floors allows comparison between various floor layouts and verifies our initial assumption that students are sometimes confused on the path to classrooms on campus.
The below table shows the observation results:

Floor Level in MC building	Floor Layout Complexity	Total Number of Students Passing By	Number of Map Observers	Percentage Observing Map (round to 2 decimal)
First Floor	Easy	76	11	14.47%
Second Floor	Medium	53	15	28.30%
Third Floor	Hard	13	4	30.77%

Analysis Using Goetz and LeCompte Framework:

- First Floor: On the first floor, which has a comparatively simple organization due to the existence of a huge lecture hall, it was noted that as few as 14.47% of the students referred to the floor map. Such a low percentage of map usage by the students on this floor is possibly due to students knowing this route already since the large lecture hall is a popular destination. The simplicity of the layout minimizes confusion, reducing the need for students to rely on the floor map.
- Second Floor: On the second floor, the layout becomes slightly more complex with more medium-sized classrooms, and 28.30% of students were observed consulting the map. It indicates that students will be more likely to seek navigation aid by checking the floor map when they are in a layout that offers more routes and destinations. In this case, students may be unsure about their classrooms and locations, leading them to check the map for confirmation.
- Third Floor: In terms of the third floor, which has the most complex floor layout with smaller units for offices and classrooms, has the most significant percentage of students checking the floor plan. This floor lacks significant landmarks leading students to rely on navigational support. Students who are visiting this floor for the first time are the more frequent users of the floor map.

In conclusion, our observation confirms that students' reliance on floor maps increases with the complexity of the building's layout. This could be justified quantitatively that the percentage of map observers increases as we observe from the first floor to the third floor in the MC building. These findings are evidence of the fact that there is a need for a more comprehensive indoor navigation system on campus. Such a system could minimize the need to use static maps and give students real-time instructions. This would not only enhance the overall experience of the students but would guarantee that every user, including those unfamiliar with the building, will be able to make their way around the campus taking less time and feeling confident.

1.4 Observation: Overall Observation

Key Takeaway: <u>There are an extensive amount of efficient shortcuts existing on campus; there are three main types of shortcuts - sky bridges, joints, and ground/underground passages.</u>

The core point of observation in the third part is where the campus of the University of Waterloo. We mainly observed buildings such as E2, E3, E5, E7, CPH, RCH, PHY, and DC in the South Campus. The main content of observation is the shortcuts in these buildings. In order to observe these shortcuts, we walked through all of them based on the campus map. We found that the majority of buildings on campus are connected together; in the picture below (Figure 1.4.1), there are as many as 20 shortcuts connecting the main buildings. That is to say, students can easily switch classrooms by taking indoor shortcuts. These shortcuts not only save time, but also help students avoid rain, snow, or high temperatures.

Figure 1.4.1

In addition, we found that there are mainly three types of shortcuts on campus: sky bridges, joints, and ground/underground passages. Below are some examples with photos:

Skybridge between E5 and E3

Figure 1.4.2

Figure 1.4.3

Figure 1.4.4

Joint between E3 and E2

Figure 1.4.5

Figure 1.4.6

Underground Passage between E2, RCH, and DWE

Figure 1.4.7

Figure 1.4.8

Figure 1.4.9

1.5 Section Conclusion

Our preliminary observations have revealed navigational challenges faced by the University of Waterloo community.

1. The first observation highlighted that even when indoor shortcuts offer safer and more direct routes between buildings, a significant number of users opt for alternative ground routes. This indicates a lack of awareness or difficulties with accessibility to these shortcuts.
2. The second observation demonstrated that reliance on static floor maps increases with the complexity of the building's layout, indicating that students often struggle to find their way in more intricate environments like the MC building.
3. The third observation revealed that while numerous indoor pathways connect major campus buildings, the diversity in shortcut types—such as sky bridges, joints, and underground passages—can be overwhelming without proper guidance.

These findings underscore the necessity for a comprehensive indoor navigation system tailored to the unique architecture of the campus. Such a system would not only make the existing shortcuts more accessible but also enhance the overall efficiency of campus navigation. By providing real-time, user-friendly directions and emphasizing ideal routes, including lesser-known shortcuts, we may greatly improve the commuting experience for students, visitors, and employees.

2. Contextual Inquiry Protocol

2.1 Executive Summary

- **Objective**: Construct the contextual inquiry (CI) protocol based on previous findings.
- **Methodology**: Using the Master-Apprentice model to construct the CI model.
- **Insights from this section**:
    1. A route between E7 (1st Floor) and E3 (4th Floor) is selected to perform the CI.
    2. Collect relevant data, such as time, audio, pictures, and reaction notes.
    3. Ask questions to let the participants take the lead in the conservation instead of us teaching them what to do.
    4. Properly code the collected data for further analysis.
    5. Refer to the pilot test result to finalize the CI protocol.
- **Conclusion**:
    1. The project outline expands the current knowledge base for group members to further improve the project.
    2. The initial CI has been established, group members will conduct a pilot test first before proceeding further.
    3. Future work includes refining the protocol based on pilot test results and proceeding with data collection.

2.2 Initial Construction of Contextual Inquiry Protocol

Key Takeaway: Constructing the first draft of the CI protocol based on a rough idea as a starting point There could be things that don't work as expected, such deficiencies will be addressed during the pilot test.

2.2.1 Definition and Methodology

Key Takeaway: The study aims to analyze student navigation between E7 and E3, focusing on route choices, navigation tools, challenges, and efficiency during peak times.

- **Objective**
    - To understand how participants move within campus buildings, and in particular which routes they take and whether they take shortcuts while deciding on the routes.
    - Key Focus: Concentrate on the behaviors of the participants during the selected route from E7 (1st floor) to E3 (4th floor) with special regard to:
        - Choices of routes (short-cuts vs standard route)
        - Navigation tools used (signs, mobile apps, asking for directions)
        - Challenges encountered (loss of direction, confusion, hesitation)
        - Time taken and efficiency of the selected routes

- **Target Users / Stakeholders**
    - Primary Users: University of Waterloo students, especially those who frequently travel between buildings such as E7 and E3.
        - Focus on students from different years as well as from different departments in order to get a wider perspective.
        - Participants will be approached randomly in E7, asking if they can teach researchers how to walk to E3 as part of the inquiry.
    - Stakeholders:
        - Students: End-users of the proposed navigation system.
        - UW staff: Possible stakeholders who might support or pay for navigation systems improvement.

- **Data Collection Environment**
    - Where: E7 (1st Floor) to E3 (4th Floor), which includes many different routes and chances for students to take shortcuts.
    - When: At peak time during class-switching to make sure that students are available and navigating between classes. Data will be collected in multiple sessions to record different users and environmental settings.

2.2.2 Sample Questions

Key Takeaway: Sample questions the researchers will ask the participants during the CI task.

During the task:

- After you know the destination, what is your first step?
- When you are looking for this destination, what tools would you like to use(Maps App, asking others, road signs, etc.)?
- Why do you go this direction here or how do you choose the direction?
- What is the reason you go this route? (shortest time, most familiar, or whether there is an elevator, etc.)
- What is your reference to judge whether you are on the right route? (road sign, room number, mobile location, etc.)
- How do you get to the classroom when you arrive at the building?

After the task:

- Do you know there is a shortcut between E7 and E3?
- After knowing this shortcut or if you knew it before, when would you like to take this shortcut?
- For the route you took, which part of it do you think is the hardest?
- What information or tools do you like to find a route?
- We are designing a new system for navigation on campus. What function do you want for this system?

2.2.3 Data Collection Methodology

Key Takeaway: Data should be collected in observational and conservational probes, using the master-Apprentice Model. Researchers should use pilot test results to reflect and make changes to CI protocols.

- **Approach**
    - Use the “master-apprentice” model, where participants will be asked to teach the researcher how they navigate between the two buildings.

- **Tools and Methods**
    - Observation: Observe how the participants navigate, what shortcuts they attempt, what tools they use, and where they face problems. Record their walking time and any instances of loss or hesitation.
    - Conversational Probes: During the walk, ask sample questions to understand their decision-making process.
    - Post-task Feedback: After the task, ask questions to collect information such as the overall experience of the participants, what challenges they encountered, and what are their views regarding improvements.
    - Use the Master-Apprentice Model, where participants will be asked to teach the researcher how they navigate between the two buildings.
- **Pilot Tests**
    - Participants: Engage with 1 or 2 participants to pilot the inquiry protocol.
    - Approach students randomly on the E7(1st floor), ask them to teach us about E3(4th floor), and observe their route choices.
    - Researchers need to collect crucial information from pilots, like whether they took any shortcuts or what navigation tools were used.
    - Goals for the Pilot:
        - Assess the task request's clarity (whether participants understand the task).
        - Evaluate the efficacy of the “master-apprentice” approach.
        - Determine any logistical challenges in data collection (e.g., recording time, and taking notes while observing).
        - Refine questions to get detailed insights into their navigation process.
- **Reporting and Adjustments**
    - After carrying out the pilot, review the data collected; researchers should reflect:
        - Was the inquiry successful in determining how participants make navigation decisions?
        - What patterns of behavior occurred, and were there any unexpected challenges?
    - Adjust the protocol if needed:
        - Refine the questions or methods regarding pilot findings.

- Add any missing elements that would improve data collection for the whole study.

2.2.4 Initial CI Protocol

Key Takeaway: <u>This is our first draft of the CI protocol. We will ask students to lead the way to teach us what their experience is about navigating on campus. We will document kinds of data along the way.</u>

To identify the potential and actual challenges students encounter while navigating around the campus, particularly regarding their awareness and use of indoor shortcuts, we conducted a contextual inquiry using the Master–Apprentice Model. This model allowed the researcher to observe and learn from the participants in the course of their normal daily activities rather than being the ones doing the activities alone.

We voluntarily engaged university students at the University of Waterloo without restrictions. We randomly approach the participants on the first floor of the Engineering 7 (E7) building during a working day between 10 AM and 2 PM, when most students are on campus. All participants are verbally informed of the study's intentions, emphasizing monitoring and timing their navigation processes.

In the initial engagement part, we will find students moving towards either an exit or intentionally moving to another building, and we will approach them. After a brief introduction, we will ask if they could assist us by "teaching" us how to get from E7 (1st floor, our current location) to Engineering 3 (E3, 4th floor). Using such words helps address the Master-Apprentice Model, whereby the participant is the master. As researchers, we learn from them instead of leading them in a specific direction.

Once the participants agree to complete the task, we walk with them from E7's first floor to E3's fourth floor. Throughout the journey, we observed their behavior, taking notes of their route choices and decision-making processes; in addition, any signs of hesitation or confusion should also be marked down in our notes for future analysis.

We will encourage participants to think aloud without intentionally leading from our questions. We will also encourage them to share their thoughts on how they decided which paths to take. We will refrain from guiding them, allowing their natural navigation strategies to arise so that we can learn more about the actual user behavior.

In addition, we will record the time elapsed for each participant in order to reach the destination without using the shortcut (the sky bridge connecting E5 and E3), we call this time “time to destination,” and this number is expected to vary for ten different participants. A group member will also walk from E7's first floor to E3's fourth floor and mark the time taken; we call this time “optimal time.” After the task, we will ask the participants the previous questions and record their answers and reactions.

We both took notes and audio notes during the observation and the semi-interview and captured verbal and body language. Audio will also be recorded for analysis, and we will obtain the participants’ approval for recording sessions to the best of our ability. Furthermore, key waypoints and signs or maps that the participants used and referred to as maps that directed tasks are collected, and we will take recordings and pictures under the university photography and videography code to avoid filming personal identifying details.

As future engineers, we must consider ethical factors while conducting contextual inquiries. Firstly, we will obtain consent from the participants; they will be informed about the purpose of the study and assured that their data will be kept confidential and solely for SYDE 600 course use. Secondly, all other personal identifiers will be deleted from the source data files of all participants to protect participant privacy. Thirdly, we will conduct this inquiry under the condition of “non-intrusive observation,” where we ensure that our presence will not interfere with participants’ natural behavior.
As a result, at the end of the data collection section, we will have an Excel workbook that records 10 participants’ time to destination and compares it with our optimal time. We will also have rich photos, videos, audio recordings, and written notes on participants’ reactions.

2.2.5 Data Analysis Protocol

Key Takeaway: Data such as audio, reaction notes, and time sheets should be collected. We need to use Excel, and SPSS to analyze the data.

After the data collection process, we will analyze the recorded data.

- **Audio**: Audio will be transcribed into Word documents for bookkeeping purposes. Researchers will use the transcribed documents to extract details from participants' verbalizations for later use. Transcriptions will be organized systematically, and each team member should verify the transcription to ensure accuracy.
- **Participants' Reaction Notes**: The open coding technique will be used to categorize those observations and participants' responses. For example, categories like "navigation strategies," "awareness of shortcuts," "reliance on signs," "reliance on mobile maps," etc, will be used for detailed analysis. In addition, we will count behavioral cues from the participants, such as hesitation, backtracking, or consulting maps and signage.
- **Time Comparison**: As stated in the previous section, we will compare the optimal time and time to the destination. We will use virtualization tools like bar charts and line charts to better understand participants' behavior. This allowed us to quantify the efficiency difference between the routes. We will calculate the time difference (difference between optimal time and time to destination) and the percentage difference (time saved using the shortcut in percentage).

Some tools could be used for conducting such analysis, such as NVivo or Atlas.ti for coding and thematic analysis and Excel, SPSS, or R for quantitative computations. Finally, we will use Tableau or Microsoft Power BI to create visual representations of the data.

2.3 Revised Contextual Inquiry Protocol

Key Takeaway: Revised CI protocol based on the pilot test result in section 3.2. Some key points have been addressed such as privacy concerns, time limitations, clarity on how we ask them questions, and active asking participants for feedback.

Note: Please refer to section 3.2 the results and insights from the pilot test.

While conducting the pilot test, we were able to identify a few issues with the initial protocol, and we have improved the context inquiry protocol in several ways. This section highlights and discusses the revisions made to the protocol and the new procedure for implementing the contextual inquiries.

2.3.1 Adjustment Factors

Key Takeaway: We need to clarify task instructions, reduce participant stress, and enhance interaction with participants. In addition, we need to have a more complete plan for data analysis, such as building a mathematical model for collected data.

1. **Clarifying Task Instructions**: Participants misunderstood the task, resulting in unintended route choices. For example, one participant thought that any floors above the 1st floor in E7 were prohibited, so her choice of route was affected.
   Revision: Participants will receive more explicit and more precise directives. Instead of saying “Please show us how you approach the 4th floor of E3”, we say "Please treat me as a student who just arrived here and teach me how to get from here to the 4th floor of E3. Please share any information that influences your route choice as we go."
2. **Reducing Participant Stress**: Participants were under stress when told that we would ask questions throughout the walk, and this influenced their natural behavior.
   Revision: To avoid unnecessary interruptions during the walk, we shall reduce the number of questions asked. Participants will be assisted in eliciting their thoughts, but we will only ask clarifying questions when necessary.
3. **Enhancing the Master-Apprentice Interaction**: We did not collect enough verbal feedback from the participants, which left the researcher with little information about what their decisions were anchored on.
   Revision: We will emphasize the master-apprentice model more clearly and encourage them to ‘teach’ us as if we are learners. This should encourage them to talk spontaneously about their route choice and related matters.

4. **Updating Data Collection Techniques**: Students were reluctant to participate in our inquiry due to time commitments and privacy issues, especially regarding video recording.

   Revision: We will shorten the inquiry so that it takes no more than 5 minutes, excluding the walking time. We will still take pictures (with consent) instead of video recording, and audio recording (with consent) will be used for note-taking purposes.
5. **Participant Recruitment**: Trouble motivating and finding participants willing to spend their time on the inquiry.

   Revision: We will create a quick introduction script that clarifies the aim and provides reassurance about the time investment and the privacy of the information provided by the participants. Depending on the budget, we may give out small rewards, such as a coffee voucher.

2.3.2 Revised Contextual Inquiry Protocol

Key Takeaway: We learned that we need to care about how users feel and ask questions that are easy for them to understand in the CI protocols. We also need to find target users correctly and go from their perspective.

1. **Preparation**
   a. Materials:
      - Consent forms (verbal consent is also acceptable, but written consent forms are also available.)
      - Audio recorder or smartphone with recording ability.
      - Notepad for notes.
      - Campus map for reference and route recording (available to participants upon request).
   b. Team Responsibilities:
      - Zhiyao Yu: Introduction, task explanation, and obtain consent.
      - Junyan Chen: Reaction observation of the participants and notes taking.
      - Faye: record audio and recording routes
      - Yifei Liu: timekeeping and taking additional reaction notes

2. **Recruitment of Participants**
   - Recruit potential participants individually in the starting location (E7 entrance).
   - Refined introduction script:

     "Hi, we're a group of graduate students and we are conducting a brief study on campus navigation for SYDE 600. It involves a short walk from here to E3, we will also ask you some questions along the way. It will take about 15 minutes of your time. Would you be interested in participating?"
   - Letting participants know their responses will be kept confidential and that researchers will not note any of their personally identifiable information.
   - Consent (verbal or written) and for audio/video recording.
3. **Task Instructions**
   - Clearly state the task:

     "Please imagine that I'm a new student here at uwaterloo. I need to get from here to the 4th floor of E3. Could you teach me how to get there? As we walk, please share any thoughts on how those guide your choices."
   - Emphasize that they are required to elaborate on their actions and thought processes as if this information is to be given to someone who hasn't been to this campus.
4. **During the Walk**
   - Participant Role: The participant is the master, they will guide the researcher on how to get to the destination. This applies to the Master-Apprentice model.
   - Researcher Role:

   a. Follow the participant without leading the way or interrupting their choices.
   b. Encourage participants to say their thoughts. Say things such as: " We would love to hear your thoughts." or " Please say what you have in your mind."
   c. Avoid being very inquisitive during the walk to enable the participant to act as naturally as possible.
5. **Data Collection**

   Our previous data collection protocol is still intact. Please refer to **3.2.4** for this section.
6. **Ethical Considerations**

   Our previous ethical considerations are still intact. Please refer to **3.2.4** for this section.
7. **Post-Walk Interview**

- Once the destination is reached, ask the participants the following sample questions selectively:

  “Where did you get your route information from?”

  "Are you aware of any alternative routes or shortcuts?"

  "Did you face any challenges during the navigation?"

  "What information or tools do you think would help new students navigate better?"

  "If there were an indoor navigation app available, what features would you find most useful?"

  Please refer to 2.2.2 for more questions Our previous sample questions are still intact.

8. **Data Management and Analysis**

   Our previous data analysis methods are still intact. Please refer to **3.3.5** for this section.

9. **Contingency Plans**

- We have developed this contingency plan section for unexpected events.

a. If a participant is uncomfortable or would like to stop, we will thank them for their time and discontinue the inquiry.

b. Be ready to adjust to varying circumstances, such as building closures or extreme weather. We would check relevant news in advance online to avoid this.

10. **Additional Notes**

- Make sure that all team members understand the updated protocol and their responsibilities.
- Carry out a short debrief after every session, during which the team can make comments, share their findings, and address any concerns.
- We should also consider traffic factors and avoid carrying out the experiments in an excessively crowded situation.

2.4 CI Work Model

Key Takeaway:

1) Based on the flow model - stairs and elevators could have an impact on the overall time taken by the user - especially during busy hours with crowds.

2) Based on the sequence model - unexpected events could happen that affect overall user behavior such as trains passing by, weather, etc.
3) Based on the artifact model - users will interact with various objects where missing /additional interaction with objects will largely affect their reaction and route chosen.
4) Based on cultural models - Users prefer to increase their overall efficiency but such could be affected by subjective factors.
5) Based on the physical model - there are a fixed amount of routes for users to choose from. They tend to choose routes that they usually travel the most often.

2.4.1 Flow Model

The flow model integrates both the interaction and the communication among the various users within the navigation pilot test, mapping out the different decisions and the consequences of each route. It also points out how external factors, such as other pedestrians, may introduce breakdowns in the efficiency of navigation, influencing the overall outcomes observed by the team.

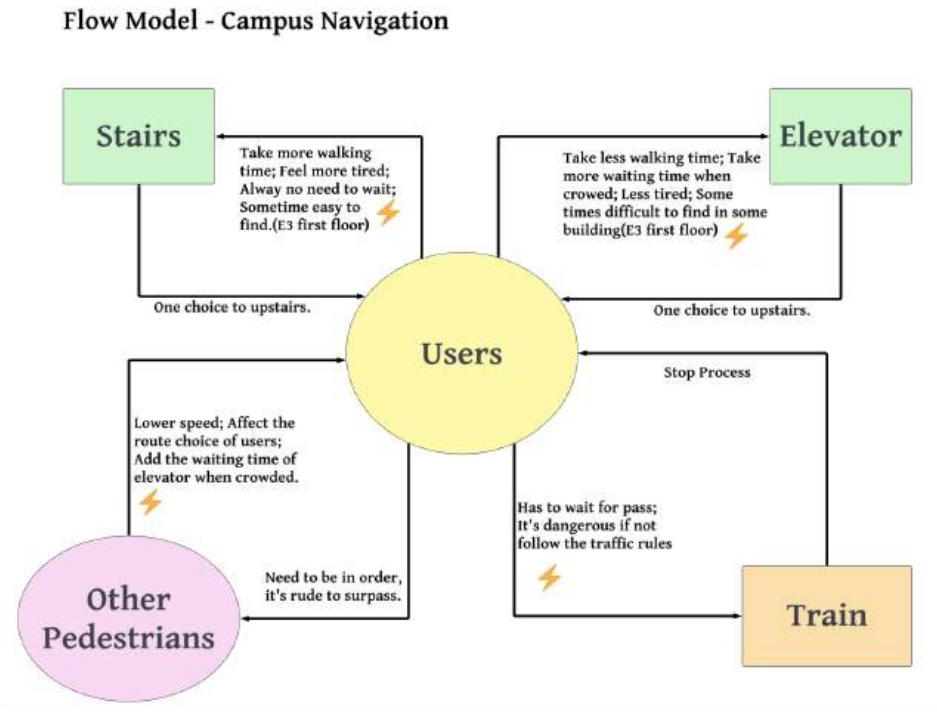


Figure 2.4.1 Flow Model

- **Stairs vs. Elevator and Crowd Impact**: Stairs offer faster access without waiting, but require more physical effort; elevators are less tiring but often involve long waits when crowded. Crowding significantly influences elevator wait times, impacting route choices. Thus, we should integrate real-time comparisons for elevators v.s.Staircases, allowing these users to choose the fastest option based on current conditions.
- **Train Safety**: Participants must follow traffic rules near the train. We should require clear reminders while navigating.

2.4.2 Sequence Model

The sequence model is step-by-step information on how work is done. It includes the intent behind the action, the trigger that led the user to the action, and breakdowns that create problems.

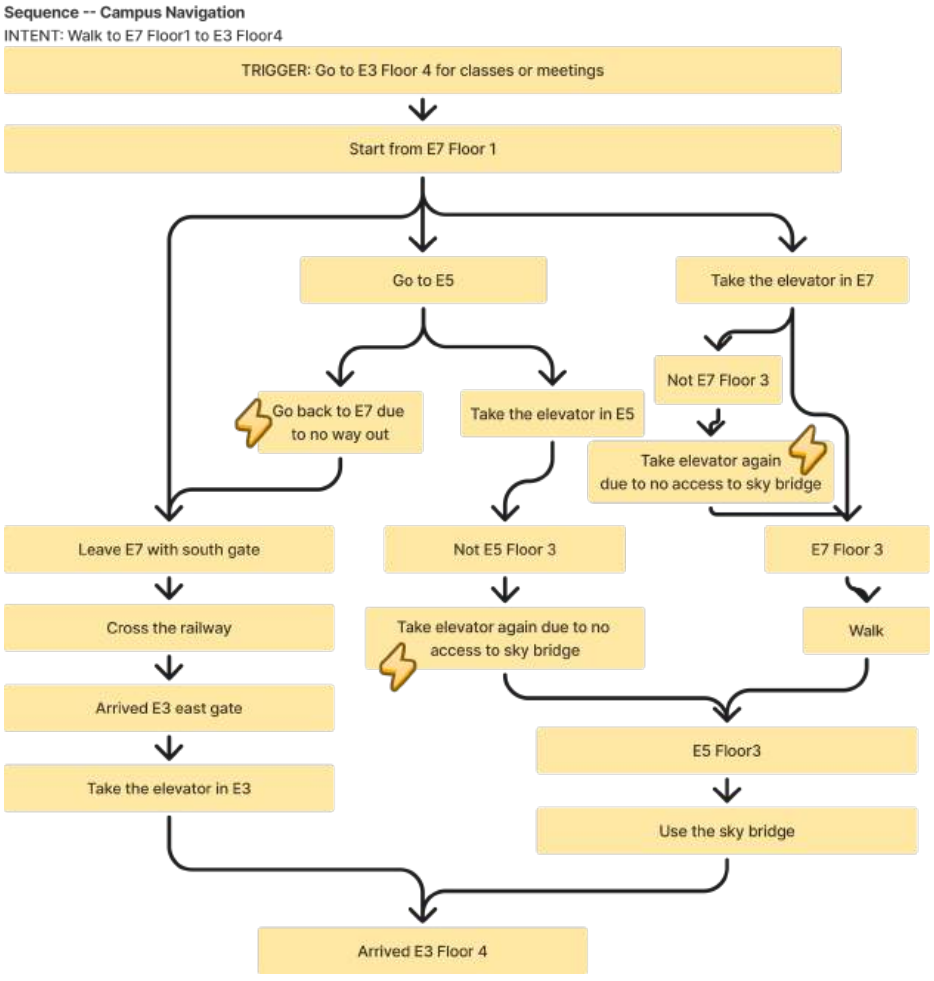


Figure 2.4.2 Sequence Model

The sequence model above clearly shows how the users navigate themselves on campus step-by-step, it includes the separated intents in navigating, the corresponding actions, and anything that happens changes the process.

2.4.3 Artifact Model

The artifact model is the model that documents the physical artifacts that are used in work. In our case, the participant is the key in our contextual inquiry process and they are the major subject of observation. The following artifact model has listed all the physical objects that the participants will use during the CI process.

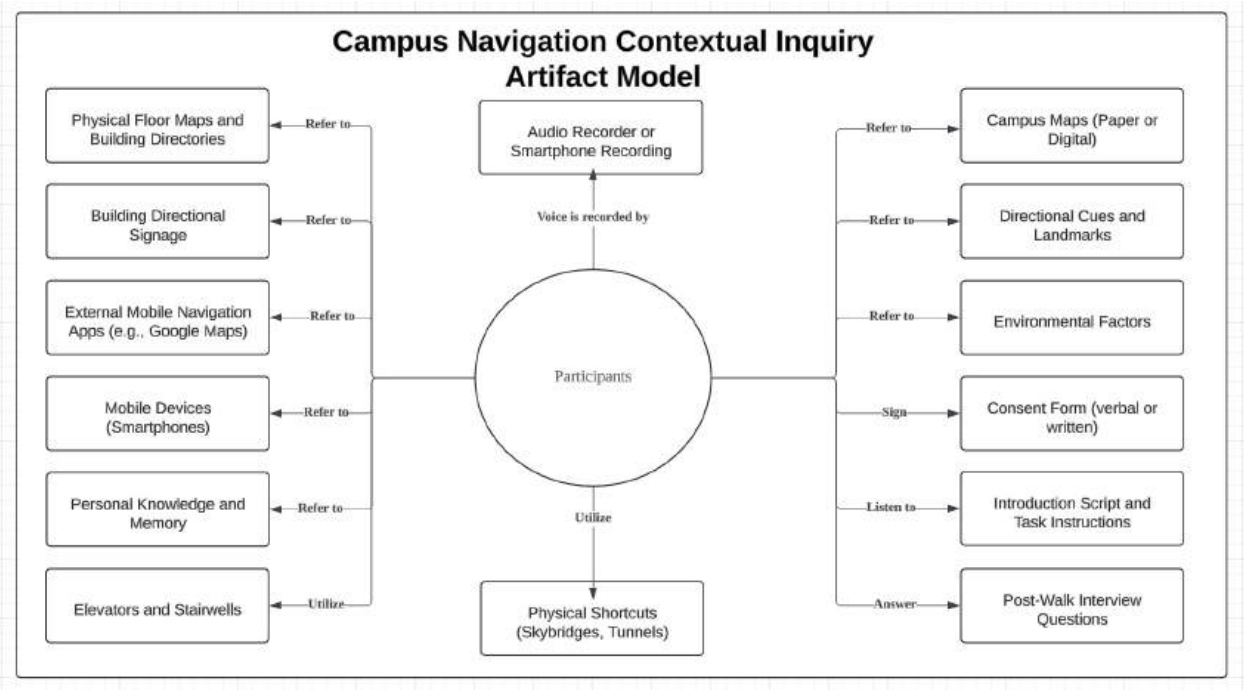


Figure 2.4.3 Artifact Model

The artifact model above critically shows how participants interact with various physical and digital tools during the navigation task. It identifies the tools that aid their navigation experience and highlights breakdowns of these artifacts, showing the overall efficiency of campus movement.

2.4.4 Cultural Model

The cultural model is captured by the language used to describe the work, the tone of the place, the policies, and the influence of the overall organization.

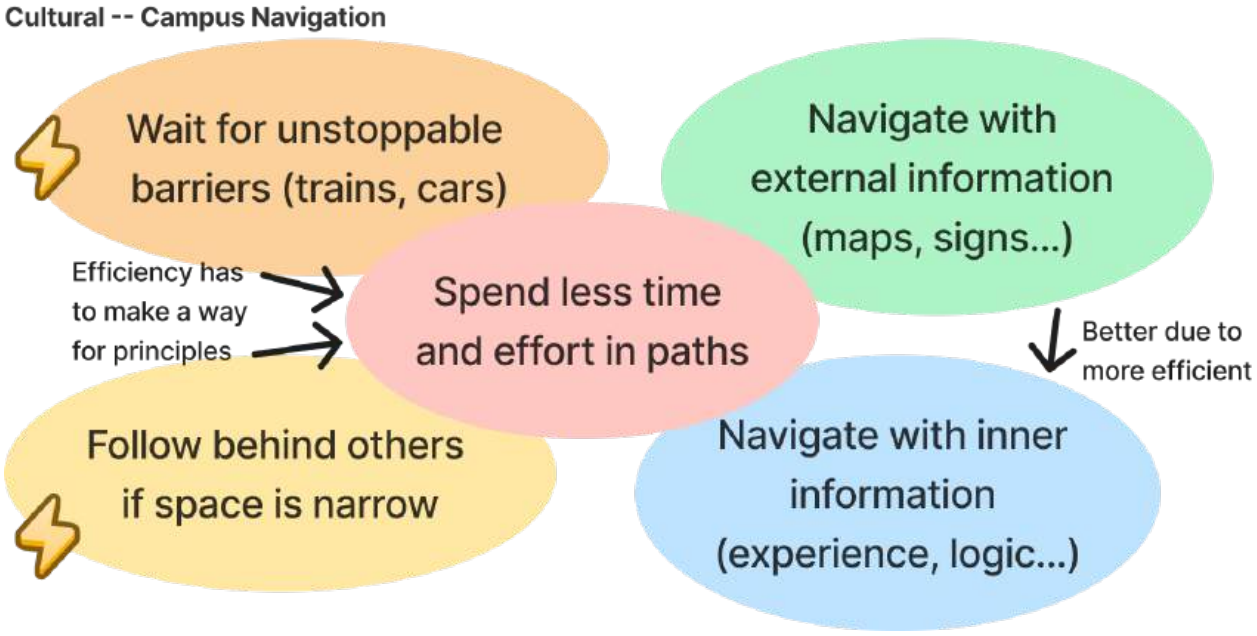


Figure 2.4.4 Cultural Model

The cultural model above critically shows how the backgrounds affect different pieces of the task. It talked about the relationship between the different users and their shared or opposing goals.

2.4.5 Physical Model

1. Outdoor Route

In the Outdoor Physical model, there are seven different routes (Red, Orange, Yellow, Green, Blue, Indigo, and Purple) taken by the users. There are 7 different (2 same) user pain points (lightning) in the figure 2.4.5.1.

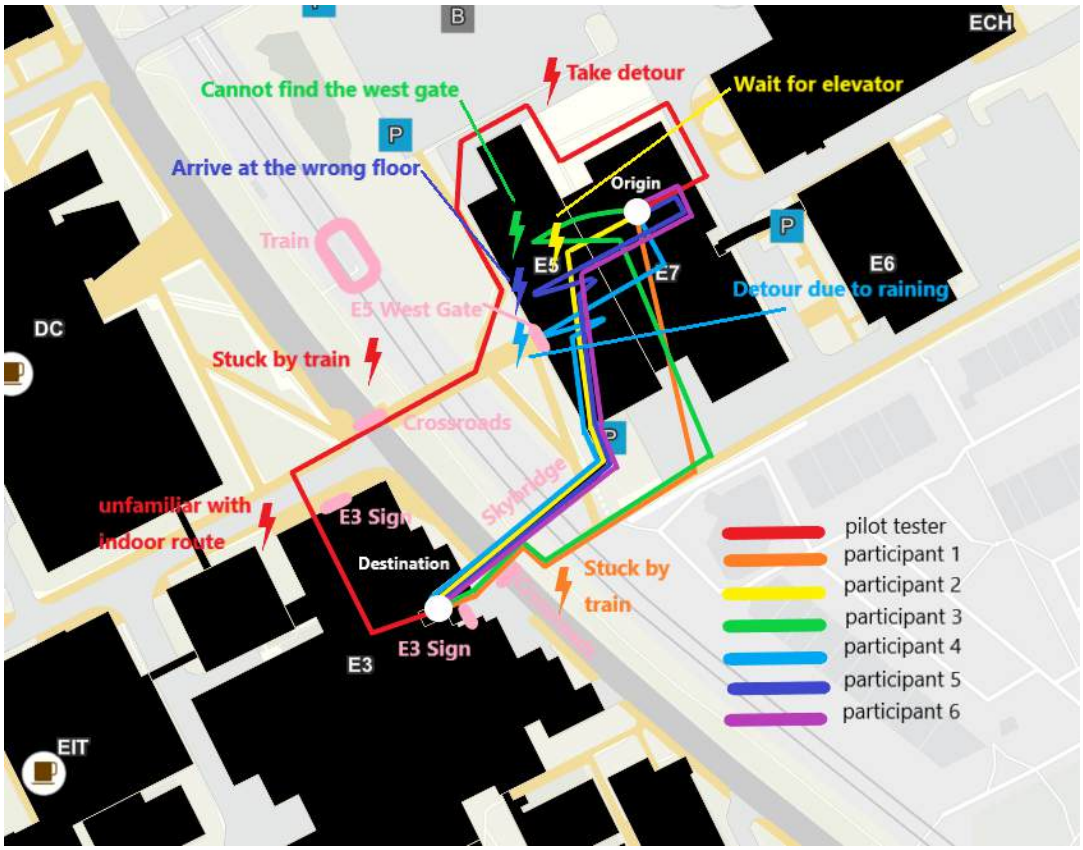


Figure 2.4.5.1 Physical Model

- Route 1 cannot access the west side of the building directly, so user had to take a detour.
- The user was delayed due to the train blocking the way.
- The user was not sure about the indoor route, so the user had to find the floor plan.
- The user took some time waiting for the elevator
- The user couldn't find the west gate, so went back and took a detour.
- The user was stopped by rain and rescheduled the route by taking the indoor skybridge.
- The user arrived at the wrong floor, so the user had to correct the route.

There are some environmental factors (pink) relevant to the routing work.

- E5 West Exit. It is on the second floor, so the user cannot take this exit on the first floor directly.
- Train. It may block the user if the user takes the outdoor route.
- Crossroads. The user has to pay attention to the traffic conditions.
- E3 Building Sign. It can help the user confirm the destination.

- Skybridge. It is the shortcut from E7 to E3.

2. **Indoor Route**

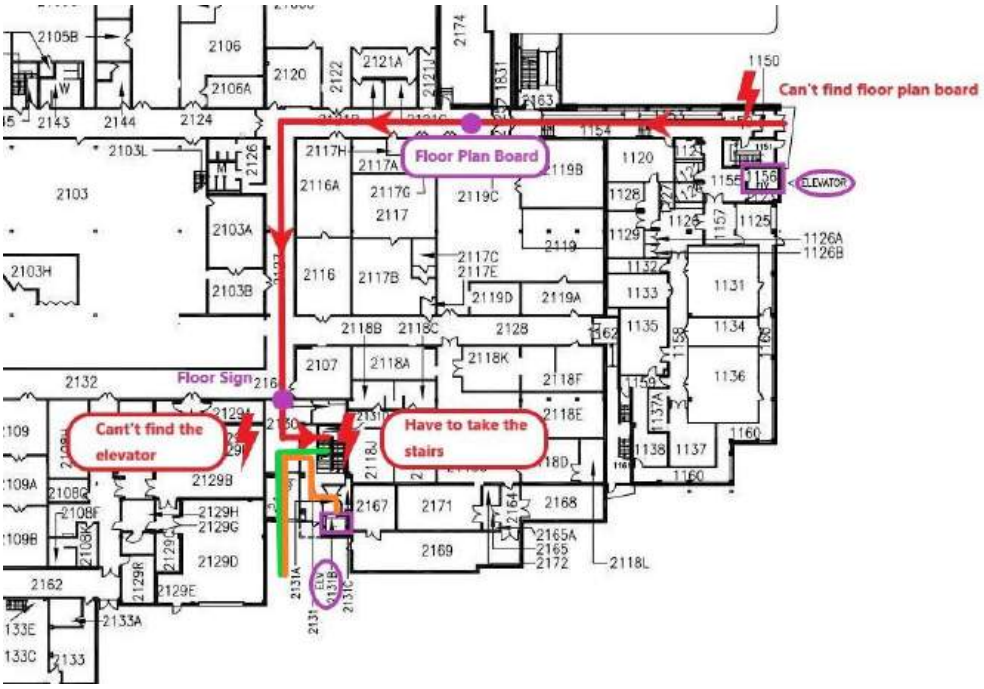


Figure 2.4.5.2

In the E3 indoor physical model, the user took 3 routes (Red, Orange, and Green). There are no pain points for Orange and Green. While there are three user pain points (red lightning) for red in the picture.

- Firstly, the user couldn't find the floor plan board, so the user had to go deeper into the building. As a result, the user missed the nearest elevator.
- Secondly, the second elevator is not obvious. Although the user saw the elevator marks on the floor sign, the user couldn't find the elevator.
- Thirdly, the user finally had to take the stairs.

There are some environmental factors (purple) relevant to the routing work.

- The first elevator: It is the nearest elevator.
- Floor plan board: It can help the user find the route in the building.
- Floor sign: It can help users confirm their route.
- The second elevator: It is unobvious to find.

3. Pilot Test and Field Data

3.1 Executive Summary

- **Objective**: To initiate a pilot test that focuses on further development of a contextual inquiry protocol and modify the current CI protocol; field report
- **Methodology**: The Master-Apprentice model was used to conduct a pilot test between E3 (4th Floor) and E7 (1st Floor). Data was gathered through observation, audio recording, timing, and taking reaction notes.
- **Findings and Insights**:
    1. Rather than taking the indoor sky bridge, the participant used an external ground route (which aligns with our initial assumption).
    2. Collected relevant data such as route choices, time taken, participant's thoughts, and challenges faced.
    3. Some participants did not agree to take the test due to time concerns.
    4. Noted that there were problems with the instructions given to participants, and they were having a hard time understanding the task.
    5. Asking questions during the walk influenced participants' natural behaviour.
    6. We need to reduce participant stress and clarify the Master-Apprentice model to encourage more verbal feedback.
- **Conclusion**:

1. The drawbacks during the pilot test demonstrated a certain weakness of the initial CI protocol.
2. The CI protocol has been updated to provide clearer instructions, reduce participant interruptions, and enhance data collection methods.

3.2 Pilot Test

Key Takeaway: Our pilot test result mostly align with our expectation. The pilot test user is experienced with campus but she has chosen a route that is time-consuming without using shortcut.

3.2.1 Pilot Test Overview

Key Takeaway: Pilot test reveals that even the most knowledgeable targeted users sometimes unaware of shortcuts' existence on campus.

To refine our contextual inquiry protocol, we performed a pilot test to observe anything we could improve. In this section, we will share some findings from the pilot test and make necessary adjustments to our protocols based on our results from the pilot test.

The pilot test was conducted with two participants who were randomly selected out of the participants located on the first floor of Engineering 7 (E7) at the University of Waterloo. The key objective was to carry out contextual inquiry and look for how the users navigated within the two buildings in a natural way, starting from E7 (1st floor) level to E3 (4th floor). We used the master-apprentice method, with the "masters" being the participants and researchers are the "apprentices" being taught how the masters navigate through the two buildings.

3.2.2 Contextual Inquiry Details

Key Takeaway: Things such as finding potential participants, introducing tasks to them, actions should be taken during the test and important data should be documented afterwards.

We conducted our pilot of the contextual inquiry protocols on 3.2 on October 4th, 2024, at 10:30 a.m., and we expect more students will be available on the E7 first floor this weekday and during regular class hours. All four group members joined the contextual inquiry; the workload has been distributed as follows:

- Junyan Chen: take photos and reaction notes
- Zhiyao Yu: introduce tasks and ask prepared questions
- Faye: record audio and recording routes
- Yifei Liu: timekeeping and taking additional reaction notes

1. **Locate Potential Participants & Introduction**

We approached potential participants and introduced ourselves as a group of graduate students doing a social experiment for our research regarding campus navigation, we invited students for this social experiment, which will not take more than 20 minutes. Fortunately, we found one candidate A, who was willing to participate in this experiment. We have collected her demographic, such as year of study, major of study, familiarity with campus, etc. In addition, we also obtained verbal consent for participation and an audio recording of the session for note-taking purposes.

Zhiyao then explained the task to her: "Could you please teach us how you would go from here, the 1st floor of E7, to the 4th floor of E3?" Once the participant understood the tasks, Yifei started the timer, Faye started the audio recording, and Junyan started taking photos when necessary.

2. **During the Walk**

   We followed the participants and encouraged them to think aloud as she was “teaching” us something. We also stated that we would appreciate her sharing thoughts and decision-making processes. In addition, we observed her route choices, navigation tools used, any signs of hesitation or confusion, and their reactions to resolving confusion. Meanwhile, Zhiyao started asking questions along the way, and Faye would record A’s responses.

3. **Post-Walk Review**

   After the walk, we asked follow-up questions (2.2.2) to gain deeper insights into their navigation experience. To be specific, we were interested in their awareness of shortcuts, challenges faced, and suggestions for functions/features in our design.

   Yifei also recorded the optimal time, which is the time taken walking from E7 first floor to E3 fourth floor.

3.2.3 Pilot Test Result & Discussion

Key Takeaway: Data such as the route the participant taken, the significant quote from the transcripts and time taken. It turns out that the participant did not use the efficient shortcut but using a time-consuming route. We have discussed some potential such as the demographic of the participant - she is not very familiar with the campus and researchers did not properly deliver the instructions.

- **Route Map**

During our pilot test, the participant picked the route to E3 from E7 as shown in Figure 3.2.3.1:

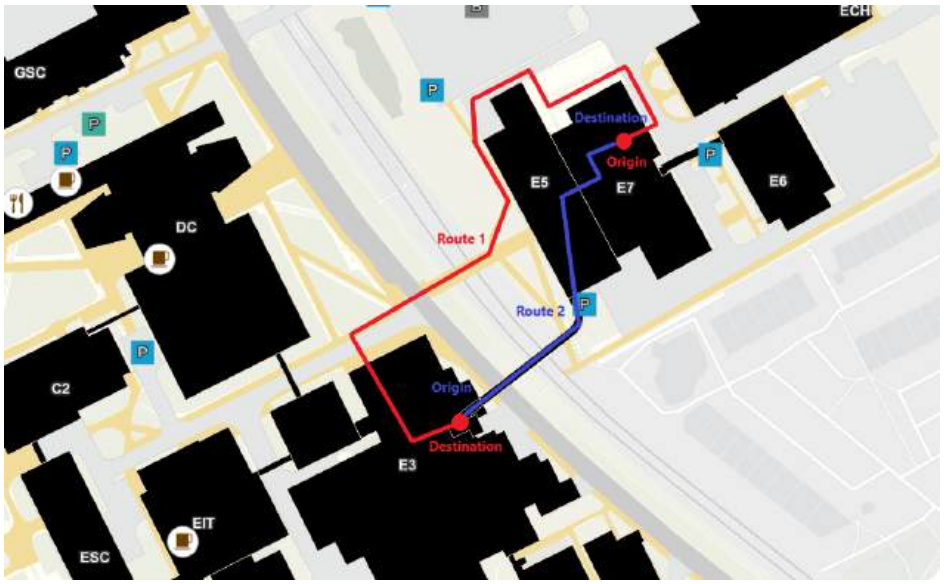


Figure 3.2.3.1: Outdoor Route Taken by the Pilot Test Participant

The red line indicates the route the participant chose to take. Instead of shuttling from inside the building, the participant chose to take her route completely outside. She exited the E7 building from the north exit and chose to detour, cross the railway, and approach the E3 building externally. As soon as she walked into E3, she took the following route, shown in Figure below:

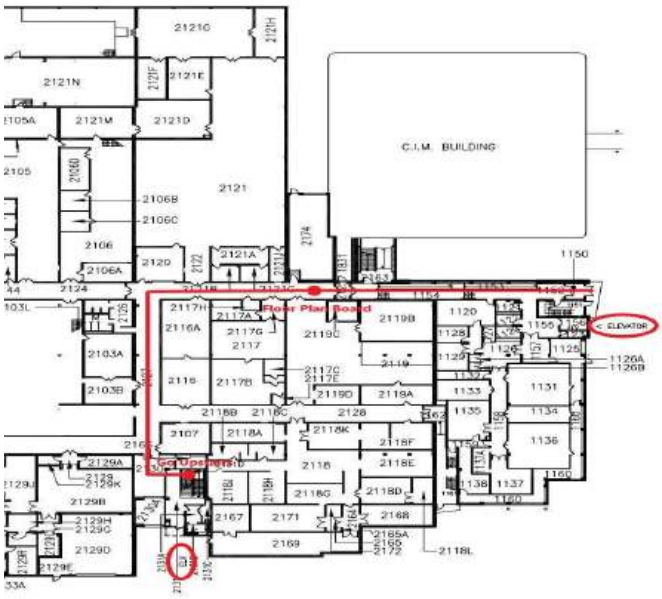


Figure 3.2.3.2: Indoor Route Taken by the Pilot Test Participant

Instead of entering the E3 building from the ring road entrance, the participant enter the E3 building from the entrance facing the DC library. This choice has increased the total time taken for the participant to reach the destination. While looking for paths to go upper floor, the participant was confused on where the stairs were. She also referred to the floor map, which will be discussed in the later section of the result section.

We were satisfied with the paths the participant chose; however, the participant did not use the sky bridge which is a shortcut for this task. In the field report, where a large dataset will be collected, we expect to see similar routes from the participants and conduct analysis of those data to come to a conclusion on why this is the case.

- **Audio - Transcript**

  During the walk, the participant mentioned as follows:

  - Initial Route Choice: The nearest exit from E7 first floor was picked by this participant as it was easy to get to, and it was not crowded at all.
  - Navigational Cues: The participant mostly relied on memory, mentioning that she had only visited the engineering buildings a few times and estimated her familiarity with this part to be around 20%.
  - Encountering Obstacles: When reaching E3, the participant looked for the elevator but was unable to find it, and eventually gave up and took the stairs.
  - Use of External Aids: The participant referred to the floor map on the first floor of E3 to locate the stairs to the fourth floor, but did not use any mobile apps like Google Maps, which she noted is useless inside buildings.
  - Reflection on Route Efficiency: The participant noted that there was a skybridge built between E7 and E3, but she will not use it as the walk began on the first floor of E7. The participant highlighted various concerns including the inability to effectively find one's way around the campus and suggested the incorporation of a 2D or 3D map into the UW Portal app.

  Below is the Code-to-Quote between the interviewer and the participant:

Code	Participant Quotes
Unfamiliarity with Area	- "Like 20%, because sometimes I go to engineering buildings for quiet studies."
Avoidance of Getting Lost	- "I will find the nearest door of E7 and get out of E7 in order not to get lost."
Minimal Use of External Navigation Tools	- "Actually not, but I have a map of the School."
Reliance on Memory	- "Actually, no, by memory I think."
Knowledge of Skybridge	- "I think, if you are going to test how fast to go to E3, there is a skybridge."
	- "Actually, if I am not on the first floor of E7, I would use the skybridge to the fourth floor of E3. But we started on the first floor, then I used the ground route."
Difficulty Finding Elevators	- "Because the University of Waterloo is a strange place, the elevator is just like playing hide-and-seek with us."
	- "Maybe finding the elevator will be right."
Challenges with Google Maps Indoors	- "Actually not, because sometimes Google Maps couldn't help you find the right direction in the buildings."
Desire for Integration with Portal App	- "If you could design it in the portal app, I think it would be the best, you know, I think all the students have the portal app."
Preference for Detailed Maps	- "I think 3D maps are usually the best, but I think it's probably pretty hard... I think 2D would be also good. And if you can show a map of every floor and then show

	it in the apps."
Constraints Due to Starting Location	- "Because you're telling me that we are going to start at the E7 first floor, I think."
Limited Use of Campus Maps	- "Yeah, I do. Actually I have a university map in my phone. Yeah, it is just a copy of the map."
Ineffectiveness of Existing Maps	- "Actually not, because sometimes Google Maps couldn't help you find the right direction in the buildings."

Table 3.2.3.3: Pilot Test Code-to-Quote

- **Reaction Notes**
    - The user did not use any mobile navigation or ask anyone for directions. Most route design was generated from the internal existing information in mind. The only time the external information was used was the map at the entrance on the first floor of E3 since the user needed to figure out how to access the 4th floor from the 1st floor in E3.
    - During the pilot test, the user appeared to be confident and determined on the path chosen overall. There were not many moments when the user was confused or hesitated. Except for the moment mentioned above when observing the map in E3, 2 objective reasons caused slowing down. One was caused by the train, the other one was caused by the other pedestrians going upstairs.
    - The user appeared to be unsure when we asked her some questions, which caused a slight speed loss. Some questions were too vague and some required the user to try to remember. Those questions interfered with the process the user walked more or less.

- **Time**

Route	Start	End	Total (mins)	Note
1	11:13	11:24	11.48	Ground Route User Picked
2	11:24	11:27	2.83	Through Shortcut E5-E3

According to our record, the user took around 11.48 minutes to complete the task, while it only took around 2.83 minutes if the task was completed by going through the shortcut, which is the sky bridge between E5 and E3.

More reasons than we expected caused extra time spent on the task. First, the user began with an unnecessary part of the route. Adding distance increases the time taken to finish the task. Second, some barriers appeared on the path the user chose. The user had to stop for the train on the ground and was slowed down by other pedestrians while climbing the stairs in E3. Third, the user spent some time observing the map in E3 trying to figure out how to go up, but she would directly arrive on the 4th floor of E3 if she chose to take the shortcut from E5 to E3.

- **Participant Demographic**

At the beginning of the pilot contextual inquiry, we collected comprehensive demographic information from the participants to provide a richer context for our inquiry, and we generated the following table. The following table summarizes the demographic details of the participants. For our pilot test, we have collected the following information:

Participant ID	Academic Year	Field of Study	Self-Rated Familiarity with Campus	Preferred Navigation Method	Self-Rated Technology Proficiency
A	Fourth-Year	Science	Low	Personal knowledge	High

3.2.4 Limitation

Key Takeaway: This section lists the things to improve in our initial CI protocol. Overall the initial CI protocol is intact but some amendments are needed. For example, how to properly recruit participants, how to get active feedback from the participants and how to convey clear task instructions. Those problems should be addressed in the finalized CI protocol (2.3.2).

The pilot test demonstrates what our contextual inquiry will be like. The process is mostly successful and it testified to the accessibility of our contextual investigations. However, we will adjust and improve a few things to make the process more reliable and efficient.

Firstly, we encountered some challenges when inviting users to our pilot test. More rejected candidates were worried about taking too much time, privacy issues, and complicated procedures. To make it easier for data collection, we need to refine our contextual inquiry to make it more clear and standardized. First, we need to limit the time to 5 minutes excluding the time it takes the user to walk since it depends on the path the user chose. Second, we also changed the contextual inquiry from recording videos which most people do not feel comfortable with to taking pictures and recording audio. Third, the users can feel stressed when they are told that we will continue asking questions while walking. So we plan to limit the questions we ask during walking to make it more acceptable.

Secondly, we did not receive enough feedback or context in the expected master-apprentice style contextual inquiry. The user walked from E7 to E3 in silence, but we expected her to explain and introduce the route to us while walking, so we could know the reasons underneath the route design. Though, understandably, different people have different teaching styles, we agreed that we could have expressed such a need more clearly before we started our experiment. Instead of saying “Please show us how you approach the 4th floor of E3”, we could have rephrased it to “Please treat me as a student who just came here and teach me how I can approach the 4th floor of E3, also please tell me as much related information that makes you walk that route as possible”

Thirdly, as mentioned above, the user walked from E7 to E3 in silence, so most information we gained in the pilot test was from our questions and the user's answers. However, our questions were an interruption that could draw the user out of her linear internal task management. We noticed every time we asked questions, the user appeared to walk slower and the facial expression showed her attention was pulled to somewhere else or her mental mode was changed from accomplishing a task to searching for a memory. Therefore, we decided to reduce the number of questions we ask during the users walk, so their mental mode and internal task management could be more natural.

Fourthly, in this pilot test, the user took us to walk around north E7 outside at the beginning of the route. We thought that was the user's plan so we did not interrupt. At the end of the contextual inquiry, we asked if she was aware of the existence of the shortcut and why she walked around north E7 at the beginning, she replied that she thought we were going from the 1st floor of E7, which means any floors above the 1st floor in E7 was prohibited. Such confusion should be avoided in future contextual inquiries. We plan to make our task more precise. For example, the task was "from the 1st floor of E7 to the 4th floor of E3", while the new task will be "from here to the 4th floor of E3" since we always meet the user at the starting point.

3.3 Field Data

Key Takeaway: This section will present rich data such as route, transcripts, reaction notes, and time during the field test. As this section only organizes and presents field data, data analysis, and preliminary design will follow shortly after.

After having an intact CI protocol, which was developed over the pilot test and several amendments, the finalized CI protocol is ready to put into use. We have conducted several field tests, working with different participants using the CI protocols developed in section 2.3.2. Data will be properly organized for further analysis.

3.3.1 Route Taken

Key Takeaway: This section documents the routes taken by six participants during the navigation task. The routes are summarized below for clarity.

Participant 1:

```
E7 First Floor
      |
[Exit via South Gate]
      |
[Walk West]
      |
[Cross Railway & Driveway]
      |
E3 East Gate
      |
[Use Elevator]
      |
E3 Fourth Floor (Destination)
```

Participant 2:

```
E7 First Floor
      |
[Walk Inside to E5]
      |
E5 Elevator to Third Floor
      |
[Turn Left to Sky Bridge]
      |
[Cross Sky Bridge]
      |
E3 Fourth Floor (Destination)
```

Participant 3:

```
E7 First Floor
      |
[Walk West to E5 First Floor]
      |
[Backtrack to E7 First Floor]
      |
[Exit via South Gate]
      |
[Walk West Outside]
      |
[Cross Railway & Road]
      |
E3 First Floor
      |
[Go Upstairs]
      |
E3 Fourth Floor (Destination)
```

Participant 4:

```
E7 First Floor
      |
[Go Upstairs to E7 Second Floor]
      |
[Enter E5 Second Floor]
      |
[Proceed to West Gate]
      |
[Stop & Return to Stairs]
      |
[Go Up to E5 Third Floor]
      |
[Walk to Sky Bridge]
      |
[Cross Sky Bridge]
      |
E3 Fourth Floor (Destination)
```

Participant 5:

```
E7 First Floor
    |
[E7 Elevator to Fourth Floor]
    |
[Walk to E5 Fourth Floor]
    |
[Stop & Return to Elevator]
    |
[E5 Elevator to Third Floor]
    |
[Cross Sky Bridge]
    |
E3 Fourth Floor (Destination)
```

Participant 6:

```
E7 First Floor
    |
[E7 Elevator to Third Floor]
    |
[Walk to E5 Third Floor]
    |
[Cross Sky Bridge]
    |
E3 Fourth Floor (Destination)
```

Below is a table that summarizes the detailed layout of each participant's route:

Participant	Route Type	Used Sky Bridge	Outdoor Portion	Notable Actions
1	Outdoor route	No	Yes	Exited E7 via south gate; crossed railway
2	Indoor route with sky bridge	Yes	No	Used elevator to E5 third floor; crossed sky bridge
3	Mixed route	No	Yes	Attempted E5 route; backtracked; then went outside
4	Indoor route with sky bridge	Yes	No	Attempted west gate in E5; then used sky bridge
5	Indoor route with	Yes	No	Corrected after

	sky bridge			finding no sky bridge on E5 fourth floor; Crossed on third floor.
6	Indoor route with sky bridge	Yes	No	Used elevator directly to the E7 third floor, and crossed the skybridge

Table 3.3.1: Route Taken Summary

3.3.2 Transcripts

Key Takeaways: This section codes the conversation between researchers and participants (a.k.a. transcripts). Organizing data using effective coding will help us quickly identify key insights from those contextual inquiries. We only extract essential quotes from the transcripts.

This table summarizes the key codes that emerged from the participants' transcripts, along with representative quotes that illustrate each theme.

Here is a table mapping significant quotes to codes:

Code	Participant Quotes
Unfamiliarity with Area	- Participant 1: "I have never been to E3 before, so I would say I am not familiar with this area."
	- Participant 3: "I am unfamiliar with the Engineering faculty."
	- Participant 5: "I think there’s a skybridge

	between E5 and E3, but I’m not too familiar with it."
Reliance on External Navigation Tools	- Participant 3: "I will open my Google Maps to find out where E3 is..."
	- Participant 5: "Let me check the UWaterloo Map to figure out that skybridge is on which floor. I see, it is on the third floor, let's go back to the elevator and go to the third floor."
Use of Building Signage/Floor Maps	- Participant 1: "I think I have seen the sign of building E3 before. I know where that building is so I am walking towards that building."
	- Participant 3: "Let me check with the floor map... It seems like there is no west gate on the first floor."
	- Participant 4: "Do you see the sign? We need to go across E5 first to reach the west gate."
Preference for Shorter Routes	- Participant 2: "E7 actually is internally connected with E5, and there is a sky bridge connecting the third floor of E5 and the fourth floor of E3."
	- Participant 1: "I knew there was a sky bridge but I didn’t realize it connects E7 and E3."
	- Participant 3: "Yes, I see. This skybridge is

	definitely the shortcut."
	- Participant 4: "The skybridge seems to reach E3, let's take the skybridge."
	- Participant 5: "I think there's a skybridge between E5 and E3, but I'm not too familiar with it."
	- Participant 6: "E7 is connected to E5 internally, and there's a skybridge that links the third floor of E5 to the fourth floor of E3."
Preference for Shorter Routes	- Participant 2: "I like to search for short paths, so I can save some time. Time is money."
	- Participant 4: "Because going through the west gate is a shorter route."
	- Participant 6: "I like finding shortcuts to save time."
Issues with Building Layout	- Participant 1: "It's just confusing that we were on the third floor of E3 according to the elevator, but it suddenly became the fourth floor..."
	- Participant 3: "I cannot find the west gate... I don't know if E5 doesn't have a west gate."
	- Participant 3: "Maybe the function to find gates, you know, I just got lost because I couldn't find the west gate."

Adaptability to Environmental Conditions	- Participant 4: "Oh, it’s raining. It’s not a good idea to go outside now... Let’s take the skybridge."
Desire for Improved Navigation Tools	- Participant 1: "Since Google Maps doesn’t contain the sky bridge. I hope it would be nice if you have that."
	- Participant 3: "Maybe the function to find gates..."
	- Participant 4: "I think indoor route navigation would be a good function... If we can totally go indoor route, we don’t need to use an umbrella or get wet."
	- Participant 5: "It would be great if it showed clear indoor routes, like the skybridge, or shortcuts between buildings."
Reliance on Personal Experience	- Participant 2: Interviewer: "So you rely on experience to find paths." Participant: "Yes."
	- Participant 6:"I’ve explored these buildings and found the best paths, so I know the shortcuts."
Serendipitous Navigation	- Participant 1: "Honestly, I did not know the path before. We were lucky."
Value of Indoor Routes to Avoid Weather	- Participant 4: "If we can totally go indoor route, we don’t need to use an umbrella or get wet."

Confusion with Floor Numbering	- Participant 1: "It's just confusing that we were on the third floor of E3 according to the elevator, but it suddenly became the fourth floor..."
	- Participant 5: "The E5 third floor is connected to the E3 fourth floor, which initially led me astray."
Time-Saving Motivations	- Participant 2: "I like to search for short paths, so I can save some time. Time is money."
Use of Elevators/Stairs	- Participant 1: "There is an elevator. Let's take it."
	- Participant 2: "We could arrive earlier if we directly used the stairs going up to the third floor of E7, it's just too exhausting."
	- Participant 5: "I will use the elevator to the fourth floor of E7."
	- Participant 6: "Waiting for elevators will take a while, but it's still faster than taking the stairs every time."
Constraints Due to Building Features	- Participant 1: Interviewer: "We can only go to the third floor by the elevator." Participant: "It's okay. We can figure it out after we are up there."

Table 3.3.2: Transcripts Quotes to Codes

3.3.3 Reaction Notes

Key Takeaways: This section organizes the reaction notes for each participant into a data structure that can be read and processed further. A table is constructed for such a purpose.

A table that documents essential insights from reaction notes raw data:

Participant	Familiarity with Area	Used Mobile Navigation	Obstacles Encountered	Sign or Hesitation Level	Hesitation/ Observation
1	Low	No	Yes	High	Yes
2	High	No	Yes	Low	No
3	Low	Yes	Yes	High	Yes
4	High	No	Yes	Low	No
5	Low	No	Yes	High	Yes
6	High	No	No	Low	No

Table 3.3.3: Participant Reaction Summary

Observation:

- Participants with low familiarity (Participants 1, 3 and 5) exhibited higher hesitation.
- Participants with high familiarity (Participants 2, 4 and 6) exhibited lower hesitation.

3.3.4 Time Comparison

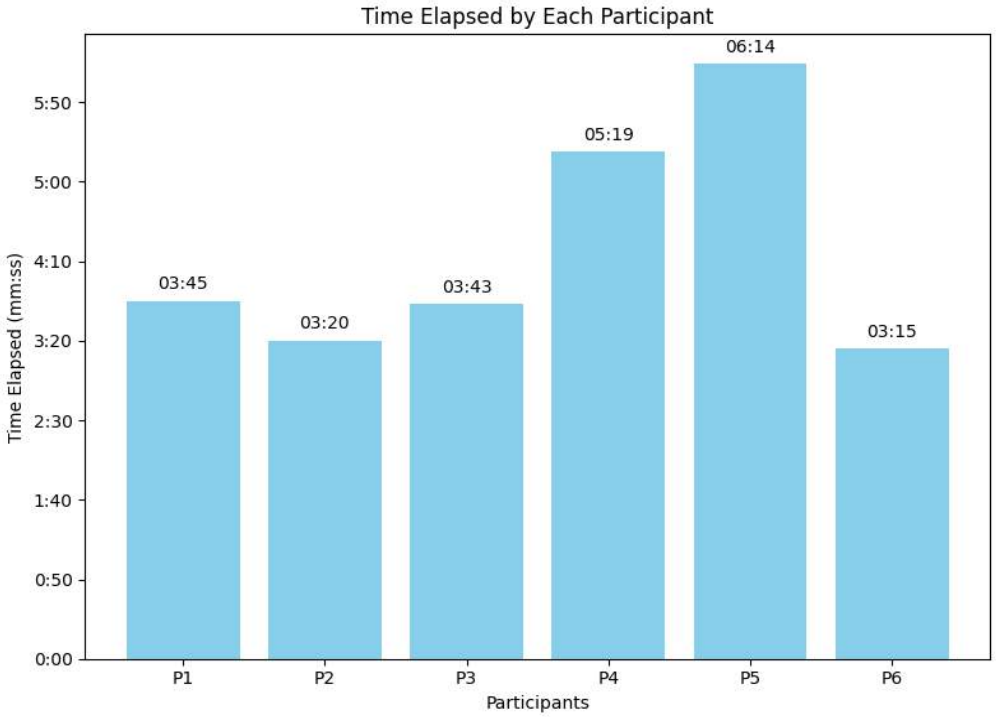
Key Takeaways: This section compares the time each participant took to complete the navigation task. A graph illustrates the differences in completion times among participants.

Time taken by each participant - Raw Data:

Participant	Time Elapsed (min:sec)
1	03:45
2	03:20
3	03:43
4	05:19
5	06:14
6	03:15

Table 3.3.4.1: Time Elapsed by Each Participant

To better visualize the time differences, we have created a bar chart displaying the time elapsed for each participant.



Graph 3.3.4.2: Time Elapsed by Each Participant

3.3.5 Thematic Analysis

Key Takeaways: Users' route choices are influenced by a combination of objective factors, efficiency goals, personal preferences, and individual situations. Key constraints include building layout, weather conditions, and familiarity with navigation tools and shortcuts. Users prioritize efficient routes but adapt based on personal experience, environmental factors, and situational needs.

Here is a table mapping low-level insights based on different participants:

Participant	Low-level Insights
Pilot tester	- Users would be **stuck by the train** when taking the outdoor route. We can consider **train passing information** when designing routes. - Elevators are significant for users to take upstairs or downstairs. We can highlight the **location of the elevator** on the map. - When designing a route, it is significant to determine the direction. We need to **choose the route in the target direction as far as possible**.
1	- Users can have different familiarity levels for different areas, we need to **assume the user is not familiar with any area**. - Users have various levels of road/building signs capture abilities, we need to **let the user know their own location** and the **next direction** as soon as possible. - Other map apps don't show the **sky bridges**, which we can prompt in our design.
2	- **Time spent waiting for the elevator** is unsure, time estimate can be hard if the **elevator** is included in the path. - There are a lot of shortcuts on campus, it satisfies the users if we **contain as many shortcuts as possible**, including different types like **sky bridges, indoor routes, tunnels**.

3	- Finding the gate of a building is an important step for navigation. We can **highlight all the gates** of the building on the map and with their **number of floors**. - Sometimes users have to confirm a building outside of it. We can provide some **pictures of the building to help users** - Finding the floor plan is an important step for indoor navigation. We can **provide floor plans for the users on the system**.
4	- Users tend to take indoor routes when encountering rainy, snowy, cold or hot weather. We can **integrate weather information into our system to design corresponding routes.**
5	- Sometimes users know the existence of skybridge, but have inaccurate memory of its floor and exact location. We should **include precise prompts in our navigation system** to ensure users can locate the shortcut easily. - The floor numbering differs across buildings on campus, which can be confusing when moving between them. We need to **inform users of the floor number of the new building after crossing a skybridge or shortcut** to prevent disorientation due to sudden floor changes.
6	- Users are familiar with the skybridge locations but prioritize time savings over route familiarity. We should **integrate real-time comparisons for elevators and staircases**, allowing these users to choose the fastest option based on current conditions.

Table 3.3.5.1: Low-level Insights Based on Different Participants

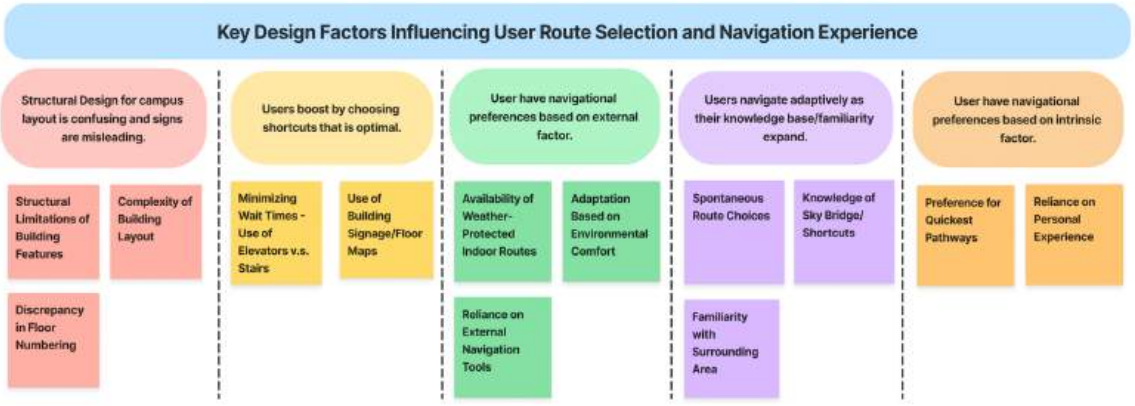
To obtain high-level insights, we clustered codes into groups and refined them.

High-level Insights	Code From Transcripts 3.3.2
Objective factors can affect the route choice.	Constraints Due to Building Features

Route choice has to be built on key map information.	Issues with Building Layout
	Confusion with Floor Numbering
User's first goal in the route choice is efficiency.	Use of Elevators v.s. Stairs
	Use of Building Signage/Floor Maps
External personal preference can affect the route choice.	Reliance on External Navigation Tools
	Adaptability to Environmental Conditions
	Value of Indoor Routes to Avoid Weather
Individual situations can affect the route choice.	Serendipitous Navigation
	Awareness of Skybridge/Shortcuts
	Unfamiliarity with Area
Intrinsic personal preference can affect the route choice.	Preference for Shorter Routes
	Reliance on Personal Experience

Table 3.3.5.2: High-level Insights Based on Codes

Here we use affinity diagrams to consolidate all high-level insights.



Graph 3.3.5.3: Affinity Diagrams of Navigation Factors

Throughout the process of thematic analysis, we identified **5 main issues** now existing in navigating on campus. Those issues reflect what our users need and what they require in the design. The table below intuitively shows the user requirements and what issues generated them.

Participatory Design Requirements:

1. Confusing Structural Design and Misleading Signs

2. Need for Optimal Shortcuts

3. Navigational Preferences Based on External Factors

4. Adaptive Navigation as Knowledge Expands

5. Navigational Preferences Based on Intrinsic Factors

Here is the user requirement based on navigation issue:

Issue	User Requirements
Structural Design for campus layout is confusing and signs are misleading.	Since it is impossible to correct the confusion or misleading existing in the building, our navigation system has to present precise and detailed information to the users. The incorrect signs in reality will be marked in the system so the users do not get confused when they use both the navigation system and the signs.
Users boost by choosing shortcuts that are optimal.	All users share the same goal in the process of route choice, which is getting to the destination more quickly. However, due to a lack of information, users sometimes are unable to choose the best route. We need to include all the sky bridges and shortcuts as an option in the route for the user to choose.
Users have navigational preferences based on external factors.	Environmental features like weather affect the users' choices. The system needs to display the current environmental barriers like rain or roads in construction, so the users can avoid unexpected conditions.

Users navigate adaptively as their knowledge base/familiarity expands.	Personal knowledge is a frequently used resource in navigating. However, since users can have different levels of familiarity with the area, the system has to assume them having no familiarity with the area, so it can provide sufficient information for them to navigate.
Users have navigational preferences based on intrinsic factors.	Like personal knowledge, personal experience is another frequently used resource in navigating. Here it emphasizes the aspect that the user's potential preferences like using stairs or elevators. The system needs to cover options for both of them so the users are able to choose the routes they feel the most comfortable.

Table 3.3.5.4: User Requirement Based on Navigation Issue

In addition, we are able to map our 5 requirements into the work model that we have updated in the early section 2.4 CI Work Model.

1. Confusing Structural Design and Misleading Signs

- Best-fit Work Model: Artifact Model

  Explanation: The Artifact Model documents the physical artifacts used in work, such as signs, and floor maps. In this case, **confusing building layouts and misleading signs are physical artifacts that impede navigation**. By acknowledging these issues in our navigation system, we address the limitations of these physical artifacts. Our design should act as a reliable digital artifact, and it should compensate for the shortcomings of the physical environment and enhance the user's navigation experience.

2. Need for Optimal Shortcuts

- Best-fit Work Model: Flow Model

  Explanation: The Flow Model illustrates how work is carried out, focusing on the coordination and communication between different elements. **Users aim to move efficiently through the campus, and the flow of their navigation is crucial.** By including all available possibilities, like sky bridges and tunnels, in the navigation

system, we want to give optimal flow to users' movements, reducing unnecessary steps and optimizing their routes. This directly supports users' goals of time-saving and efficiency within the flow of their activities.

3. Navigational Preferences Based on External Factors

- Best-fit Work Model: Sequence Model

  Explanation: The Sequence Model provides a step-by-step account of how work is done, including the intent behind actions and triggers that lead to those actions. **External factors like weather conditions or construction work act as triggers that influence users' navigation sequences.** By incorporating real-time environmental information into the system, we help users adjust their navigation steps accordingly. This ensures that the sequence of actions aligns with their preferences and situational needs.

4. Adaptive Navigation as Knowledge Expands

- Best-fit Work Model: Physical Model

  Explanation: The Physical Model represents the physical environment in which users operate, including spatial layouts and physical constraints. **Users' familiarity with the campus evolves over time, affecting how they navigate the physical space**. By providing detailed maps and comprehensive guidance, the navigation system aids users in building accurate mental models of the campus, facilitating adaptive navigation. The system bridges the gap between the complex physical environment and the user's understanding, accommodating users at different levels of familiarity.

5. Navigational Preferences Based on Intrinsic Factors

- Best-fit Work Model: Cultural Model

  Explanation: The Cultural Model captures the influence of culture, policies, and personal preferences on how work is performed. **Intrinsic factors such as personal preferences for elevators over stairs or avoiding crowded areas are shaped by individual values and norms**. By allowing users to customize their navigation preferences, the system respects and accommodates these intrinsic factors. This alignment with users' personal and cultural preferences enhances satisfaction and usability.

4. Participatory Design

4.1 Executive Summary

- **Objective**: Construct the participatory design (PD) based on previous findings.
- **Methodology**: Invite users to participate in the process of design.
- **Findings and Insights**:
    1. Users prefer using stairs rather than elevators.
    2. Users prefer familiar routes rather than learning new ones.
    3. Larger, simpler maps with fewer icons (≤3) and more clear labels are preferred.
    4. Users do not need too many saving options as they learn routes over time.
    5. Train and elevator wait times are unnecessary.
    6. Users like to Include starting point input and floor levels for multi-layered maps.
- **Conclusions:**
    1. Simpler and straighter designs are recommended by the users.
    2. Rare functions like elevators and trains est. waiting time are not needed as much as the team thought.
    3. A few pieces of advice proposed by the users are not feasible from the perspective of engineers.
    4. More users invited into PD can make it more precise, sample limitation exists in the current research.

4.2. Introduction

Key Takeaway: This section will accomplish a participatory design that allows the team to finalize the design's blueprint involving the users' perspective.

Project Background: As the complexity of campus buildings increases, the requirement of indoor navigation is appearing. We hope to have an effective system to help students and faculties move freely on campus.

The core of our workshop is the participation of our future users, their feedback will directly affect the results.

- **Presentation on Usability**

  Simplicity: The system should be easy and simple to use

  Efficiency: Tasks should be completed with minimal effort

  Individuation: The system should satisfy user with different preference

- **Objectives and Expectations**

  We want to design a campus navigation system that can provide navigation for the internal routes of buildings. Not only can it help students move efficiently inside buildings, but it can also facilitate their movement to another building, solving the problem that most map software can only provide outdoor routes. We expect this system to develop comprehensive functionality and appropriate performance based on the user pain points or problems we have identified, as well as the ideas of the users involved in the design, to best meet the needs and experience of users.

- **Identify Issues have been found**

  Users were stuck by the train when taken outdoor route

  Users took times to find elevators

  Users spent time waiting elevators

  Users couldn't find the gate of the buildings

  Users tried to find the floor plan first when getting in a building

  Users have to reschedule route because of the weather (rainy, snowy, cold or hot)

  Users were confused by the two different floor numbers at the link of buildings

- **Issues raised by users**
- **Set Design Goals**

  System should try to avoid planning routes which cross railways

  System should highlight the elevators or stairs at the map

  System should provide variety routes with different elevators or stairs to avoid congestion

  System should highlight the gate of the buildings

  System should provide clear floor plan of the building

  System should take weather information into account when planning routes

  System should highlight the floor number of each related buildings

4.3 Conduct

Key Takeaway: The participatory design session highlighted key user needs, such as integrating detailed indoor maps, shortcuts, real-time updates, and customizable preferences, ensuring a user-friendly, efficient, and adaptable navigation system.

4.3.1 Workshop Preparation

To effectively prepare for the participatory design workshop, we assembled a diverse group of participants and gathered essential materials to facilitate productive and insightful sessions.

1. **Participants:**

   A diverse group of five University of Waterloo students to represent a broad range of user perspectives.

   a. Faculty Representation: Students from different faculties such as Engineering, Arts, Statistics, Environment, and Mathematics.
   b. Year of Study: Included first-year, mid-level, and senior students with different levels of campus familiarity.
   c. Cultural Diversity: Included both domestic and international students to capture varied cultural and linguistic perspectives.

2. **Props and Materials:**

   a. Printed Campus Maps: Detailed maps of the university buildings, including floor plans and known shortcuts like sky bridges and tunnels.
   b. Sticky Notes and Markers: Participants will be asked to annotate maps, highlight problem areas, and suggest improvements.
   c. Scenario Cards: Predefined navigation scenarios (e.g., moving from E7 to E3 during bad weather) to prompt discussion.
   d. Whiteboard or Large Paper Sheets: To collectively sketch ideas, interfaces, or flow diagrams.

e. Recording Equipment: Smartphones (with consent) to photograph participants' notes, sticky notes, and sketches, and to record important discussion audio for later analysis.

To effectively prepare for our participatory design session, we developed a structured plan to guide the workshop. The session was designed to engage participants through introductions, presentations, and interactive activities, aiming to gather valuable user insights and collaboratively refine our navigation system design. Below is the detailed plan outlining each component and its objectives.

3. Session Structure and Estimate Time:

a. Introduction (5 minutes):

- Welcome Participants: Thanked them for their time and explained the importance of their contribution.
- Overview of the Session: Outlined the agenda and objectives. Emphasized that their input will directly influence the design of the navigation system.
- Establish Ground Rules: Encouraged open communication and respect for all ideas while ensuring confidentiality.

b. Presentation of Findings (5 minutes):

- Recap of Previous Research: Shared key insights from observations and contextual inquiries.
- Identified Issues: Discussed the five main issues affecting campus navigation.
- Goals for the Navigation System: Presented preliminary ideas based on prior research.

c. Interactive Activities (30 minutes):

<u>Activity 1: Map Annotation (10 minutes):</u>

- Preparation:
  - ★ Printed campus maps (Figure 4.2.1.1), highlighting buildings E7 (First Floor) and E3 (Fourth Floor).

★ Markers or pens for participants to annotate routes and navigation challenges.

- Instructions:
  - ★ Participants were provided with the printed campus maps (Figure X) and asked to highlight their chosen routes from E7 (First Floor) to E3 (Fourth Floor).
  - ★ Participants were also instructed to mark areas where they encountered navigation challenges, such as confusing signs, unclear pathways, or problematic transitions between buildings.
- Objective:
  - ★ Identify problematic locations, confusing signs, and users' preferred routes within the specified area.
- Outcome:
  - ★ Gathered visual data on navigation pain points and user insights, particularly in transitioning between buildings and floors in the designated route.

Here is the campus map we provided.

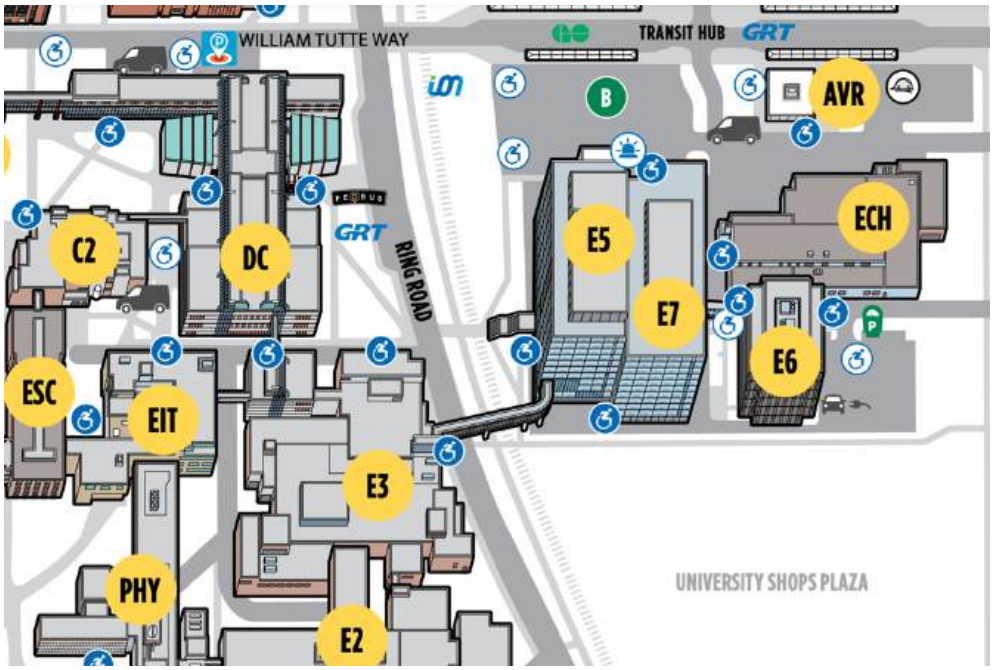


Figure 4.3.1.1

Activity 2: Scenario Exploration (10 minutes):

- Preparation:
  - ★ Provide participants with sticky notes in different colors (e.g., red for locations, blue for elevators/stairs, green for sky bridges / railways) as outlined above.
  - ★ Scenario cards illustrating various navigation challenges (e.g., navigating in bad weather, dealing with time constraints, finding accessible routes).
- Instructions:
  - ★ Participants will use the provided sticky notes to map out their navigation strategies for each scenario presented on the cards.
  - ★ For each scenario, participants will brainstorm solutions or features that would help address the challenges and annotate their ideas using the sticky notes.
- Objective:
  - ★ Understand user needs in specific contexts (e.g., bad weather, time constraints).
- Outcome:
  - ★ Generated a list of desired features and functionalities.

Here is the table for the sticky notes we prepared.

Red Sticky Notes (Locations)	E7 First Floor; E7 North Gate; E7 South Gate; E7 East Gate; E7 Third Floor; E7 Fourth Floor
	E5 First Floor; E5 Second Floor; E5 Third Floor; E5 Fourth Floor; E5 Gate (near railway); E5 East Gate
	E3 First Floor; E3 North Gate; E3 South Gate; E3 Second Floor; E3 Third Floor; E3 Fourth Floor

Blue Sticky Notes (Elevators or Stairs)	E7 Elevator; E7 Staircase
	E5 Elevator; E5 Staircase
	E3 Elevator near Corridor; E3 Staircase
Green Sticky Notes (Railway, Skybridge)	Skybridge from E5 to E3
	Indoor Path connecting E7 and E5
	Railway
Yellow Sticky Notes (Other Navigation Elements)	Signage for Direction to E7 Elevator
	Signage near E3 Elevator to Fourth Floor
	Floor Map
Small Sticky Notes (Scenario Card)	Bad Weather
	Time Constraints
	Injury or Discomfort
	Accessibility Concerns
	Navigating at Night

Table 4.3.1.2: Sticky Notes List

- **<u>Activity 3: Interface Sketching (10 minutes):</u>**
    - Preparation:
        - ★ Provide participants with interface templates (Figure Y) paper for sketching.
        - ★ Include markers, pens, or pencils for drawing.

★ Offer examples of navigation app features (e.g., route visualization, accessibility options) for inspiration.

- Instructions:
  - ★ Participants were tasked with sketching their ideal navigation app interface, either individually or in pairs.
  - ★ They were encouraged to include features they found essential, such as route visualization, accessibility options, or alerts for navigation challenges.
- Objective:
  - ★ To capture user expectations for the design, functionality, and usability of a navigation app tailored to their needs.
- Outcome:
  - ★ A collection of user-generated interface sketches showcasing desired features and design preferences, which can be used as inspiration for app development.

Here is the initial layout design we provided Figure 4.3.1.3.

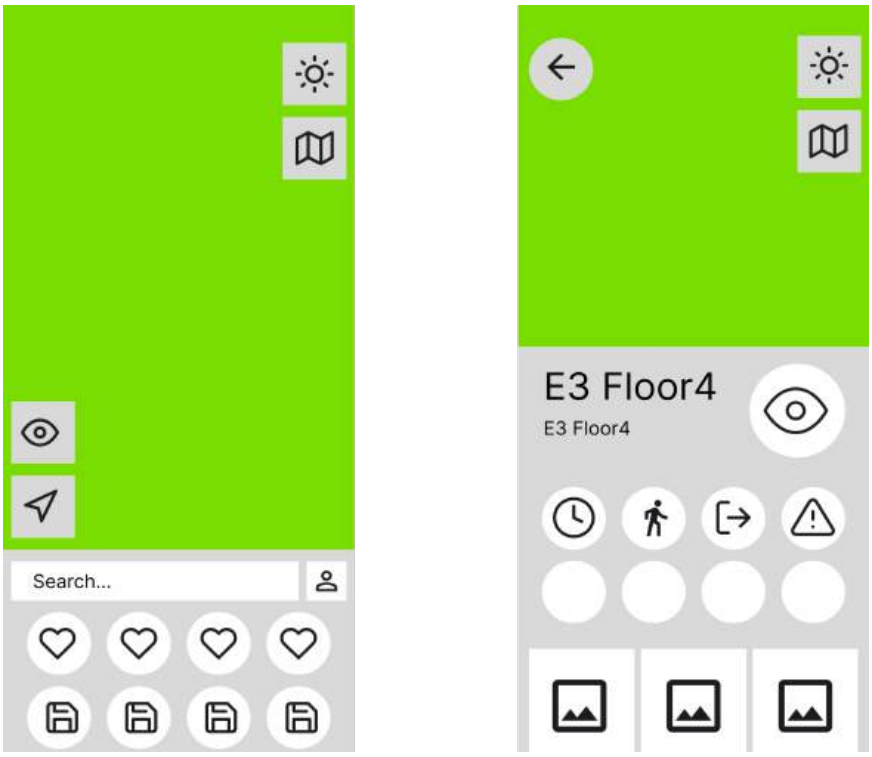


Figure 4.3.1.3: Initial Layout Design

d. Group Discussion and Consensus Building (20 minutes):
    - Discussion of Ideas: Participants shared their sketches and ideas for the activities providing insights into preferred features and design elements specific to navigation system design.
    - Addressing Conflicts: Participants considered different perspectives and worked towards compromises, such as balancing detailed information with a simple, user-friendly interface, ensuring the app meets diverse user needs.
    - Identification of Consensus: Facilitated a discussion to highlight recurring suggestions, such as the need for detailed indoor maps, integration of campus shortcuts, and customizable user preferences. This helped us prioritize features that are most important to our users.

4.3.2 PD Pilot Test

4.3.2.1 Pilot Test Participants

1. Participant A (Alex Lim):
- Faculty: First-year international student from the Faculty of Arts
- Background: Unfamiliar with the campus layout and building connections
- Cultural Background: Comes from a country where indoor navigation apps are commonly used (Singapore)
2. Participant B (Brenda Parsons):
- Faculty: Fourth-year domestic student from the Faculty of Engineering
- Background: Highly familiar with campus buildings and shortcuts
- Experience: Has prior experience in user interface design through co-op placements

4.3.2.2 Pilot Test Procedure

We conducted the PD pilot test following the structure outlined in **section 4.2.1 Workshop Preparation**. The session included the following:

1. Introduction
2. Presentation of Findings

3. Interactive Activities:
    a. Activity 1: Map Annotation
    b. Activity 2: Scenario Exploration
    c. Activity 3: Interface Sketching
4. Group Discussion and Consensus Building

4.3.2.3 Pilot Test Results

Participant A (Alex Lim)

Activity 1: *Map Annotation*

- Route Selection: Alex chose an outdoor route from E7 to E3. He was unaware of the indoor sky bridge.
- Annotations:
    a. Marked confusion points near railway crossings.
    b. Highlighted difficulty in finding building entrances, especially E3's main door.
- Key Quotes:
    - "I often get stuck waiting for trains here; it's frustrating when I'm in a hurry."
    - "The entrances to buildings aren't always obvious; clearer signs would help."

Activity 2: *Scenario Exploration*

- Bad Weather Scenario:
    - Expressed a strong desire for indoor routes to avoid rain and snow.
    - Suggested the navigation app should adjust routes based on weather conditions.
- Time Constraint Scenario:
    - Emphasized the need for the fastest route.
    - Unaware of shortcuts; relies on familiar paths, which may not be optimal.
- Key Quotes:
    - "If the app could show me the quickest indoor route when it's raining, that would be great."
    - "I didn't know there's an indoor way to get to E3; the app should highlight these shortcuts."

Activity 3: *Interface Sketching*

- Design Suggestions:
  - Proposed a simple interface with a clear map showing indoor pathways.
  - Suggested real-time alerts for train crossings and weather updates.
  - Recommended clear indicators for building entrances and exits.
- Sketch Highlights:
  - Included icons for elevators, stairs, and entrances.
  - Added a toggle feature between indoor and outdoor routes.
- Key Quotes:
  - "A toggle between indoor and outdoor routes would let me choose based on the weather."
  - "Icons for entrances would help me find my way into buildings more easily."

Participant B (Brenda Parsons)

Activity 1: *Map Annotation*

- Route Selection: Brenda annotated the indoor route using the sky bridge between E7 and E3.
- Annotations:
  - Pointed out areas where signage is misleading or absent.
  - Noted confusion due to inconsistent floor numbering between buildings.
- Key Quotes:
  - "Even though I know the shortcut, the lack of signs can be confusing for others."
  - "The floor numbers change when crossing the skybridge; it's easy to get disoriented."

Activity 2: *Scenario Exploration*

- Accessibility Scenario:
  - Highlighted the importance of accessible routes for individuals with mobility challenges.
  - Suggested the app should offer routes that avoid stairs when necessary.
- Time Constraint Scenario:

    - Emphasized the need for real-time updates on elevator wait times to choose between stairs and elevators.
- Key Quotes:
    - "The app should allow users to select preferences, like avoiding stairs or elevators."
    - "Including estimated elevator wait times could help decide the fastest route."

Activity 3: *Interface Sketching*

- Design Suggestions:
    - Proposed an interface that allows customization of route preferences (e.g., fastest route, accessible route).
    - Suggested incorporating floor plans with detailed room numbers and landmarks.
    - Recommended alerts for changes in floor numbering when transitioning between buildings.
- Sketch Highlights:
    - Included a customizable settings menu for route preferences.
    - Added notifications to alert users when floor numbers change.
- Key Quotes:
    - "A settings menu would let me customize the route to my needs each time."
    - "Notifications about floor changes can prevent confusion when moving between buildings."

4.3.2.4 Findings on PD Pilot Test

Finding from users' behaviours:

- Participants' **varying levels of campus familiarity** significantly impacted their engagement and the effectiveness of the activities.
- Essential user needs were identified such as the **inclusion of detailed indoor maps, real-time updates on environmental factors, and customizable route preferences**.
- Both new and experienced students face significant navigation issues due to **inadequate signage and inconsistent floor numbering** across buildings.

- Users emphasized the importance of **customizing navigation preferences** to individual needs, such as avoiding stairs or elevators.

Based on preliminary observation, we know what to include in our design.

Things we should put into our design:

1. Create a navigation system having **indoor maps**, **all shortcuts, and consistent floor numbering**
2. Integrate **live information on train crossings, weather conditions, and elevator wait times**
3. Implement features that allow users to **tailor their routes based on personal needs and preferences,** such as accessibility options and preferred route types.

4.3.2.5 Suggestions for PD Protocols

- Adjust the PD protocol to **accommodate different familiarity levels** by providing clearer instructions and support for less experienced participants.
- Allocate more **realistic time frames** for each activity.
- Enhance facilitation techniques to **balance participation** and prevent dominant individuals from overshadowing others.
- Incorporate explicit focus on **accessibility and diverse user needs**.
- **Make sure time is just enough for us to learn the user to a satisfied extent.** With some activities running longer than expected, this leaves us little time for group discussion.

4.3.3 Filed Data

Participant 1 (Emily Carter)

Activity 1: Map Annotation (Figure 4.3.3.1)

- Route Selection: Emily provides two feasible routes:
    - Outdoor route (pink route) starts from E7 North Gate, crosses the railway, and enters E3 from the west gate.

    - Indoor route (red route) by taking the Skybridge between E5 and E3.
- Annotations:
    - Marked confusion points near elevators.
    - Highlighted difficulty in finding skybridge.
    - Stress floor numbers at both ends of the skybridge
- Key Quotes:
    - " Sometimes I can't find the elevator, so I try to follow the crowd or check the floor map to locate it. And I prefer to follow other students, sometimes it's very helpful."
    - " Actually, I'm not sure which floor the skybridge is on, so in practice, I would walk to see where it is."
    - "The floor numbers on both sides of the skybridge are actually different? This is the first time I've learned that!"

Here are the feasible routes drawed by participants, the pink route and red route are two routes by Emily Carter.

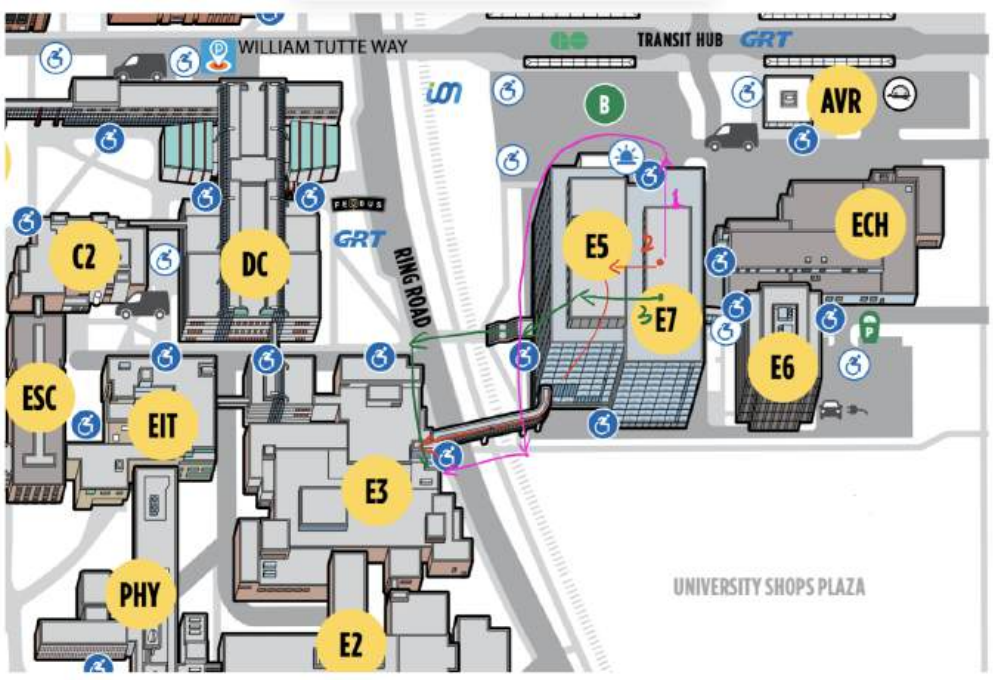


Figure 4.3.3.1 Participants' Routes Choices

Activity 2: Scenario Exploration

- Elevator vs Stairs Scenario:
    - The participants think the stairs are always better.
    - First, they can get some exercise by climbing the stairs.
    - Second, they think elevator waiting time is too long, they are all willing to take stairs, especially under time constraints.
- Time Constraint Scenario:
    - Sometimes the participants already know a route, so they will go along with their memory.
    - They won't seek a new route which is more efficient because it takes effort to learn.
- Key Quotes:
    - "Stairs are quicker than waiting for the elevator, especially when I'm in a hurry."
    - "Climbing stairs is a good way to stay active while getting where I need to go."
    - "If I already know a route, I'll stick to it rather than spending time learning a new one. Even if it may be faster, it's not worth the extra effort to figure it out during a busy moment."

Activity 3: Interface Sketching

- Design Suggestions:
    - **Icons Redesign:** Use intuitive icons with universally recognized symbols, and consider adding descriptive text labels to enhance clarity.
    - **Simplified Main Page:** Design a clean main map interface with fewer buttons, while moving detailed features and options to secondary pages.
    - **Streamlined Saved Locations:** Limit the number of saved places to a manageable few and enable users to pre-save destinations for quick access during their trips.
    - **Improved Street View Access:** Replace the street view icon with a more intuitive design and highlight its importance as a feature for location orientation.
- Key Quotes:

- "The icons are confusing, especially the weather icon, which we thought was for brightness. Icons with clearer meanings or adding text beside the icons would help a lot."
- "I prefer a larger and simpler map on the main page, with fewer buttons. It's better to have detailed information separated across different pages, not cluttered on one."
- "We don't need too many favorite/saved places. We usually get familiar with the same destinations, so fewer saving options would be better. A good idea is to save a location before the trip and start with one click when the time comes."
- "The street view icon is confusing, but I like the idea of including it. It's really useful to see where you are, especially for users who need to relocate themselves."

Participant 2 (Sophia Bennett)

Activity 1: Map Annotation

- Route Selection:

  Sophia takes an outdoor route (green route). She goes up to the second floor, exits the building through the E5 west gate, crosses the railway, and then enters E3 through the west gate.

- Annotations:
  - Drew confusion mark on the E7 building.
  - Noted question mark near the skybridge.
- Key Quotes:
  - " I tend to get lost indoors easily, so I prefer taking outdoor routes as they make it easier to navigate.."
  - " Oops, I had no idea there was an overpass there!"

Here are the feasible routes drawed by participants, the green route are two routes by Sophia Bennett.

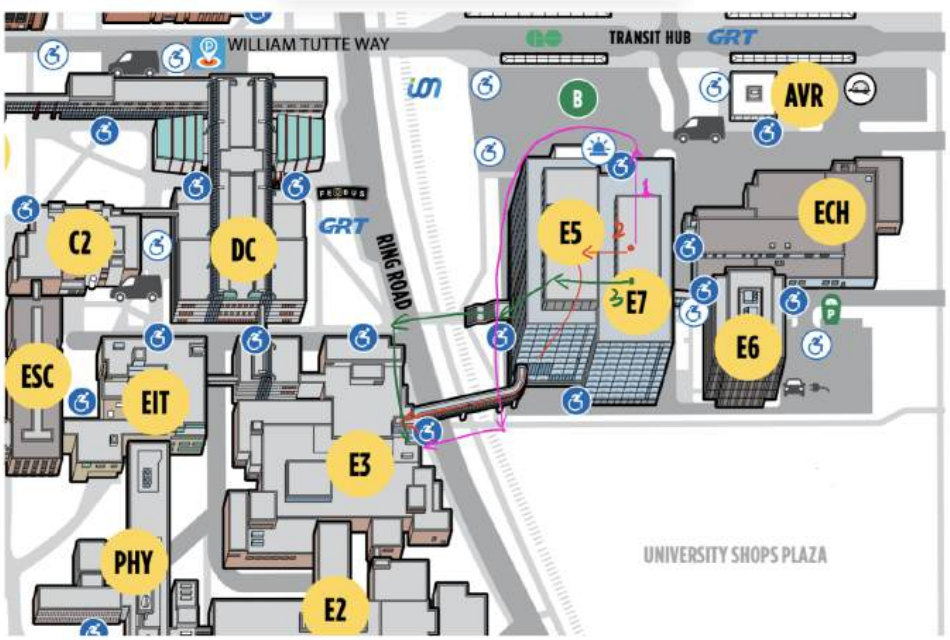


Figure 4.3.2.2 Participants' Routes Choices

Activity 2: Scenario Exploration

- Weather Scenario:
  - Proposed a shocking opinion that she does not care about rain or snow quite a lot. She thinks it is acceptable if the outdoor distance is short.
- Map Devices Use Scenario:
  - Indicated She would use both google maps and floor maps.
- Rail time Scenario:
  - She doesn't consider it necessary to include the railway schedule in the app.
  - She believes the railways come every 10 minutes so it is easy to estimate.
- Key Quotes:
  - "Rain or snow doesn't bother me much as long as the outdoor distance is short."
  - "I usually rely on both Google Maps and floor maps to find my way."
  - "I don't think it's necessary to include railway schedules; they're easy to predict."

Activity 3: Interface Sketching

- Design Suggestions:

    - **Enhanced Photo Feature:** Incorporate user-shared photos of places, showing both interior and exterior views, to help users better visualize the destination.
    - **Simplified Route Information:** Remove elevator and train wait times from route info, focusing instead on more relevant navigation details like stairs and paths.
    - **Flexible Search Bar:** Allow users to input a custom starting point and floor level to improve navigation in multi-level maps.
    - **Minimalist Main Page:** Limit the main page to no more than three essential icons for a cleaner, user-friendly interface.
- Key Quotes:
    - "We like the idea of pictures. Though this function is meant to be shared by other users, a picture of a place from both inside and outside the building can be really helpful. This could help users better visualize the place, even though it's part of a community-driven feature."
    - "We don't care about seeing the elevator or train wait times on the route info. Elevators are always too crowded and the wait time is too long, so we usually consider stairs instead. For trains, we know they come every 10 minutes, so there is no need for the schedule in the app."
    - "The search bar should let us enter the starting point, not just the current location. It's also important for users to specify their floor level, especially since the map has multiple layers."
    - "We prefer a simpler main page with fewer icons, ideally no more than three. Reducing the number of icons would make the app cleaner and easier to navigate."

4.3.4 Consensus

Key Takeaway:

- Route Preferences: Favor stairs over elevators; familiar routes over learning new ones.
- Interface: Prefer large, simple maps with fewer icons (≤3) and clear labels.
- Personalization: Fewer saved places as users learn routes over time.
- Schedules: Train and elevator wait times are unnecessary.

- Usability: Include starting point input and floor levels for multi-layered maps.

Throughout the participatory design session, our team and the participants reached several key consensus on the design of the navigation system:

Activity 2: Scenario Exploration

- Time constraints: Sometimes the participants already know a route, so they will go along their memory, instead of seeking a new route, even though there is a possibility that the new route is more efficient because it takes effort to learn.
- Elevator vs Stairs: The participants think the stairs are always better. First, they can get some exercise by climbing the stairs. Second, they think elevator waiting time is too long, they are all willing to take stairs, especially under time constraints.
- Weather: The participants proposed a shocking opinion that some people like them do not care about rain or snow quite a lot. They think it is acceptable if the outdoor distance is short.
- Map Devices: Both 2 participants use Google Maps, and one of them uses floor maps too.
- Rail time: They do not consider it necessary to include the railway schedule in the app. They believe the railways come every 10 minutes so it is easy to estimate.

Activity 3: Interface Sketching

- The interface icon is confusing. The participants could have misunderstood some of the icons. An example is the weather icon which they thought was the brightness icon. Icons with more precise meanings are needed, or adding text beside the icon.
- More simplified app. The participants expressed their preference for larger and simpler maps. Compared with detailed information and multiple functions on one page, they prefer them to be separated on different pages, so there is a simple clear map with a few buttons on the main page.
- They don't like to have so many favorite/saved places. They think we can have fewer of them. The participants proposed a valuable angle which we've never thought about that the users can get familiar with the same destination day by day so they might not need

too many saving options. One goal to preserve it is that users can save it before the trip and start the trip at that time with one click.

- The street view icon is confusing. The participants also misunderstood the street view icon, but they thought it was a good idea to include the street view icons because the users frequently need to relocate themselves and figure out where they are.
- They like the picture. Almost the same reasons for the street view icon. Though this function was meant to be shared and uploaded by the other users, which constructing a community online gradually in the future, they mentioned that a picture of a place from the inside and outside of the building can be quite helpful for the users.
- Don't put elevator/train schedule wait time on the route info. When we mentioned we were about to include the elevator in the route plan and its estimated time on the map, the participants seemed not to care about the function. They believe the elevator is always too crowded and takes too much time to wait. They prefer to consider only the stairs. A similar thing happened regarding the train schedule. They believe the train always comes every 10 minutes.
- The search bar includes the current location (floor levels). The participants mentioned there should be a place allowing the users to enter their starting point because the users could be viewing their route from somewhere else other than their current location. Also, since our map includes multiple layers, it could be important for the users to be able to specify their level when they are at the building.
- 3 icons (less) on the main page. As mentioned, the participants prefer simpler pages, therefore, fewer icons on the main page also help. They hope we can reduce icons to less than 3.

4.3.5 Conflicts

Key Takeaway: Participants' suggestions highlighted several design conflicts, but not all participant suggestions were feasible. We must balance user preferences (e.g., stairs vs. elevators, weather info, train schedules) with broader needs and design constraints. Also, specifying the user's floor level remains crucial due to current height-detection limits.

Some design advice from the participants is valuable, but some are not feasible from the point of view of design. The participants indicated that the weather conditions are not quite annoying for them, however, we decided to keep weather related to our functions, due to the existence of people who hate walking in the snow or rain.

The participants also suggested we consider the stairs only, but we will reserve the elevator options, not only because the elevator is possibly faster, but also because that is an accessible option for certain groups of people. The participants said they think the railway comes every 10 minutes, but they are wrong. After our team discussion, we agreed that presenting the schedule to the users could be too complex, so we decided to partially take their advice by considering it only when automatically generating the route in which the user will not be involved.

In terms of interface layout, the participants suggested we move all the buttons on the main page to the top-right corner, which they thought would make the page more clear. However, that would cause the users' focusing point from the center to the bottom-left region since the information on the diagonal is covered, decreasing the users' experience. We will keep spreading the buttons in the top-right region and bottom-left region distincting by their functions.

Lastly, the participants mentioned we could provide a search bar for a starting point on the search bar of the destination on the main page. At first, we thought we were not taking it because our original plan was to present that bar after the users specified their destination like the other maps in the market. During our discussion, we gradually realized the difference between our map and the other existing maps, which is, leveling is an important feature in our map. We urgently need to make the users able to specify their current level when they are in the buildings since the current technology is not able to detect the users' height location.

4.4 Evaluate

Key Takeaway: The participatory design session gives the team a lot of insights. Integrating those insights, our team has made a lot of decisions on the design, though some known limitations still exist but we are not able to solve them now,

4.4.1 Results

In the participatory design session, we invited the participants to share their thoughts on the final design. This session helped us to verify whether the design meets user needs and expectations and to find any potential issues existing in the current version of system design. The participants' interaction and feedback will guide the next development phase, we can iterate the design to the final stage.

Talking about the aspect of functions, we eventually decided to build a navigation app specifically being used on the campus of the University of Waterloo. The app allows the users to enter their destination which is precise to a certain room in a building. Based on the integrated consideration of weather, personal preference, and efficiency, the app will provide the most optimized route for the users. The users will also be able to specify their current location, which is also precise to a certain room in a building. There will be additional functions like street view and pictures supporting the users to figure out their location and the destination's location, so the difference between the screen and reality could be minimized. The user will also be able to save a place so they can start the navigation immediately when they want to.

On the side of the interface, we have built a more clear blueprint throughout this participatory design session. Like the trend of fashion and technology, complicated and fancy appearance no longer attracts the users. Users nowadays prefer simpler and neater designs. Though we want to provide as many functions available to our users, we can't have our cake and eat it. First of all, the main page has to provide as few buttons as possible. The main page is a space where the user can explore the graphical map so the map must occupy most of the screen. After a tough decision, we reserved the bottom search bar, top-right weather and layer buttons, and bottom-left street view and relocating buttons. The search bar will pop up when clicked and the saved places will be shown under the search bar. The choice of icons also has to be polished. We must find out the most accurate icons for each button, so we can make the page look simpler by avoiding using text for buttons. On the route display page, we will keep the style of allowing the users to switch different modes like efficiency, walking, and outdoor. We will keep the design of providing

pictures for every named place and this is going to be a community zone where any users can share a picture of that place.

Since we are mainly focusing on shortcuts and sky bridges, layers of the map are especially important. Since the 3D display will be technically hard for the team to accomplish, we have to make it easier and simpler for the user to switch from layers to layers, which corresponds to levels to levels in reality. As we mentioned above, the user will be allowed to enter their starting level, then the navigation will start displaying the specified level when the user follows the navigation, the display must be able to automatically switch to another layer when the user's floor has changed. This is going to include massive calculations and optimized algorithms, even with an accumulation of data for a long period. So a testing version of the navigation app is quite important before the final version gets launched.

4.4.2 Limitations

As we mentioned above, our navigation app will allow the user to specify their starting point specific to the level in a building. But reality does not always come in the way we dream. There is a possibility that the users are misled by the incorrect road signs or the users do not know their current location at all. For a situation like that, our current solution is providing an option of "I don't know" when the system asks the users for their current level, and the system will assume the user is currently on the first floor and guide the user. If the route in different levels is different, the system can detect the possible levels the user is at, if not, the user will be guided to the next checkpoint on the route like an exit or elevator where the user will be able to know their level right now. We understand such a solution is not perfect and even not good, it hurts the efficiency and increases the workload of the user, creating a bad user experience, but the other option is not feasible now, which is waiting for GPS to be able to detect the level of the user.

The next limitation is also related to technology, but we can solve that issue by inviting experts into our team. If we could introduce the AR function in our app along with 3D map illustration, the issue above even more issue could be solved. If we are sufficient in technology, we prefer to build this map in a 3D fashion, which decreases the disconnection between the screen and reality, so the users can know where they are and where to go more clearly. Even more, if AR

technology is equipped within the app, the navigation instructions can directly be shown on the real-time video captured by the phone camera.

Other than those 2 limitations above, sample limitation is the last one in our design. We had only 4 participants in the participatory design session, their opinions were limited and not able to cover most users' points of view. If we can have a larger number of participants, we will be able to get objective and fair feedback. Then our design decisions will be more technically feasible and appropriate for the users.