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Conceptual Design Specifications (CDS)

Project #	80	Date	5th April 2021

Project Title	Laundry Room Accessibility at Manor Green
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Please check off which components you are submitting for your assignment.

✓ CDS submitted as a PDF to Quercus with the following components:

- ✓ Cover Page
- ✓ Executive Summary
- ✓ Introduction
- ✓ Problem Statement
- ✓ Service Environment
- ✓ Stakeholders
- ✓ Detailed Requirements (FOCs)
- ✓ Alternative Designs
- ✓ Proposed Conceptual Design
- ✓ Measures of Success
- ✓ Conclusion
- ✓ Reference list
- ✓ Appendices

Executive Summary

This document covers the project requirements for the Laundry Room Accessibility Project at Manor Green. After a discussion with the client – Margie Carlson – this has been generated by Team 80 in accordance with their mission to foster social equity and equal opportunity through housing.

The issue lies in the common laundry room at Manor Green, where there is little room for residents with disabilities to maneuver. Designs are scoped to altering the infrastructure of the room without changing the current washing machine models. The goal is to fulfill the need for free movement of people on mobility assisting vehicles whilst satisfying the Ontario Building Code accessibility requirements.

The Service Environment the design will operate in is the common laundry room in Manor Green, Newmarket Ontario. The laundry room is 5.91m by 4.03m, with a usable area of 15 m2. The design will experience normal temperatures ranging from 15º C to 25º C, with humidity from 30% to 60%. It has standard electrical and wireless internet connectivity with residents and their pets having access to the room. The stakeholders involved are individuals and organizations with a legal, economic, social, and ethical interests in this project. The staff, laborers, architects, contractors, and manufacturers of the laundry machines are all valid stakeholders.

The detailed requirements – Functions, Objectives, and Constraints – have been discussed to set the design space. The main function of the design is to increase accessibility features for people with disabilities and/or of old age, with secondary functions to increase maneuverability in the room, facilitate free movement between washing and drying machines, and allow for the movement of at least one mobility assistive device. The objectives refer to international standards which recommend how the accessibility of a building can be improved. This includes more space for movement and turning of mobility aids inside the laundry room, improved access to the payment card terminal, improved positioning of electrical sockets, and better lighting to avoid the risk of injuries.

The constraints are those that the design must meet all the rules and regulations stated in the Ontario Building Code. The design shall not involve relocating or hiring an operator for the Laundry Machines of any kind. As mentioned by the client, the design must not involve changing the Laundry Machines since all of them are brand new card-operated machines.

The team went through a rigorous idea generation process using methods such as brainstorming, lateral thinking, blue-sky thinking, analogy method and SCAMPER to list over 50 potential solutions, which were narrowed down to 3 viable solutions by filtering the ideas with feasibility checks, multi voting, Pugh method and a graphical decision chart. Out of the three ideas, redesigning the laundry room by changing its layout and destroying some structures was the best solution. It meets all our objectives in a well-rounded way and is within the constraints described in the document. The idea significantly increases the amount of free space in the laundry room and does it in a cost-effective way that doesn't require radical action.

To ensure the idea is successful, the team tested the idea using a maneuverability test, which was a success. To ensure the design will work, the team plans to collect data from residents and run a simulation-based analysis. The next step for the team is to finalize the design details and present our work in a presentation, to persuade our supervisors to let us pursue with the design. This presentation will be available to the client by April 26th, 2021.

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1. Introduction

For this project, our client Margie Carlson, Executive Director of Birch Housing, tasked Team 80 to focus on one of their properties–Manor Green–with the aim to increasing accessibility of its common Laundry Room for its residents. This project will aid the 5% of the residents with disabilities and people of old age that access this space and will also update the building to follow the Ontario Building Codes as well.

The document identifies the problem, project requirements, boundaries and the processes the team underwent to create a feasible and satisfactory solution that improves accessibility at Manor Green.

2. Problem Statement

The laundry room at Manor Green had been built before the current revision of accessibility codes in Ontario. With that said, the current layout of the laundry room is too compact for users, restricting movement inside the room.

The lack of space makes it difficult for users – the residents of the building many of whom are elderly and/or disabled and use mobility assistive devices – as they cannot move freely and easily transfer laundry between machines.

The gap, therefore, is the absence of space inside the laundry room at Manor Green which allows smooth movement of mobility aids including wheelchairs and scooters inside the laundry room (Figure 1).

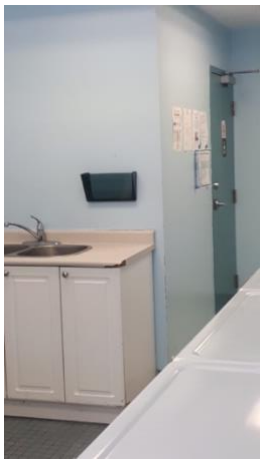


Figure 1: The inside of the laundry room. [Client Provided]

Figure 2. The entrance of the laundry room. [Client Provided]

The scope of this project includes any alterations of the room's physical infrastructure provided they comply with the Ontario Building Code (Appendix A). Relocating the laundry room, hiring workers to do the residents' laundry, or changing the models or quantities of washing machines has been placed out of scope by the client.

Thus, the problem at hand is to fulfill the need for residents' free movement in the Laundry Room, accounting for their age, mobility assistive devices, and Ontario accessibility requirements.

3. Service Environment

The Service Environment is the common laundry room at Manor Green, 400 Crossland Gate in Newmarket, Ontario. Aspects considered are the physical dimensions as well as different types of connectivity (electricity, ducts, internet, water outlets), and living things in the laundry room.

3.1. Physical Environment

- Equipment:
  - 6 AODA Compliant Huebsch front load washers
  - 6 AODA Compliant Huebsch electric dryers
- Physical Connectivity:
  - 120V 60Hz AC Electricity through standard outlets [14]
  - Ductwork for Air and Water, with easily changeable outlets/inlets near dryers
- Dimensions of the Laundry room:
  - 4.03m by 5.91m (~24m^2)
  - Area available for appliances and movement: 23m^2
- Internal Environmental Conditions:
  - Temperature [2][3]
    - Normal temperature: 15℃-25℃
    - Extreme temperature: 1°C-30℃
  - Relative Humidity [4]
    - Normal humidity: 30%-60%
    - Extreme humidity: 0%-100%
  - Sunlight and artificial light [Figure 2]

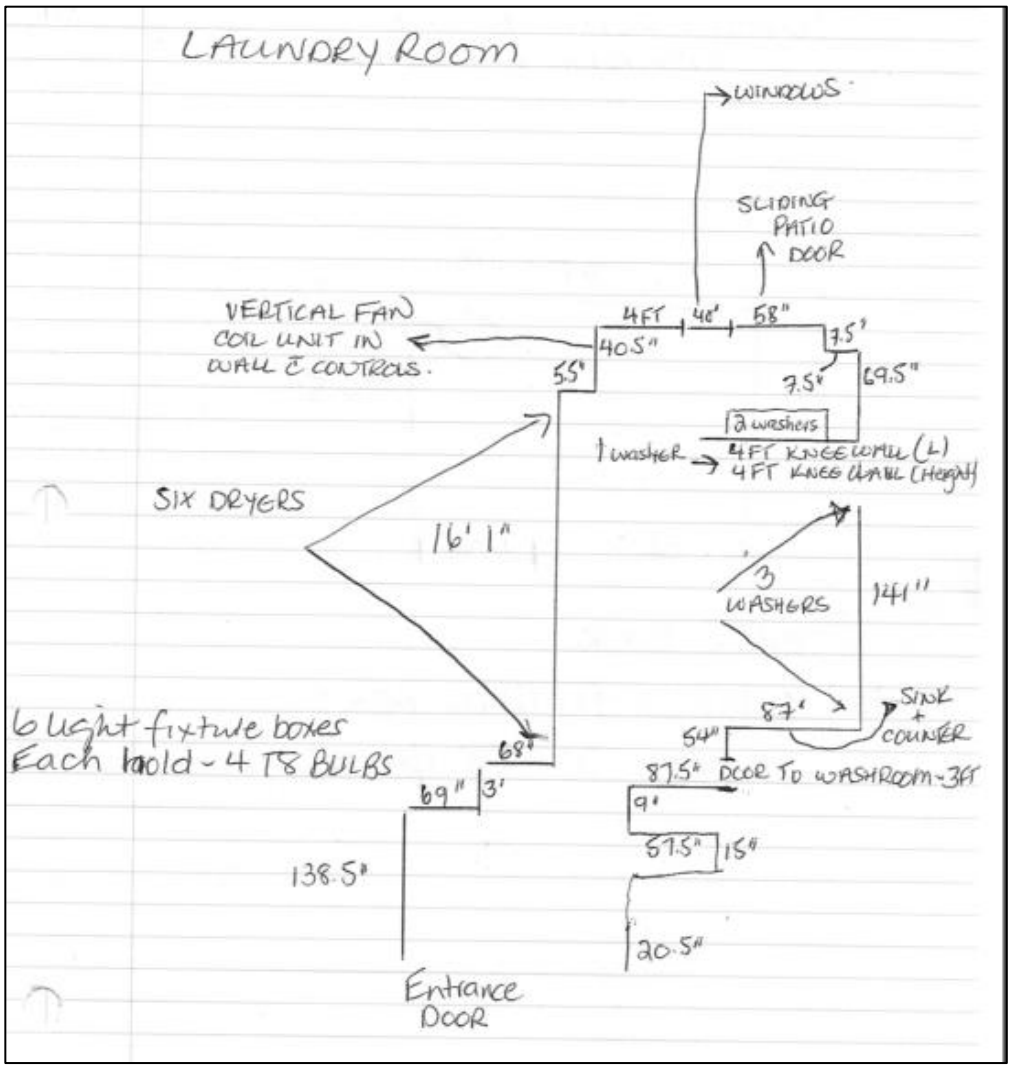


Figure 3: Sketch of laundry room provided by the client.

3.2. Virtual Environment

- Wi-Fi Connectivity

3.3. Biotic Environment

- Apartment Residents of all age groups and people with disabilities.
- Common pets, such as cats and dogs, belonging to the residents.
- Microbes, such as common bacteria and fungi.[15]

4. Stakeholders

The stakeholders involved in this project are various individual entities, Governmental and Non-Governmental Organizations with legal, economic, social, and ethical interests.

Table 1: Stakeholders

Stakeholder	Interest
Laundry room maintenance staff	Human factors • must adapt to laundry room changes while working.
Laundry Machine Contractor	Economic: • responsible for replacements in case of technical issues • may be contacted for information regarding the model, compatibility, and durability of the machines.
Building and Development Branch of the Ministry of Municipal Affairs and Housing and Building Officials.	Legal: • the Code provides regulations that must be complied during solution implementation [5]. • modifications pertaining to the solution and the building permit application inspected by building officials.[6]
The Building Permit holder	Legal: building permit holder contacts the Local Municipal Building Department for registering an inspection.[6]
The Development and Infrastructure Commission in New Market	Legal and Economic: provides inspectors for on-site inspections.[7]
Architect and Workers	Economic: An architect: • Provides floor plans, site plans and specifications. • responsible for overlooking the

	renovation/reorientation process. Workers: • responsible for renovation/reorientation.
Government Agencies like the Canadian Human Rights Commission, Non-Governmental Organizations like the Council of Canadians with Disabilities	Social and Ethical: devoted to inclusivity and universal designs for disabled people.[8][9]

5. Detailed Requirements

Below are the detailed requirements consisting of functions, objectives, and constraints. These define the boundaries of the project and will be used to create potential solutions.

5.1. Functions

The primary and secondary functions of the design solution have been formulated using the Black Box method (Appendix B).

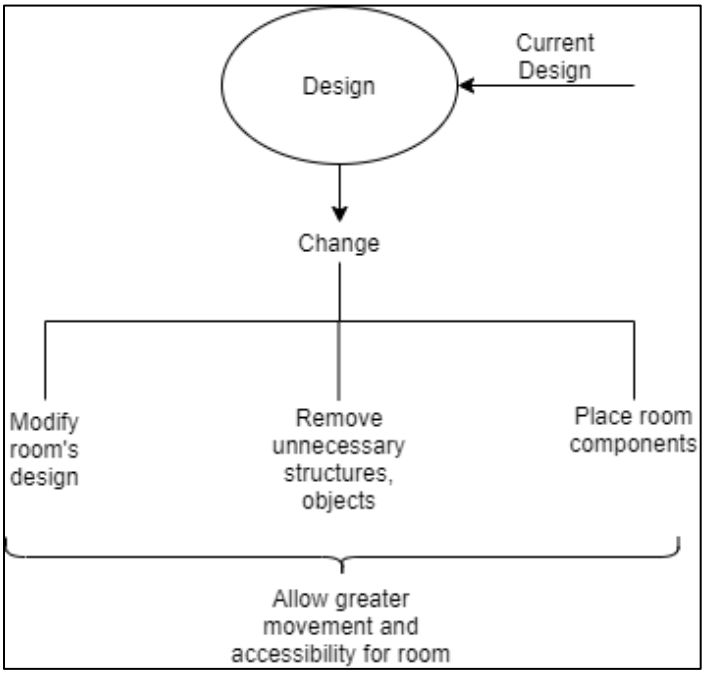


Figure 4. Functional Basis

Table 2: Primary and secondary functions

Primary Functions	Secondary Functions
Increase accessibility for people with disabilities and/or of old age.	• Increase maneuverability so that at least one assistive mobility device can turn in the room. • Make it easier to move laundry between washers, dryers, etc.

5.2. Objectives

An objective is a measure of the effectiveness of the design. The objectives have been defined to exceed the expectations of the client and are as follows:

Table 3: Objectives from most important to least important

Objective	Goal	Metric*
There should be some space that allows a convenient 180° wheelchair turn.	Space should be more than 2m in direction of travel and more than 1.5 m wide [10]	Dimensions can be measured using a measuring tape.
The user should have no difficulty in swiping the card while using the machine.	The card slot should be at a height between 0.8 m and 0.9 m from the ground [10]	Dimensions can be measured using a measuring tape.
The passage should be wide enough to allow free movement of 2 wheelchairs.	The width of the passage should be more than 1.5 m [10]	Dimensions can be measured using a measuring tape.
The solution must be economically feasible and should have a low budget.	1875 CAD (Estimated minimum cost) (Appendix C)	Can be calculated based on how much material and human effort is required.
There should be enough light to avoid any injuries.	Illumination level should be more than 100 lux [10]	Illumination rating can be checked on the lighting source.
The power sockets should be at a suitable height.	Power socket should be at a height of more than 0.400 m and less than 1m from the ground [10]	Dimensions can be measured using a measuring tape.

* Dimensions for designs will be measured prior to implementation on a 3D model. Refer to Appendix D for the Pairwise Comparison.

5.3. Constraints:

The constraints are stated such that the design must follow certain limitations and restrictions. These include:

- The design must fit at least one wheelchair/e-scooter into the Laundry Room and allow the wheelchair/e-scooter to move freely within.
- The design must meet the safety and accessibility standards as imposed by the Section 2 of Ontario Regulation 191/11 and the Accessibility for Ontarians with Disabilities Act, 2005, as imposed by the Ontario Government.[11][12].
- The laundry room must not be changed or moved to another location.
- The Dryer and Washing machines are brand new and shall not be replaced with a different model.
    - If the design requires stacking of machines, a change in the models can be requested from the same company, Huebsch.
- According to the Ontario Building Code 3.4.4.4(8), Laundry Rooms shall not open directly into an exit.[12]

6. Alternative Design Generation, Selection and Description

The following section describes the processes used to generate and select the three potential design solutions for the issue.

6.1 Idea Generation Process:

The team undertook a rigorous idea generation process to ensure that every possible approach was considered before recommending a solution. The following steps were taken:

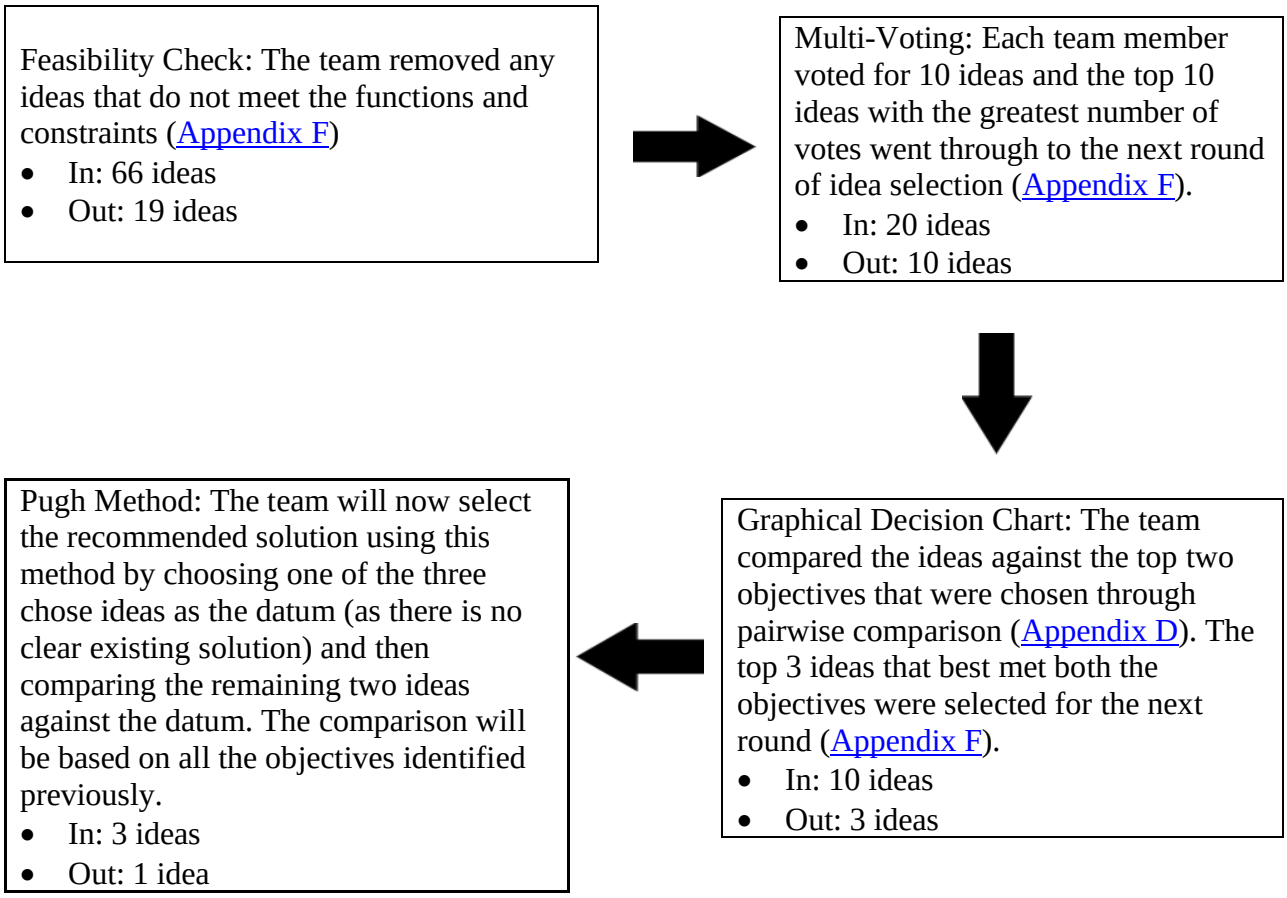
1. First. the team collectively **brainstormed** 4 categories of ideas that would capture the entire design space. The categories were:
    a. Layout Adjustments
    b. Artificial Intelligence/Technological solutions
    c. Mechanical Methods to increase accessibility.
    d. Human operation based.
2. Thereafter, approximately 15 ideas were collectively put together. These were ideas that had seemed like ‘obvious’ solutions and had been conceptualized previously.
3. Each team member then individually conceptualized 7 ideas through **lateral thinking** for each category. This was done to ensure that every perspective was considered. After eliminating duplicates, about 45 ideas remained.
4. The team then collectively added about 10 ideas using **Analogy Method** (Appendix E)– likening our current problem to others seen in completely different systems.
5. Finally, each team member was to contribute at least 2 ideas that could not be captured in any of the categories. This practice of **Blue-Sky Thinking** (Appendix E) enabled the

team to think ‘out of the box’ and consider uncommon ideas. Furthermore, the team was able to establish a thought process from basic axioms of what was possible instead of by the restrictions of what is commonly done. A list of about 65 ideas remained.

These steps enabled the team to explore the entire design space from a multitude of perspectives. Furthermore, the use of ideation methods such as SCAMPER, analogy method, lateral thinking, and blue sky thinking all allowed a directed approach with creative goals. Thus, the team was able to consolidate a list of over 50 potential solutions, from which a viable solution can be recommended.

6.2 Alternative Design Selection Process:

After removing any duplicate ideas, the team went through the following idea selection process:



6.3 Alternate Designs

Below are the top three designs the team thinks will solve the accessibility issue of the laundry room at Manor Green.

6.3.1 Design 1: Redesigning the Laundry Room:

The team identified three structures in the current layout of the laundry room that could be removed–

1. Adjacent bathroom– 5.38m^2
2. Parapet– 0.382m^2
3. Sink cabinet– 0.984m^2

Removing these three structures saves approximately 6.746m^2 area on the floor that could then be utilized to make the laundry room more accessible.

The laundry machines will be relocated within the room and placed in pairs (washers and dryers) to enable easy transfer of laundry between machines. The sink will be rebuilt using much less space in the corner of the room. The parapet is simply a distraction that can be eliminated without major consequences to the room. The following pictures demonstrate what these changes would encompass:

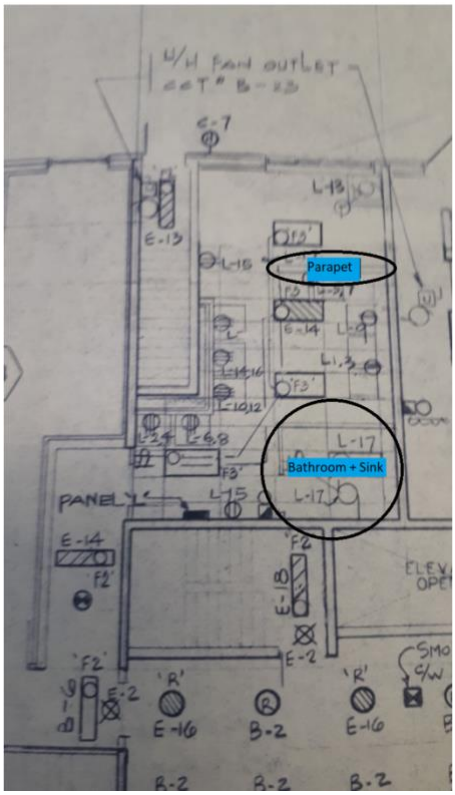


Figure 7. The entrance of the laundry room

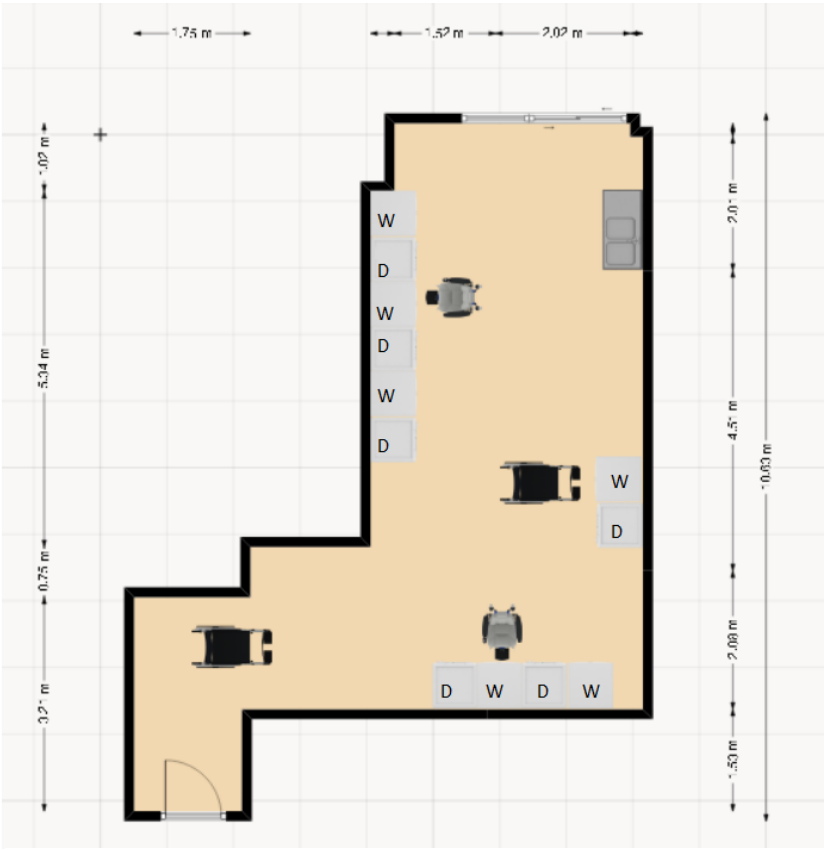


Figure 6: Layout Plan [Floor Planner]
(W= Washer, D= Dryer)

Figure 7. 3D model of the new layout of the room [FloorPlanner]

Objective	How this solution meets the Objective
1	With the breaking of the Parapet and the Bathroom, there will be enough space for wheelchairs or e-scooters to take a 180° turn.
2	The payment systems are 1 m above ground on each machine which is an accessible height for everyone.
3	Obstacles have been cleared from the entrance of the Laundry room, allowing movement of more than 2 wheelchairs/e-scooters.
4	The major cost will only be to break Bathroom Walls and Parapet Wall. (Appendix C).
5	With the breaking of the Parapet, the window will be free of any obstruction of light.
6	Power Sockets will be rarely used but will be placed at a suitable height.

6.3.2 Design 2: Laundry Robot

Design 2 is a laundry robot capable of moving laundry from people's homes to washers/dryers and back. With the help of an app, a user can "call" the robot to their front door, deposit their laundry in the robot, and the robot will deliver the laundry to the washing and drying machines, collect it and return it to the user. The robot will be waist high so even wheelchair-bound users can use it and will move around on 4 wheels. To aid in AI navigation, it will have 6 cameras giving it 360-degree colour vision, and a lidar sensor and ultrasonic distance sensors for object avoidance. It has a robotic arm mounted on its back to help it open and close washers/dryers, in addition to pressing elevator and other buttons.

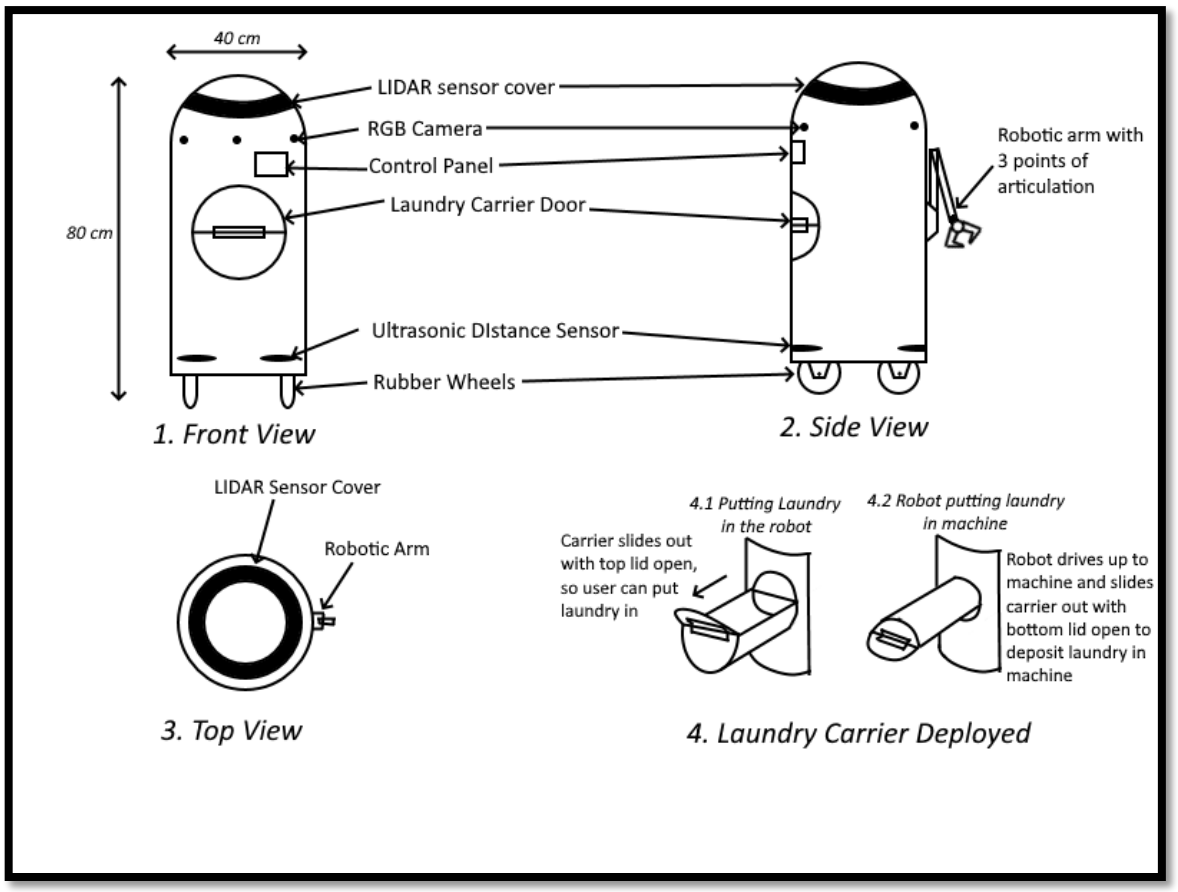


Figure 8. Labelled diagram of the robot

Objective	How this solution meets the Objective
1	User doesn't need to access laundry room anymore.
2	The app will automate payments.
3	User doesn't need to access laundry room.
4	Robot is a one-time cost, no other infrastructure required.
5	User doesn't need to access laundry room.
6	User doesn't need to access laundry room.

6.3.3 Design 3: Stacking of washing machines.

Another potential solution is the stacking of washing machines with dryers. This has been discussed with the client who has authorized changing some machines with stackable models. Four of such machines (stacks of 1 washer and 1 dryer each) will be availed from Huebsch – the current provider – and will have width 0.683 m, depth 0.704 m, and height 1.986 m.

This would allow freeing about 1.923m^2 of space without infrastructural alterations. Additionally, after the layout has been adjusted with these new machines, the maneuverability area increases by 9.55m^2 (9m^2 to 18.55m^2). The design layout can be seen below:

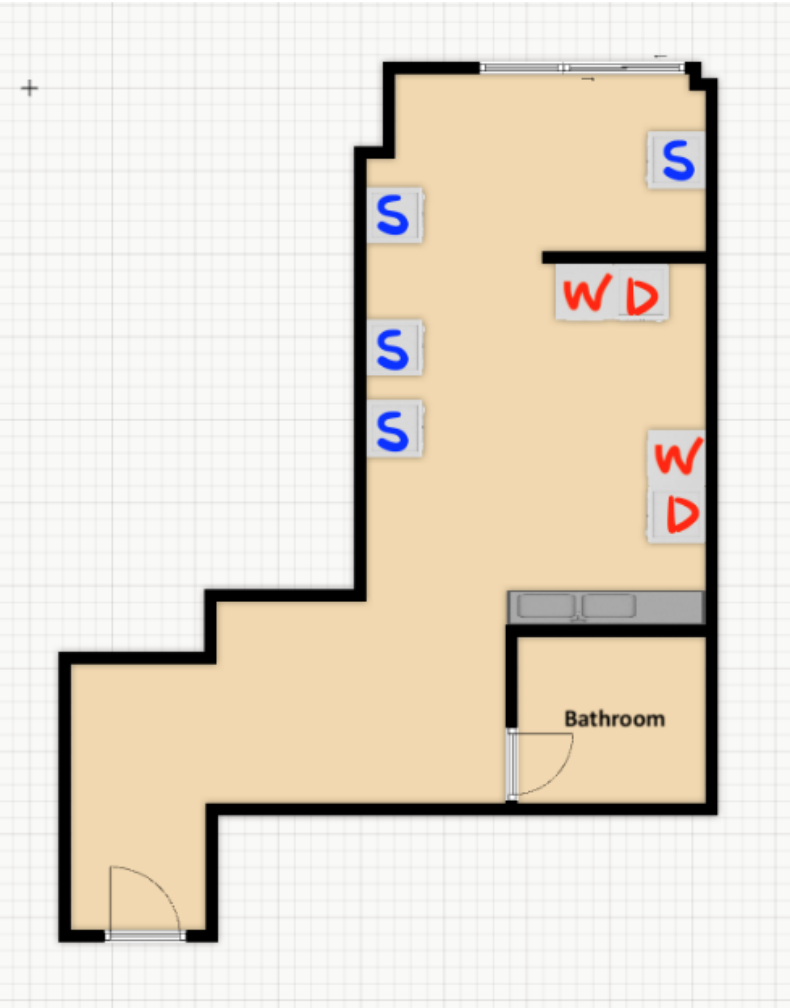


Figure 9. Layout of the room [FloorPlanner]
S=Stacked Washer-Dryer, W=Washer, D=Dryer

Figure 10: 3D-model of the design [FloorPlanner]

Objective	How this solution meets the Objective
1	The space to maneuver is approximately 18.55m^2, giving sufficient space for a wheelchair to move.
2	The card slot is 1 meter above the ground, installed on the center of the machine, making it accessible to all residents.
3	Two wheelchairs with a 1.5 meter turning circle (each) take a total of 2.53m^2 space. With 18.55m^2 to move around, two wheelchairs can easily fit.
4	The cost of replacing four washing machines and four dryers for four stacked Washer-Dryer machines will be considered but should be minimal.
5	The light from the window/door and installed lights in the room has not been altered, hence the lighting will stay constant and be sufficient.
6	The Power Sockets will be placed suitably such that they can be accessed easily.

7. Proposed Conceptual Design

Having conceptualized 3 solutions that carried out required functions under project constraints, the team carried out the Pugh Method, to recommend a design. This can be found below:

Objective	Weights	Stacking	Layout	Robot
Convenient turns for wheelchairs	6	S	+6	-6
Ease of card swiping.	5	S	0	+5
Free movement of 2 wheelchairs	4	S	+4	-4
Economically feasible	3	S	+3	-3
Enough light	2	S	0	0
Height of power socket	1	S	+0	0
SUM	21	0	+13	-8

This establishes Design 1–Redesigning the Laundry Room–as the most superior design based on Objectives established earlier.

Thea team believes that this is the best design for the following reasons:

1. There is a significant increase of free ground space in the laundry room (approximately 6.616 m^2 or 23%).
2. It is much easier to move in the laundry room even in wheelchairs/e-scooters.
3. More than one wheelchair can easily maneuver in the room.
4. There is no constriction when entering the laundry room as there was before.
5. It is easier to transfer laundry from washers to dryers due to the pairing of machines.
6. The parapet breakdown allows natural light to enter the room from the sliding doors and window.

8. Measures of Success:

Steps Conducted:

Test Name: Maneuverability Test
Date: April 1, 2021
Location: Remote Experiment
Personnel: Group members

To test maneuverability the team used legal constraints (ISO 7176-5[16]) to evaluate the solution. The team researched the minimum lengths required [16] for 90° and 180° turns for both manual wheelchairs and electric wheelchairs. The test was performed using a scaled floorplan of the laundry room and studying possible paths for wheelchairs to freely maneuver (Appendix G).

Future Steps:

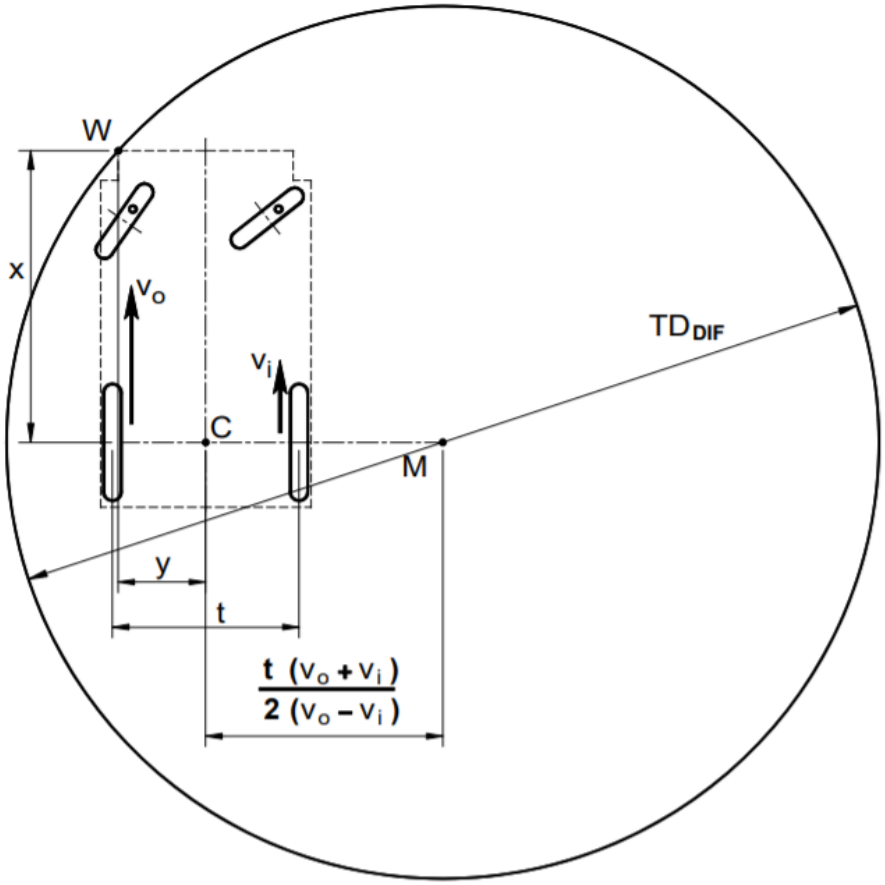
Test: Simulation based analysis
Date: April 14, 2021
Location: Remote Experiment
Personnel: Group members

Using a virtual 3D model of the laundry room and models of the vehicles, the team will run simulations in SketchUp [17] with 1 or 2 vehicles being maneuvered in the room at the same time assuming none of the vehicles touch each other. By tracing these paths, the team will obtain the cases with restricted maneuverability and calculate the probability of the occurrence based on total number of paths.

The team will place additional obstructions during the simulations such as laundry baskets, and other users present in the room to measure the extent of maneuverability. To make the simulations more accurate the team will use data logging to track the consumption pattern of washing machines and study the placement of obstructions that are introduced in the service environment during daily use.

Test Name: Data Collection from Residents
Date: April 28, 2021
Location: Remote Experiment
Personnel: Group members

The team plans to collect data from the residents and commonly used assistive vehicles used in the region to gather information regarding wheelchair and assistive vehicle models to research dimensions and turning radii. This will enable the calculation of minimum length required for turning. This is the formula used for minimum turning diameter (TD_{DIF}) [16]:



$$TD_{DIF} = 2 \times \sqrt{\left(\frac{t(v_o + v_i)}{2(v_o - v_i)} + y \right)^2 + x^2}$$

Figure 11. Formula for turning diameter with supporting diagram.

This test is essential for creating a personalized experience for the residents at Manor Green.

9. Conclusion

This document identifies the lack of accessibility in the laundry room of Manor Green and presents an idea generation and selection process leading to the recommendation of a solution. The service environment and stakeholders have been identified, followed by functions, objectives, and constraints. The team's idea generation and selection process have also been presented afore the alternative and recommended solutions.

Measures of the designs' success have finally been listed, with steps that have been and will be conducted to measure their efficacy. The future steps include carrying out these tests and presenting them to the client.

10. References

[1] Birch Housing, “Our Company | Birch Housing,” Birch Housing. Available: https://www.birchhousing.ca/about/our-company [Accessed: 27- Feb-2021].

[2] World Health Organization, "WHO Housing and health guidelines," World Health Organization, Geneva, 2018. Available:https://www.who.int/publications/i/item/9789241550376 [Accessed: 27- Feb-2021]

[3] S.-C. Chow, Statistical Design and Analysis of Stability Studies, CRC Press, 2007. Available: https://books.google.co.in/books?hl=en&lr=&id=x9XccGzr4wIC&oi=fnd&pg=PP1&dq=S.-C.+Chow,+Statistical+Design+and+Analysis+of+Stability+Studies,+CRC+Press,+2007&ots=b_3oWmiWSq&sig=EFjmbNAyYOfvePNU1rfzd93ikj4#v=onepage&q&f=false [Accessed: 27- Feb-2021]

[4] P. Wolkoff and S. K. Kjærgaard, "The dichotomy of relative humidity on indoor air quality," *Environment International,* vol. 33, no. 6, pp. 850-857, 2007. Available: https://www.academia.edu/25184996/The_dichotomy_of_relative_humidity_on_indoor_air_quality [Accessed: 27- Feb-2021]

[5] *Ontario.ca*, 2021. [Online]. Available: https://www.ontario.ca/page/regulatory-roles-construction-and-renovations. [Accessed: 17- Feb- 2021].

[6] *Ontario.ca*, 2021. [Online]. Available: https://www.ontario.ca/document/citizens-guide-land-use-planning/building-permits. [Accessed: 17- Feb- 2021].

[7] "New Market Building Codes", *Newmarket.ca*, 2021. [Online]. Available: https://www.newmarket.ca/TownGovernment/Pages/Departments/Development%20and%20Infrastructure%20Commission/Building.aspx. [Accessed: 17- Feb- 2021].

[8] "Home | Council of Canadians with Disabilities", *Ccdonline.ca*, 2021. [Online]. Available: http://www.ccdonline.ca/en/. [Accessed: 17- Feb- 2021].

[9] “On the path towards a more accessible Canada with the creation of the Council of Federal Accessibility Agencies | Canadian Human Rights Commission", *Chrc-ccdp.gc.ca*, 2021. [Online]. Available:https://www.chrc-ccdp.gc.ca/eng/content/news-release-path-towards-more-accessible-canada-creation-council-federal-accessibility [Accessed: 17- Feb- 2021].

[10] *Iso.org*, 2011. [Online]. Available: https://www.iso.org/obp/ui/#iso:std:iso:21542:ed-1:v1:en. [Accessed: 24- Feb- 2021].

[11] “About accessibility laws”, *Ontario.ca*, 2021 [Online]. Available: https://www.ontario.ca/page/about-accessibility-laws [Accessed: 21-Feb-2021]

[12] “O. Reg. 332/12: BUILDING CODE”, *Ontario.ca*, 2020 [Online]. Available: https://www.ontario.ca/laws/regulation/120332/v22 [Accessed: 21-Feb-2021]

[13] Samfiru Tumarkin LLP, “Ontario Minimum Wage,” Samfiru Tumarkin, Sep. 30, 202AD. https://stlawyers.ca/blog-news/ontario-minimum-wage-increase-october-1-2020/#:~:text=The%20Employment%20Standards%20Act%20was (accessed Feb. 27, 2021).

[14] "Authentik Canada - Electricity in Canada", Authentik Canada, 2020. [Online]. Available: https://www.authentikcanada.com/en/faq/electric-current. [Accessed: 12- Mar- 2021]

[15] L. J. Kagan, A. E. Aiello and E. Larson, "The Role of the Home Environment in the Transmission of Infectious Diseases," Journal of Community Health, vol. 27, no. 4, pp. 247-267, 2002.

[16]"Working Area of Wheelchairs", 2021. Author: Ing. Johann Ziegler, FIOT Wien, Austria[Online]. Available: https://www.udeworld.com/spaceworkshop2003/Papers/WEB%20-%20Working%20Area%20of%20%20Wheelchairs%20_Ziegler_.pdf. [Accessed: 04- Apr- 2021].

[17]"3D Design Software | 3D Modeling on the Web | SketchUp", SketchUp, 2021. [Online]. Available: https://www.sketchup.com/. [Accessed: 04- Apr- 2021].

[18]"Floorplanner - Create 2D & 3D floorplans for real estate, office space or your home.", Floorplanner.com, 2021. [Online]. Available: https://floorplanner.com/. [Accessed: 04- Apr- 2021].

11. Appendices

Appendix A: Floor plans of Manor Green's laundry room.

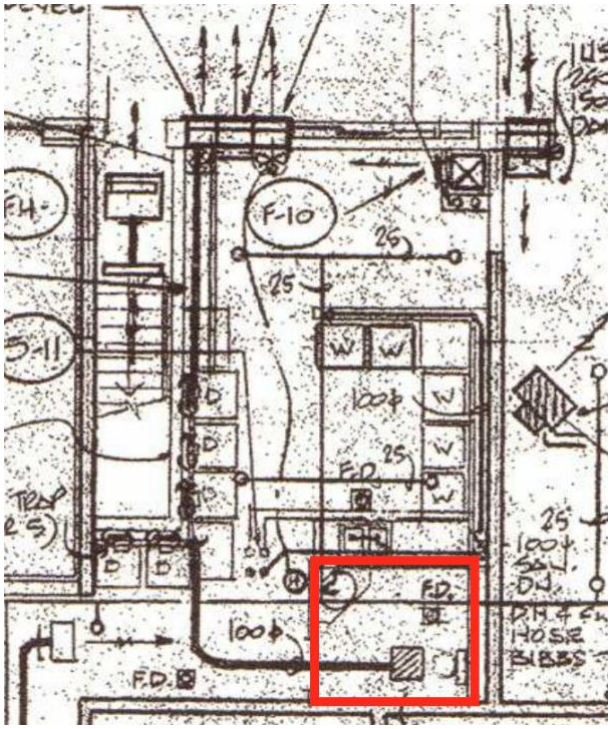


Figure 12. A snapshot taken of the laundry room's floor plan. The highlighted section represents the washroom which the client has stated can be removed [Client Provided].

Appendix B: Black Box Method for Functions

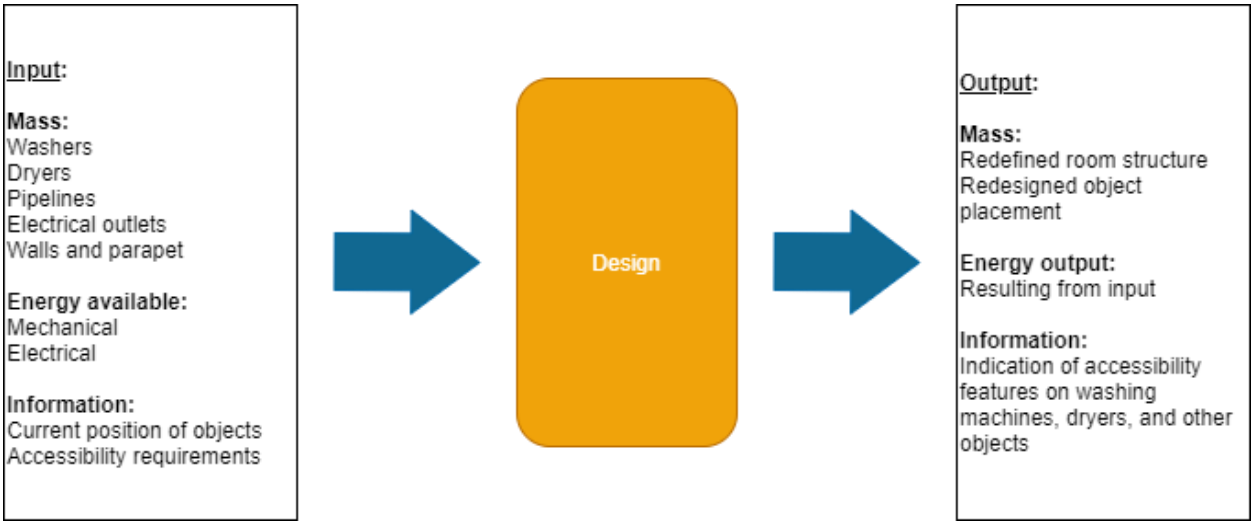


Figure 13. Black Box Method used to derive functions.

Appendix C: Estimated minimum cost.

Estimated labor cost for laundry room facility installation: $1000 (https://www.getwhatyouwant.ca/how-much-will-it-cost-to-renovate-or-repair-your-toronto-home)

There is also a possibility of removal of walls which justifies this time period. No more washing machines can be bought so we are estimating an additional cost of 75 CAD (subject to the solution proposed later).

As requested by the client, we should be mindful of the water supplies for the washing machines and the solution should comply without major changes to the water piping. Therefore, a draftsperson would be needed to make accurate drawings of the residence to make sure this requirement is met. A draftsperson typically charges 800 CAD [13]. So, the estimated minimum cost that the team wishes to achieve is 1875 CAD.

Appendix D: Shows the pairwise comparison of the objectives.

	Objective	Goal	Metric
Objective 1	The solution must be economically feasible and should have a low budget.	1046 CAD (Estimated minimum cost; refer to appendix B)	Calculate based on how much material and human effort is required.
Objective 2	There should be some space that allows a convenient 180° wheelchair turn.	Space should be more than 2000mm in direction of travel and more than 1500mm wide.	Dimensions can be measured using a measuring tape.
Objective 3	The user should have no difficulty in swiping the card while using the machine.	The card slot should be at a height between 800mm and 900mm from the ground.	Dimensions can be measured using a measuring tape.
Objective 4	The passage should allow free movement of 2 wheelchairs.	The width of the passage should be more than 1500mm.	Dimensions can be measured using a measuring tape.
Objective 5	There should be enough light to avoid any injuries.	Illumination level should be more than 100 lux.	Check illumination rating on the lighting source.
Objective 6	The power sockets should be at a suitable height.	The power socket should be at a height of more than 400mm and less than 1000mm from the ground.	Dimensions can be measured using a measuring tape.

	Objective 1	Objective 2	Objective 3	Objective 4	Objective 5	Objective 6	Score
Objective 1	X	0	0	0	1	1	2
Objective 2	1	X	1	1	1	1	5
Objective 3	1	0	X	1	1	1	4
Objective 4	1	0	0	X	1	1	3
Objective 5	0	0	0	0	X	1	1
Objective 6	0	0	0	0	0	X	0

1. Objective 2 is the most important as the client wants enough space for at least 1 wheelchair to move and turn freely. Even though multiple turns in a smaller space which allows rotation up to a smaller angle will also allow a 180° wheelchair turn, space designated for a 180° turn will save time and effort and make movement more convenient.
2. Objective 3 is also important as even though the client focused on the ease of movement, accessing the card slot should be easy too for anyone in a wheelchair.
3. Objective 4 is important to decrease any waiting time by allowing 2 wheelchairs at once inside the laundry room.
4. Objective 1 is also of significant importance as even though the client did not set a hard limit, this does not mean that the cost cannot be justified.
5. Objective 5 is an additional precaution to make sure that there is enough light to allow comfortable movement and there are no accidents caused due to lack of lighting.
6. Objective 6 is important in the case when the machine gets disconnected from the power source for some reason. People in wheelchair should not have to bend too much or stand up in the event this happens. It has a low score because of the rarity of the situation.

Appendix E: Ideas for Idea Generation

Appendix Sections:
Uses of SCAMPER.

Examples	Substitute	Combine	Adapt	Modify, Magnify, Minify	Put to other use.	Eliminate	Rearrange or Reverse.
Laundry Robots	Human use by automated systems			Automotive robots fitted with laundry operating devices.			
Layout adjustments		Breaking different combinations of the parapet, bathroom, and laundry sink.			Clearing space used by unnecessary sections.		Rearrange laundry room contents.
Stacking laundry machines			Adapt machine to make them stackable.				Rearrange machines vertically to free floor space.

Portable washing machines	Substitute the laundry room itself.					Eliminating need for laundry room	
Installing button that alerts reception for help	Accessibility substituted with help.					Need for accessibility.	
Installing laundry room in elevators		Combining elevators and laundry rooms		Modify elevators.	Using elevators for laundry		

Uses of Analogy.

Using conveyor belts in the laundry rooms like in factories and airports.
Using a central chute system directly to laundry machines like garbage disposal systems
Using a one-way track for wheelchairs like fast lanes in airports
Making foldable washing machines like foldable furniture.
Rotating platforms for washing machines for wheelchairs like in car parks.
Using pedals/buttons for conveyor belts like in dry cleaning stores.
Using segregated baskets for laundry that will be dealt with once a day – like waste management systems in cities.
Using automated robots like in factories.

<u>Consolidated List of Ideas</u>

Layout Adjustments:

1. Parapet breakdown with layout adjustment of machines
2. Bathroom breakdown with layout adjustment of machines
3. Laundry sink breakdown with layout adjustment of machines
4. Washing machine movement
5. Stacking with layout adjustment of machines
6. Move machines to the corridor.
7. Insert the machines into the wall.
8. Extend the room itself towards the outside (to the yard) without any other changes.
9. Change main entrance from door to big window main entrance.
10. Install washing machines in the ceiling, put clothes on platform that elevates.
11. Smaller laundry machines
12. Push all the machines more towards the wall.
13. Accessible Cubicle washroom- save space.
14. Stack all Machines on top of each other except the Reserved Machines.

15. Shift water and electrical outlets on the parapet to adjacent wall
16. Break the parapet, bathroom and the sink and redesign the Laundry Room with a bigger entrance as the bathroom is broken down. A small sink can be built to the side of the room. Laundry Machines can be adjusted accordingly.
17. Change the placement of the electrical and water outlets so Layout can be adjusted properly.

Artificial Intelligence/Technology Solutions:

18. Laundry Robot will put the laundry for you with layout adjustment of machines.
19. Remote Operated Machines
20. Robotic arm in laundry room
21. Platform to place clothes that load directly into machines.
22. Robot that carries washing machines door-to-door
23. Humanoid robots operable by VR
24. Drone transportation for laundry
25. App to book appointments for when to do Laundry.

Mechanical Methods:

26. Central chute system - waste disposal type
27. Conveyor belt
28. Washers and Dryers on wheels
29. Pedal system to control machines from outside.
30. Pedal system to control conveyor belt that through the room.
31. Platform system that automatically moves people on a platform around the laundry room
32. Installing a Lift from each house that opens into Laundry Room directly.
33. Track for wheelchairs above the height of the washing machines
34. Foldable washing machines like foldable furniture
35. One-way track (like for a train) for wheelchair/scooter which allows easy movement throughout the room.
36. Hanging washing machines
37. Rotating Washing machine platforms (like car parking systems)
38. One Huge Washing Machine and Dryer that starts at a particular time of a day.
39. Installing Tactical Paving Systems
40. Central Rotating Platform that rotates the wheelchair/assistive device.
41. Sliding Entrance Doors
42. Install Sound and Visual Systems to indicate which machine is full, empty or just completed a cycle.
43. Hydraulics to lift the machines when they come in the way.
44. Make a height-adjustable sink such that it can be used easily at seating as well as standing level.
45. Use bucket washing-machines.

Human enabler-based solutions:

46. Volunteers
47. Long sticks to operate machines.
48. A laundry service operating outside the building (laundromat)
49. Installing a button that alerts the reception if a resident needs assistance with anything in Laundry Room (in combination with layout adjustment).
50. Use wheeled-laundry cart to move clothes.
51. Use 2 dump baskets for light and dark clothes and they will be cleaned at day end.

Other solutions:

52. Change the washing machine to models where washing and drying can be done in a single machine.
53. Decrease the number of washing machines and limit the number of people that can enter in the room at the same time.
54. Reserve 1 washing machine and dryer for disabled residents that are kept in an open space.
55. Elevate All laundry machines such that the machine door opens at seating level.
56. Automatic Sensor Doors at the entrance so the residents don't have to push to open the door.
57. Reserve a Washing Machine and Dryer for all E-Scooter users on the entrance so they don't have to get cramped in the middle of the Laundry Room.

Blue Sky Ideas:

58. Monkey operations
59. Portable Washing Machine
60. Remove Washing Machine and Dryer from Laundry Room to replace with buckets.
61. Installing Washing Machine and Dryer in each household
62. Buying new clothes, trashing old clothes
63. Convert lift to laundry room.
64. Make self-cleaning clothes.
65. Break all walls. Open Laundry Room
66. Dogs that lick the clothes clean

Several Pictures of such ideas can be found below.

 Garbage Chute	 Conveyor Belt	 Stacking
 Humanoid Robot	 Small washing machine	 Hanging Washing Machine
 Sliding doors	 Drone operations	 Wheelchair tracks

 Robotic Arm	 Human laundry service	 App based laundry service
 Laundry cart	 Laundry lift	 Wheel for washing machine
 Automatic doors	 Hydraulic lift	 Washing machine with audiovisual aids

Appendix F: Idea selection

Feasibility Check

F1: Increase maneuverability so that at least one assistive mobility device can turn in the room.

F2: Make it easier to move laundry between washers, dryers, etc.

C1: The design must fit at least one wheelchair/e-scooter into the Laundry Room and allow the wheelchair/e-scooter to move freely within.

C2: The design must meet the safety and accessibility standards as imposed by the Section 2 of Ontario Regulation 191/11 and the Accessibility for Ontarians with Disabilities Act, 2005, as imposed by the Ontario Government.
C3: The laundry room must not be changed or moved to another location.
C4: The Dryer and Washing machines are brand new and shall not be replaced with a different model.
C5: According to the Ontario Building Code 3.4.4.4 (8), Laundry Rooms shall not open directly into an exit. (This has been grandfathered so it has been shown as met for all ideas)

Key:
1 stands for meets
0 stands for fails

Idea	F1	F2	C1	C2	C3	C4	C5
1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1
5	1	1	1	0	1	1	1
6	0	0	1	1	0	1	1
7	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1
9	0	0	1	1	1	1	1
10	0	1	1	0	1	1	1
11	1	1	1	1	1	0	1
12	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1
15	0	0	0	1	1	1	1
16	1	1	1	1	1	1	1
17	0	0	0	1	1	1	1
18	1	1	1	1	1	1	1
19	0	0	1	1	1	1	1
20	0	0	0	1	1	1	1
21	0	0	1	0	1	0	1
22	1	1	1	1	1	0	1
23	0	1	1	1	0	0	1
24	0	0	0	1	1	1	1
25	1	1	1	1	1	1	1

26	0	0	0	1	1	1	1
27	1	1	1	1	0	1	1
28	1	1	1	1	1	1	1
29	1	1	0	0	1	1	1
30	0	0	0	1	1	1	1
31	1	1	1	1	1	1	1
32	0	0	0	1	1	1	1
33	0	0	0	1	1	1	1
34	0	0	0	1	1	1	1
35	1	1	1	1	1	1	1
36	1	1	1	0	1	1	1
37	1	1	1	1	1	0	1
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41	1	1	1	0	1	0	1
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43	1	1	1	1	1	1	1
44	1	1	1	1	0	0	1
45	1	1	1	1	1	0	1
46	1	1	1	0	1	0	1
47	1	1	1	1	1	0	1
48	0	1	0	1	1	1	1
49	1	1	1	1	1	1	1
50	0	0	0	1	1	1	1
51	0	0	1	1	1	1	1
52	0	0	0	1	1	1	1
53	0	1	0	1	1	1	1
54	1	1	1	1	1	1	1
55	0	0	0	1	1	1	1
56	0	0	0	1	1	1	1
57	1	1	1	1	1	1	1
58	1	1	1	1	1	1	1
59	0	0	0	1	1	1	1
60	0	0	1	1	1	1	1
61	0	0	0	1	1	1	1
62	0	0	0	1	1	1	1
63	0	0	1	1	1	1	1
64	0	0	0	1	1	1	1

65	0	0	1	1	1	1	1
66	0	0	1	1	1	1	1

Ideas remaining after feasibility check

1. Parapet breakdown with layout adjustment of machines
2. Bathroom breakdown with layout adjustment of machines
3. Laundry sink breakdown with layout adjustment of machines
4. Washing machine movement
5. Insert the machines into the wall.
6. Laundry Robot will put the laundry for you and swipe the card as well- with layout adjustment of machines
7. App to book appointments for when to do Laundry
8. Washers and Dryers on wheels
9. Platform system that automatically moves people on a platform around the laundry room
10. One-way track (like for a train) for wheelchair/scooter which allows easy movement throughout the room
11. Reserve 1 washing machine and dryer for disabled residents that are kept in an open space.
12. Break the parapet, bathroom and the sink and redesign the Laundry Room with a bigger entrance as the bathroom is broken down. A small sink can be built to the side of the room. Laundry Machines can be adjusted accordingly.
13. Stack all Machines on top of each other except the Reserved Machines
14. Installing a button that alerts the reception if a resident needs assistance with anything in Laundry Room (in combination with layout adjustment).
15. Hydraulics to lift the machines when they come in the way
16. Accessible cubicle washroom- saves space.
17. Push all the machines more towards the wall
18. Reserve a Washing Machine and Dryer for all E-Scooter users on the entrance so they don't have to get cramped in the middle of the Laundry Room
19. Extend the Laundry Room's Entrance to the end of the corridor

Multi-Voting

Number of ideas: 19
Votes per person: 10

Idea	Vedant	Akshat	Shreyaansh	Rohan	Rishistav	Gunin	TOTAL
1	1		1		1		3
2		1		1			2

3				1			1
4			1	1			2
5			1		1		2
6	1	1	1	1		1	5
7	1		1		1		3
8			1			1	2
9			1			1	2
10	1	1		1	1	1	5
11	1	1		1	1	1	5
12	1	1	1	1	1	1	6
13	1	1	1	1	1	1	6
14		1	1		1		3
15		1		1			2
16		1			1		2
17	1					1	2
18	1				1	1	3
19	1	1		1		1	4
VOTES:	10	10	10	10	10	10	60

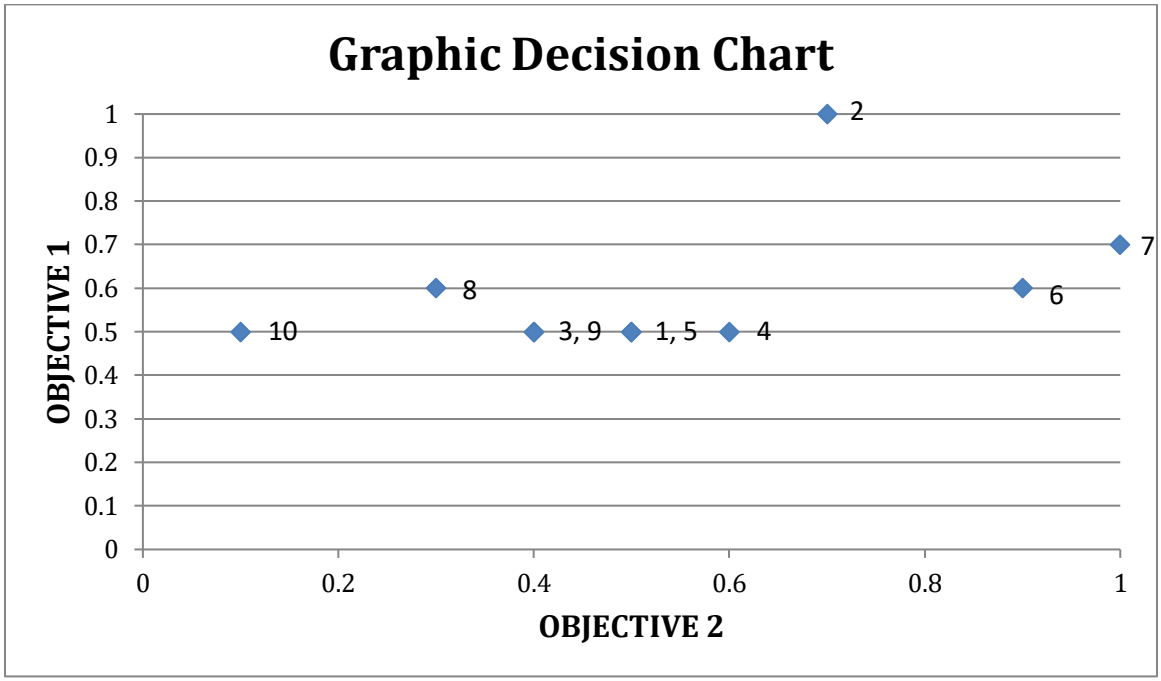
Idea numbers 1, 6, 7, 10, 11, 12, 13, 14, 18, 19 are selected for the next round of selection.

Ideas remaining after multi-voting

1. Parapet breakdown with layout adjustment of machines
2. Laundry Robot will put the laundry for you and swipe the card as well- with layout adjustment of machines
3. App to book appointments for when to do Laundry
4. One-way track (like for a train) for wheelchair/scooter which allows easy movement throughout the room
5. Reserve 1 washing machine and dryer for disabled residents that are kept in an open space.
6. Break the parapet, bathroom and the sink and redesign the Laundry Room with a bigger entrance as the bathroom is broken down. A small sink can be built to the side of the room. Laundry Machines can be adjusted accordingly.
7. Stack all Machines on top of each other except the Reserved Machines
8. Installing a button that alerts the reception if a resident needs assistance with anything in Laundry Room (in combination with layout adjustment).
9. Reserve a Washing Machine and Dryer for all E-Scooter users on the entrance so they don't have to get cramped in the middle of the Laundry Room
10. Extend the Laundry Room's Entrance to the end of the corridor

Graphic Decision Chart

Objective 1: The user should have no difficulty in swiping the card while using the machine
Objective 2: There should be some space that allows a convenient 180° wheelchair turn



- → Idea 2 is ranked highly as it automatically makes the payment and it eliminates the need to enter the room at all.
- → Idea 6 is ranked highly for the second objective as it creates a lot of space which increases the space available for turning. It is not as highly ranked for the first objective because it does not drastically reduce difficulty in swiping the card for payment.
- → Idea 7 is ranked highly as stacking creates a lot of space. As machines are being reserved for the disabled, it does not increase difficulty in swiping the card as they will still be at the same height.

Based on the result of the graphic decision chart, ideas 2, 6, and 7 will move on to evaluation based on the Pugh Method.

Appendix G: Evidence and explanation for Measures of Success

Floor Area Calculation

The team analyzed the old and new floor plans and developed a scaled down model of the laundry room using Floor Planner reference [18] and 3D modelling software (SketchUp [17]). Considering the software measurements, implementing the proposed solution increases the free area by 23%, from 28.6734 to 35.2894 m^2.

Total area of the empty laundry room including bathroom = 44.7 m^2[insert references]
Total area of the empty laundry room without bathroom = 39.32 m^2

Surface area occupied by 6 washing machines = 6 × 0.68 cm × 0.70 m = 2.856 m^2
Surface area occupied by 6 dryers = 6 × 0.68 m × 0.71 m = 2.8968 m^2
Surface area occupied by parapet = 1.18 m × 1.91 m × 0.20 m = 2.2538 m^2
Surface area occupied by old sink = 2.4 m × 1.10 m × 0.41 m = 2.64 m^2

With the above objects in the initial laundry room (excluding the bathroom) the free area is 28.6734 m^2.

The proposed solution makes the following changes to the existing laundry room:
1. Complete removal of the parapet.
2. Bathroom conversion to part of the laundry room.
3. Reduction in dimensions of sink to 1.2 m × 1.17 m × 0.61 m.

Implementing the proposed solution increases the free area by 23%, from 28.6734 to 35.2894 m^2
.

Maneuverability Test Evidence.

The team will consider the legal requirements of the building code for maneuvering wheelchairs in a 90° and 180° turn. According to the standard ISO 7176-5[16] the dimensions of a wheelchair (with user) are 1.2 m by 0.74 m by 1.5 m. To perform a 90° turn the manual wheelchair requires 0.88 m angled length. The angled length available to the user in the redesigned laundry room is 1.62 m which is greater than the maximum recommended length requirement.

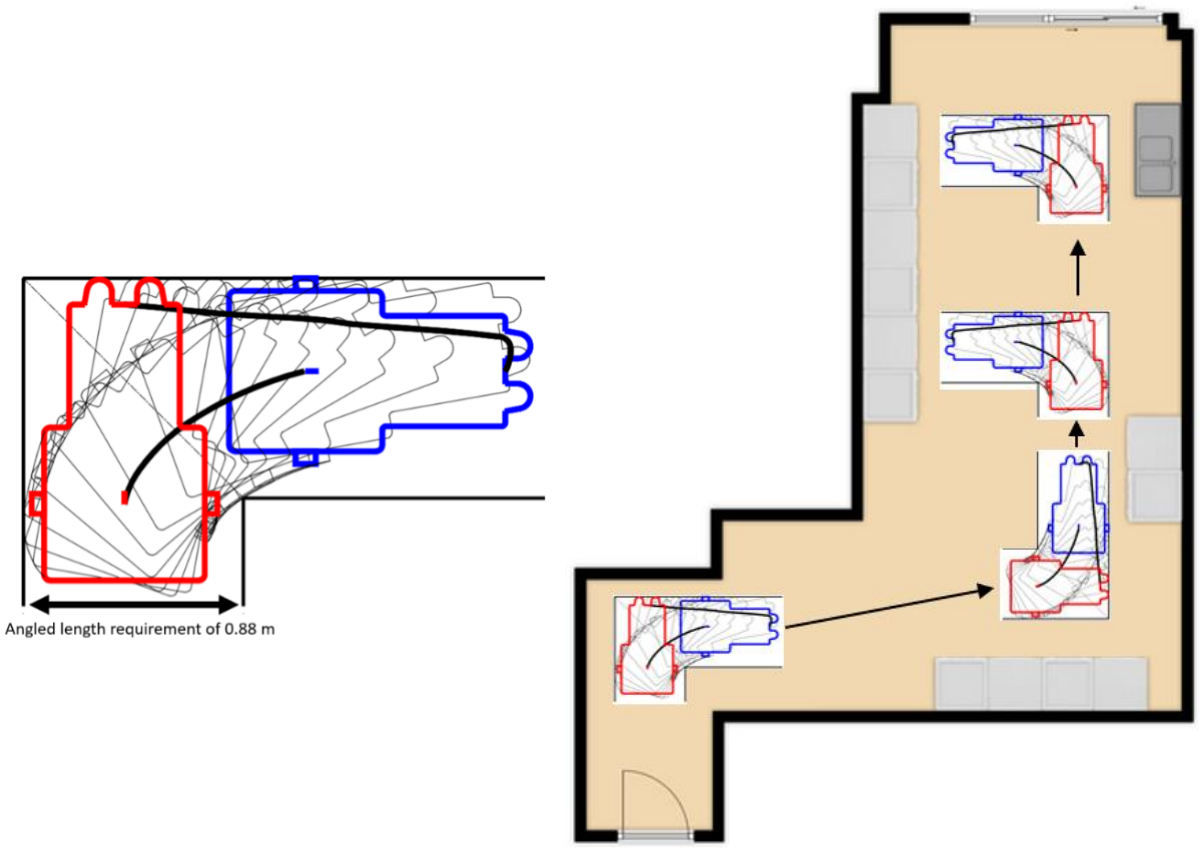


Figure 14. Laundry room layout and wheelchair movement

As the scaled figure shows, the redesigned laundry room permits the use of two wheelchair users to turn 90 degrees following the path provided, hence meeting the objectives.

For a 180 degree turn the minimum length required is 1.27 m.

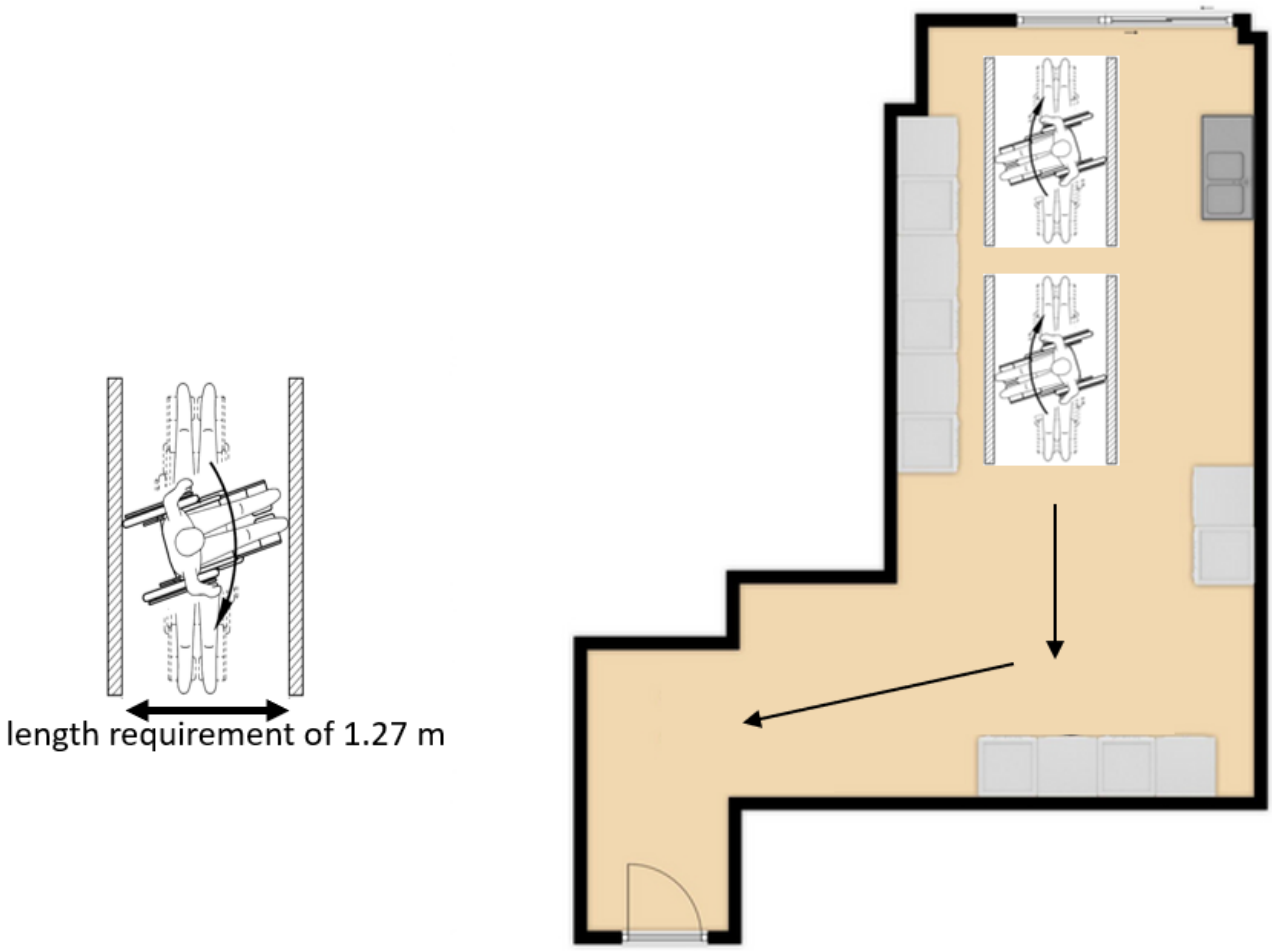


Figure 15. Laundry room layout and wheelchair turning

The redesigned room permits 180 degree turns for 2 wheelchairs simultaneously. The team researched paths used by users to turn in tight spaces. To maximise ease of use, the team considered the minimum length required to successfully turn a manual and electric wheelchair 180 degrees in just two steps.

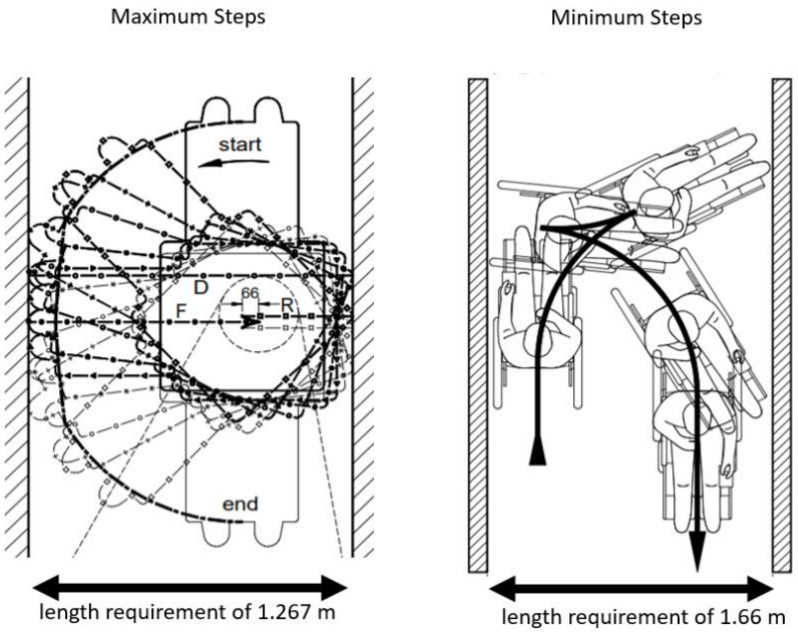


Figure 16. Wheelchair turning

This minimum length is standardised to 1.66 m which is within the capability of the design solution as shown below.

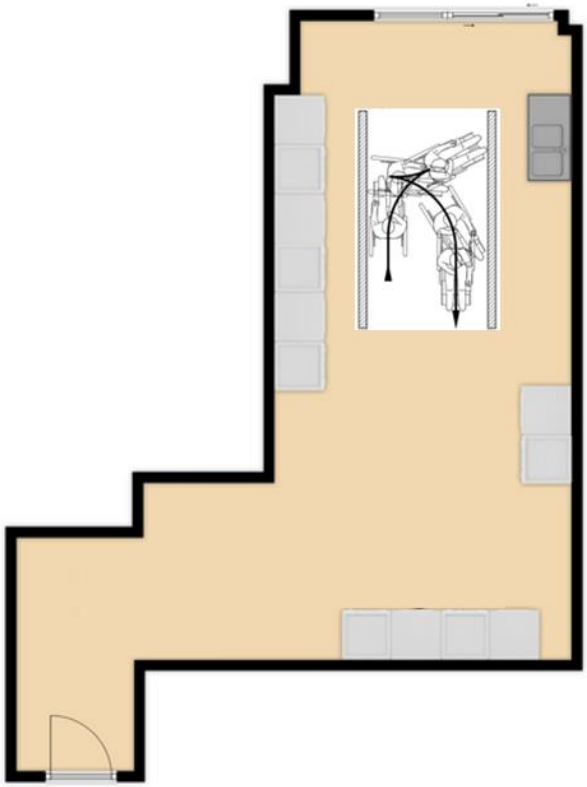


Figure 17. Wheelchair turning within the redesigned layout

Therefore, the proposed solution successfully meets the following objectives:

- There should be some space that allows a convenient 180° wheelchair turn.
- The passage should be wide enough to allow free movement of 2 wheelchairs.

These objectives are also prioritised in Pair Wise Comparison ranked 1 and 3 respectively.