University of Waterloo
Department of Systems Design Engineering
Design Team #14
BME 161 - Design Showcase Report 2

Emma Louie 20898054
Kelly Lu 20898566
Cooper Owen 20919878
Sammi Szeto 20891357
Nicholas Virzi 20889003

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Summary of Problem Space:

Situation of Concern and Situation Impact Statement:

40-66% of individuals living with a spinal cord injury are classified as overweight or obese [1]–[4]. Regular self-monitoring of one's weight is essential in the weight-loss process [5]. Unfortunately, self-monitoring is a challenge for wheelchair-bound individuals with a spinal cord injury, who suffer with limited mobility, inconsistent access to scales, and expensive alternatives, many of which are inconvenient to operate outside a clinical environment [1].

Therefore, there is a need to design a product to be used by wheelchair-bound individuals with any severity of a spinal cord injury to track and manage their weights in a home environment with minimal assistance that is easy to access and user friendly.

Table 1: Table of Requirements

Requirement 1	Must be convenient in a home environment in terms of efficiency and operability.
Requirement 2	Must be safe.
Sub Requirement 2 a)	Must support users of all weight classes for continuous use.
Sub Requirement 2 b)	Must remain secure on the wheelchair seat and footrest.
Sub Requirement 2 c)	Must be resistant to pressure or heat build-up.
Requirement 3	Must be configurable to support users regardless of their size or abilities.
Requirement 4	Must be reasonably affordable to 'middle-class' users.
Requirement 5	Must display an accurate weight reading and BMI of the user.

Table 2: Table of Constraints

Constraint 1	The angle between the backrest and seating system must not be less than 90° [6].
Constraint 2	The manufacturing budget of 50% of the target product cost must not be exceeded.
Constraint 3	The device must not wear down or become prone to malfunctions until more than 1,000 cycles have been completed [6].
Constraint 4	The completion date of the entire design process must not be past November 20, 2020.
Constraint 5	The average amount of time to complete one full cycle must not be greater than 10 minutes.

Functions:

A key function of the device is to support the user's weight whilst in use. The device will also need to receive power for the electrical components to function. The electrical components are at risk of overheating; therefore, a way to cool them is also required. The data collected from the use of the product will also need to be managed in a way that is easily accessible to the user. For this data to be secured, there needs to be a way to protect user's data from being accessed by unknown individuals. It is also significant for the product to be able to change configuration to adapt to each user. Lastly, the product must calculate the user's weight.

Solution Approach

The seat and footrest cushion scale consists of two AA battery powered cushions connected via wire where the seat cushion is embedded with an array of force-sensitive resistor sensors and the footrest cushion with four single strain gauge load cells. Both types of force sensors are located at the bottom of the cushions and on top of a hard plate to ensure level placement and protect the condition of the sensors. The force-sensitive resistor sensors cover the entirety of the bottom of the seat cushion to account for variations of pressure distribution caused by shifts in movement by the user. The force-sensitive resistor sensors provide readings generated by a processor to acquire the weight of the user. The four single strain gauge load cells are in the four corners of the footrest cushion below a force plate. The single strain gauge load cells generate readings of the user's weight through a load sensor combinator and load cell amplifier [7]. The data is encrypted to ensure the protection of user information and transmitted to the app via Bluetooth. There is a cooling vent located between the battery pack and processor to provide air circulation and prevent the buildup of excess heat generated by the processor. The seat cushion is made of memory foam to provide optimal comfort and is coated with flame retardant for protection from overheating parts. Both cushion scales are secured onto the wheelchair with velcro adhesives located at the underside of the cushions, have an exterior layer of polyester, and are available for customized sizing to fit narrow, standard, and wide seats and footrests.

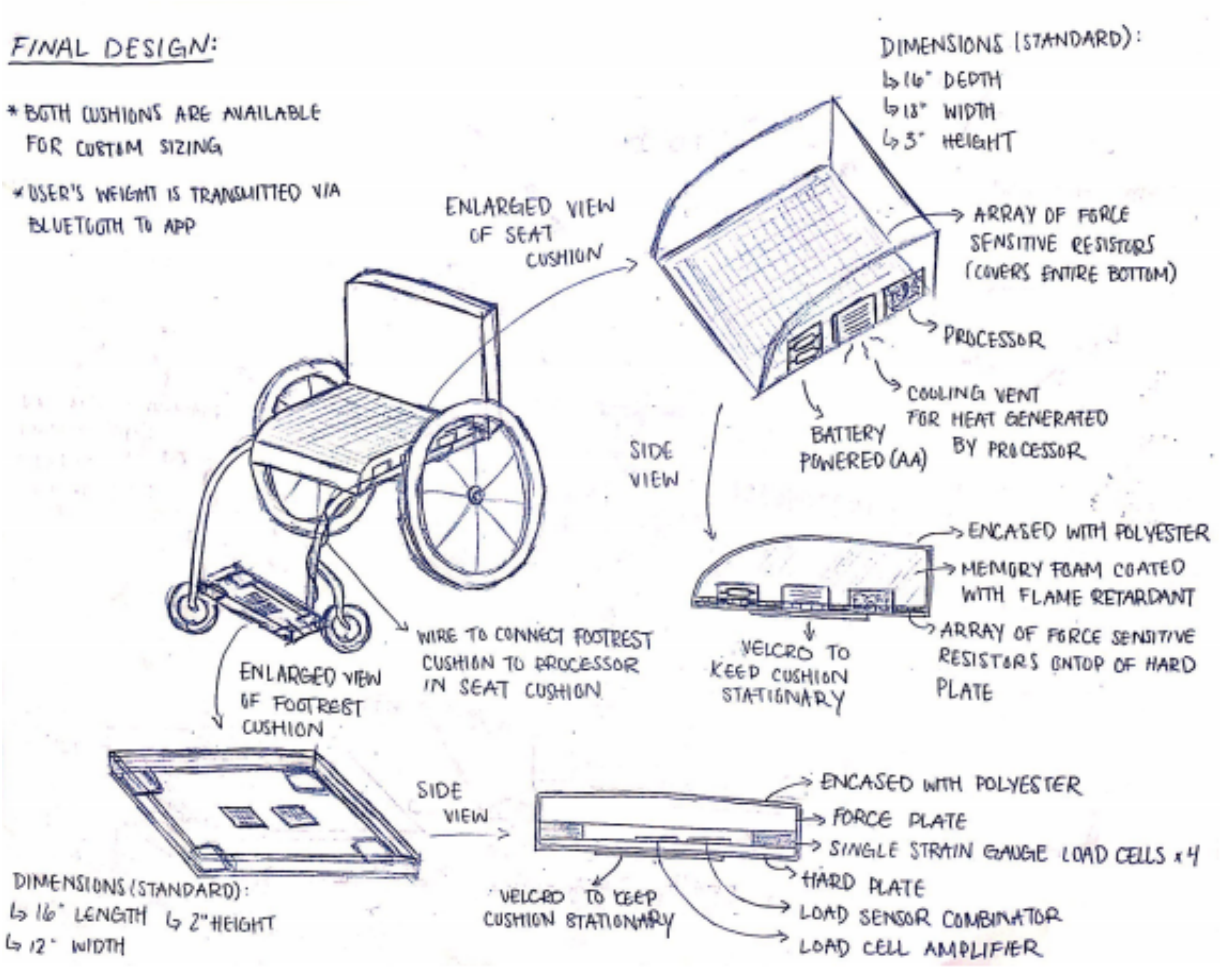

Figure 1: Final Design Sketch of Components One and Two

To use the device, place the seat cushion scale onto the seat of the wheelchair. Place the footrest scale onto the footrests of the wheelchair and secure it with the velcro straps on the bottom of the device. Connect the two scales by the provided wire into the processor of the device. Now the user will need to download the accompanying app to be able to view the results on a mobile device. With this initial setup completed, the user can now start the process of weighing themselves. To start, the user will power on the device. Then, the user will place themselves or with the help of a registered nurse/family member onto the wheelchair that has been equipped with the cushion scale. The user will need to keep their hands in their lap and for the most accurate results, they will need to have the seat and footrest cushion parallel to the ground. Finally, after a couple of seconds, the user will receive a notification on their phone from the app that will provide their resulting weight.

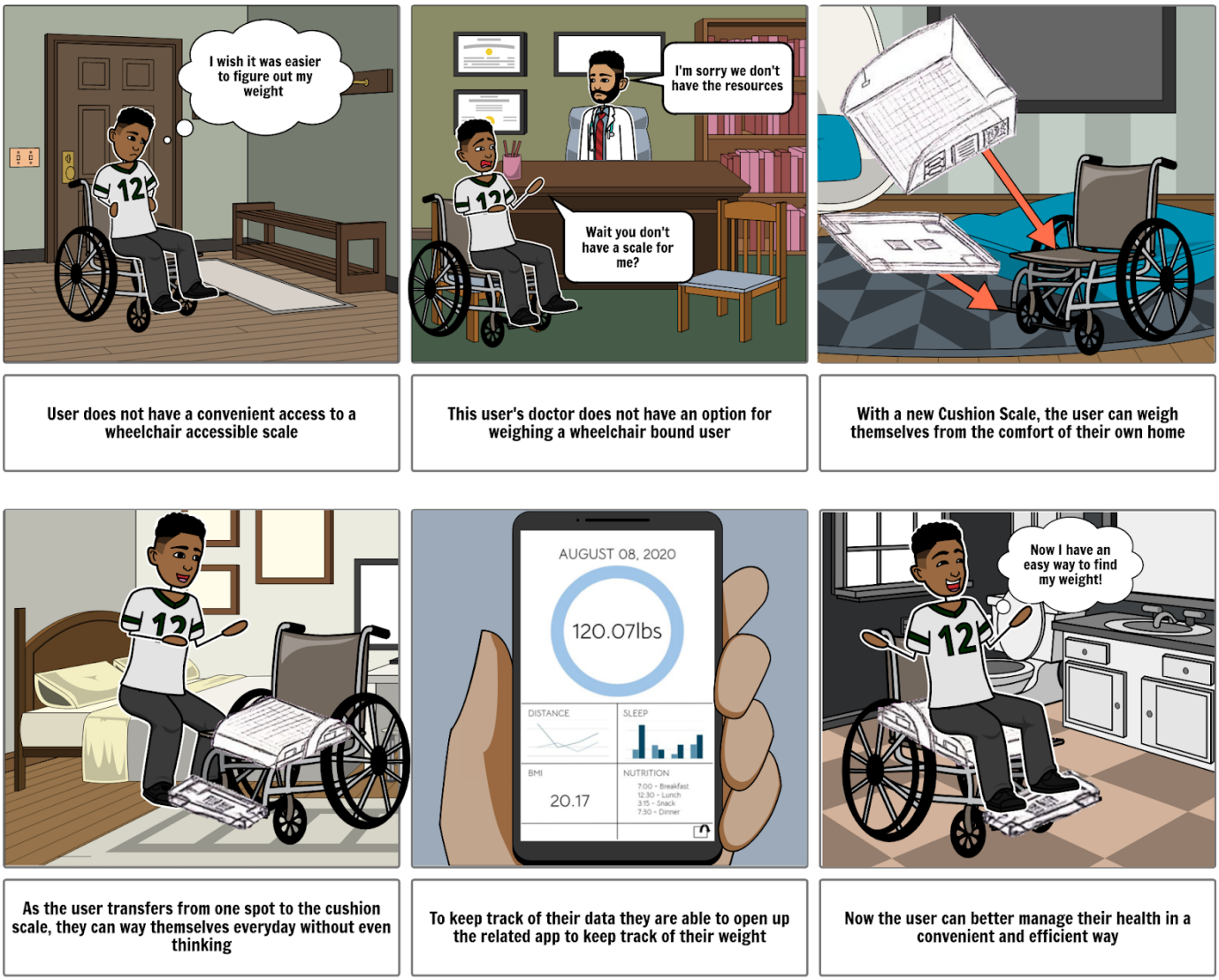

Figure 2: User Interaction Storyboard

Engineering Analysis

The engineering analysis evaluated requirement 5, which stated that the product should be accurate in determining the user's weight. Achieving requirement 5 is essential to a successful product because an inaccurate measure means that its key functionality of weighing wheelchair-bound individuals is lost. Without this function, other requirements suffer too. For example, requirement 1 considers the product's convenience. If the engineering analysis shows that the user must be positioned in a certain manner to get an accurate reading, the product will be less convenient to use. An unreliable product will also diminish its operability. These factors largely impact product success; therefore, engineering analysis was done to examine three potential locations where weight distribution may affect the product's accuracy due to uncaptured weight: the seat, footrest, and the backrest of the wheelchair. Examining potential weight uncaptured by the current design is essential because users with a spinal cord injury may be unable to adjust their position on the wheelchair, so the product must be optimized such that it will return an accurate reading regardless of the seated posture.

A statics-based analysis can be used because the user will be in a sitting position, which is assumed to be stationary when the weight is taken. This assumption was made because individuals weighing themselves on a bathroom scale are also meant to be stationary. Hence, the forces acting at the selected bodies will be a constant and at equilibrium. The analysis was performed assuming the user was in a 'TiLite ZRA Wheelchair' with seat dimensions of 18'' width x 16'' depth, a 15 ¾'' backrest height, a 101° angle between the seat and backrest, a footrest with dimensions of 16'' length x 12'' width, and a 70° front frame angle [8]. The maximum weight that the wheelchair could sustain, which was 265lbs with a standard frame, was also taken as the assumed mass of the user [8]. External contributors to weight were ignored. The material of the wheelchair's upholstery was assumed to be nylon [9]. The exterior material of both cushions was assumed to be polyester with $\mu = 0.8$ [10]. Extreme cases were considered, to prepare for the worst-case scenario.

Firstly, the situation where the user was leaning back on the wheelchair was considered. The connector between the seat and the backrest was taken to be a pin joint. The total mass on the backrest was assumed to be from the head, neck, and trunk. A downwards, vertical weight force was calculated from the mass. Then, the reaction forces at point A, the friction force caused by the nylon, and the normal reaction force were calculated. The normal reaction force was 142.92N, which indicated that the backrest held some of the user's weight, namely, 142.92N, which corresponds to 14.6kg of a 120kg individual. As another comparison, the total weight meant to be captured by the seat, which considered the mass of the head, neck, trunk, pelvis, arms, and thighs, was found to be 1100.04N, and so 12.99% of the weight is lost to the backrest.

Secondly, the amount of force inflicted on the footrest was considered to determine what type of load cells were suitable for use in the footrest cushion. The connector between the footrest and front frame was taken to be a pin joint. The total mass on the footrest was assumed to be from both the shank and feet. The downwards, vertical weight force was calculated from the total mass and force of gravity. Then, the external forces of the normal reaction, friction, and reaction forces at point A were calculated using equilibrium equations and known values of the friction coefficient of polyester, the width of the footrest, weight, and front frame angle. The normal force was 136.9N which corresponds to 14.0kg with a front frame angle of 70° and 145.7N which is 14.9kg with a front frame angle of 90°.

Finally, an analysis was conducted to determine what percentage of the weight applied to the seat by the user is measured by our current design which incorporates 4 arrays of sensors. Next, the percentage of area covered by the sensors was determined. Figure A4, located in the appendix is a map of the pressure applied during a standard wheelchair seat evaluation consistent with the TiLite Zra wheelchair [13]. The pressure is measured in mmHg at pressure points on the individual's buttocks. The 0.5'' by 0.5'' force-sensitive resistors have been scaled and mapped onto the diagram. The colour identified areas represent 10 by 10 arrays of these sensors which measure approximate sums of pressure as follows: Red—762mmHg, Blue—1,434mmHg, Purple—1,114mmHg, Black—925mmHg. Therefore, the total pressure on the sensor is 4,235mmHg. The total pressure mapped in the diagram calculated by summing up all the individual pressure points is 9,217mmHg. This means that the total pressure on the sensor as a percent of the total pressure mapped is given by (100)4235/9217 = 45.9%. Currently

the area covered by sensors is (5” * 5”) * 4 (arrays) which = 100 in², whereas the total area of seat is 18” (width) * 16” (depth) = 288 in². This means that the current percentage of area covered by sensors is (100)100/288 = 34.72%. Therefore, the percentage increase of sensors to fill the seat is (100)100/34.72 = 288%.

Based on the engineering analysis, the current design does not provide an accurate measurement of weight because some weight is lost to the wheelchair’s backrest. Consequently, these portions of the user’s weight will not be captured by the scale’s sensors. The weight is also lost to the inability to capture the total weight of the buttock area since the sensors do not cover the entirety of the surface area of the seat. Calculations from the backrest analysis indicated that 12.99% of the total weight meant to be captured by the cushion scale was lost to the backrest. There were a fair amount of assumptions made in these calculations, like assuming point forces, the weight on the backrest, and a specific type of wheelchair; however, the calculations suggest the need for further research and testing to examine the weight distribution on the backrest. Currently, there is not enough evidence to conclusively add backrest sensors, but researching other types of wheelchairs and their average backrest to seat angles and gaining more technical skills to lessen the number of assumptions made can contribute to better informing a potential iteration on the current design.

Based on the engineering analysis of the footrest cushion with consideration of the best and worst-case scenario, single point load cells would be applicable in this situation as both calculated normal forces are within their capacity range of 300g to 2000kg [11]. Through speculation, it is very likely the load cell is capable of accurately measuring the weight of the user’s shank and feet due to the large range in capacity. The width of the footrest being 12’’ raised concerns as it is significantly small compared to a single point load cell that goes up to a size of 1200x1200mm [11]. Further research was conducted to identify single strain gauge load cells as a more practical load cell to use that would be compact but still accurate as its capacity is 50kg and 35x35mm [12]. There were significant assumptions made in these calculations, such as assuming point forces, total weight on the footrest, and a male user. Therefore, researching pressure and weight distribution would provide better evidence and information regarding what exact type of load cell would generate the most accurate representation of the weight of the user’s shank and feet.

The engineering analysis conducted on the seat cushion provided some valuable information. To start, it is important to note that the conversion from pressure in mmHg to lbs/in² is linearly proportional. Therefore, if the design incorporates only the 4 sensor arrays shown, it will only be measuring 45.9% of the user's weight applied to the cushion. This demonstrates how highly inaccurate the force calculated from the pressure applied to the sensors on the cushion of our current design would be. Moreover, a scalar multiple of 2.18 (100%/45.9%) cannot be applied to this measurement to reach an accurate force calculation, because the pressure applied by all users will not be identical to that applied in Figure A4 (found in appendix). The only way to guarantee the reading is accurate with this design is to fill the bottom of the cushion with sensors to measure all weight applied by the user. This will cause a large increase in manufacturing cost: 288%.

Testing Plan

Proposed Medium Fidelity Prototype:

The medium fidelity prototype is an 18'' width x 16'' depth x 3" height [14, 15] sized seat cushion with a hard, thin metal plate as the base, one force-sensitive resistor on top of the plate that can be shifted around, a processor, a hard block to represent the battery pack, and a layer of flame retardant memory foam. This design will then be encased by a layer of polyester with a zipper on the side of the cushion. The foot scale component of the product will be a hard plate encased in polyester. The mobile application will be represented with a wireframing tool that includes the navigation pane with the respective views: 'Current Weight View', 'Logbook Overview', 'Logbook Detailed View', and 'Medical Professional Inputted Data'. Randomly generated data will be inputted since the weighing function will not be implemented in the prototype.

The prototype will be used to test requirements 1 and 2, which evaluate convenience and product safety. Testing requirement 1 requires a sample population of wheelchair-bound individuals with a spinal cord injury to use the product and rate their results on a questionnaire. Testing requirement 2 requires one force-sensitive resistor that is movable around the seat cushion base to determine whether the sensor can handle the external forces acting on it, such as pressure and potential heat generated from a processor. The medium fidelity prototype does not require the full weighing mechanism, because neither of the tests evaluates the accuracy requirement. The prototype also does not require the fully developed mobile app; however, a representation of the application's layouts are required for the user to interact within requirement 1 testing, which can be done with a wireframing tool. Testing requirement 1 needs the true materials, polyester and memory foam, so the user can evaluate product comfort, which correlates to how convenient and efficient the product is to use. Mimicked components, like the battery pack, are also required to ensure the product will feel as similar to its final version as possible. Testing requirement 2 requires the movable sensor to ensure that it can handle different pressure points and other critical areas. The polyester and memory foam are also required to ensure that there are no difficulties in using the sensor underneath the two materials.

Requirement 1 Testing and Limitations:

Testing protocol for requirement 1 focuses on the product's convenience and user satisfaction. Testing is user-focused because the problem space presented the need for a product that could be used by wheelchair-bound individuals with spinal cord injuries outside a medical environment, making it important that user feedback is considered before a high fidelity prototype is made. The testing protocol for this requirement will be collecting user experiences through a questionnaire that inquires about how the product was used, to judge efficiency, and how it felt, to test user satisfaction. The answer options include ranking on a 10 point Likert-scale and answering multiple-choice questions to give a range of opinion-based and quantitative data. Incomplete spinal cord injuries account for 60% of spinal cord injuries. More specifically, incomplete tetraplegia is the most common spinal cord injury, representing 45% of total spinal cord injuries. So, about 45% of the test group should have a form of incomplete tetraplegia and 15% should have another type of incomplete spinal cord injury. The remainder of the test group (40%) should consist of individuals with a complete spinal cord injury [16]. Both test groups should consist of users with varying sensory and motor function abilities and their type of spinal cord injury should be identified. Ideally, a test group of 50 individuals at varying ages should be used to obtain realistic, yet appropriate averages. Each participant will be given the product and a briefing on how to use the application, necessary safety precautions, and simplifications made on the medium-fidelity prototype compared to the actual product idea. Then, they will use the product for two months, given no further instructions, and will answer the questionnaire at the end of the testing period. No sensor is needed for this testing, as all the data will be gathered from the 14 questions.

A limiting factor of the testing protocol is the test group. The product is aimed to account for a range of individuals with varying motor skills and abilities to adapt to new technologies. The differences amongst the population of only 50 individuals may create many 'outliers' in the results, making a trend difficult to detect. Human variability may also sway the results of the Likert scale-based rankings, because question interpretation

and judging criteria may differ between individuals. The results to question 10 about locations of discomfort may also be challenging to interpret, because some of the pain may not be from the product; it may be a pain that the user got from another injury or action. A full medical exam including an x-ray before and after using the product could help with validating the results, but it is not a realistic testing protocol. Gathering each participant's full medical history to ensure that the discomfort is caused by the product is unnecessary, rather, the fifty survey results can be compared to determine a trend if applicable. It would be ideal to have a larger test group, but also unrealistic to make the medium fidelity prototype more than 50 times or extend the testing period to reuse the prototypes. The testing time is also limited to two months because based on the primary persona, the estimated frequency of use is bi-weekly, so two months would allow for at least 4 uses. A two-month testing time would allow for the detection of short-term pressure points, but side effects from long-term use cannot be evaluated, which is a limitation to the testing protocols. Since the medium fidelity prototype is not fully equipped, some features that may cause discomfort or inconvenience, like the battery pack, will not be included, so those features cannot be judged, although there will be mimicked versions of all the components inside the cushion.

Requirement 2 Testing and Limitations:

The testing method for requirement 2 will assess the safety of the product's design for continuous use concerning pressure and heat exposure. The force-sensitive resistors the device will be using, Interlink Electronics 0.5″ Circular 20N FSR, have a maximum operating temperature of 70°C and a force maximum of 20N [17]. If these values are exceeded during testing the sensor is at risk of failing to operate properly or breaking (posing a danger to the well-being of the user) It was previously established that the maximum weight that needs to be supported by the design is 265lbs. Therefore, at least 10% of the 50 person test group must weigh at least 265lbs (up to 300lbs) so that safety can be ensured for all proposed weight classes. They must also have function of their upper body such that they can shift their weight from a sitting position. Begin by unzipping the bottom of the pillow and center a single force-sensitive resistor on the hard underside of the pillow. Have the test subject sit in the wheelchair for 10 seconds, then record the sensor's reading. Repeat this process for a total of 5 trials, recording observations about the sensor with emphasis on its temperature as testing continues. Upon completing 5 trials, unzip the bottom of the pillow and move the sensor to the next testing position (identified in Table 3A in the appendix, the chart that will be used to record this information) and continue with this process. Since this is done to measure potential maximum forces applied, when the sensor is in the front, have the user shift their weight to the front by leaning forward, when the sensor is on the left, have the user lean to the left, etc. When all sensor positions have been fully tested, examine the sensor and note any damage (heat/physical) and whether it could pose a health/safety risk to the user. If at any point the force or temperature exceeds the sensor's maximum, the type of sensor and/or the design's weight capacity needs to be changed.

It would be impractical to build a prototype with a full array of sensors on the cushion due to the high cost that would be incurred. Instead, by using only one sensor and moving it around a similar testing result can be achieved; doing this does have a few drawbacks though. To start, it cannot be guaranteed that a single sensor is at the point that has the most force acting on it at any given time. This is somewhat mitigated by having the test subject shift their weight by leaning in the direction of the sensor, however, a result cannot be determined conclusively without any assumptions. It is difficult with a medium fidelity prototype to obtain accurate quantitative data about the temperature of the sensor when it is being used; qualitative data will be used instead. It is impossible to determine with absolute certainty if heat measured qualitatively complies with a quantitative metric (70°C). Having multiple sensors in place could also affect the sensors' temperatures as any heat from the others could contribute. For these reasons, using only one sensor could produce an underestimate of the force and heat applied which could pose a risk to the product's functionality and the user's safety.

Iteration Plan

Further advancements of the seat cushion scale design will benefit from the following iterations:

Synthesis:

Synthesis and needs assessment has shown that user-experience is an important component of addressing the problem space. Therefore, further research on components of positive user-experience will benefit the device upon further iterations. Guiding research should surround questions such as the following:

- What is the average time for one use-cycle of the device?
- What stage of the use-cycle is the user spending the most time on?
- What is the average user rating for ease-of-use of the device?
- What percentage of the user base might require external help to operate the device?
- How efficiently are users able to navigate the accompanying application once familiar with the device?

Iterating based upon data found from the above will allow for a design that is more user-friendly.

Design:

From the design stage it has been concluded that the optimal way to address the problem space is a wheelchair cushion with a built-in scale and an accompanying app to display data to the user. Further materials analysis and app optimization research will benefit the seat cushion scale by improving user-comfort and data accuracy. Possible guiding research questions are as follows:

- What sort of cushion filling is the most comfortable for the user?
- What sort of cushion casing will best protect the inner components of the device?
- How will the cushion filling affect the data picked up by the sensors in the seat cushion?
- What are the most heavily utilized features in existing health apps?

Iterating based upon data found from the above will extend the life cycle of the device and allow for a more positive user-experience.

Analysis:

The most recent analysis of the device has shown that the device accuracy may benefit from sensors placed along the backrest of the wheelchair. The device will benefit from further investigation into this possibility. Further iterations should be made after investigating the following:

- What does weight distribution look like along the backrest of a wheelchair?
- How are forces distributed on a wheelchair when in use?
- What is the optimal sensor placement to capture the most accurate weight reading?
- How does sensor location affect the discrepancy between the actual weight of the user and their weight as read by the scale?
- What position should the user be in to provide the most accurate data reading?

Iterating based upon data found from the above will allow the device to achieve more accurate data readings to provide to the user.

Prototyping:

Additional prototyping will be needed on more advanced iterations of the device. One such iteration should evaluate the accuracy of the device in its current state. Evaluations should answer the following:

- What is the discrepancy between the actual weight of the user and their weight as read by the scale?

This could be done by measuring known weights using a prototype with a full-sized array of sensors. Accompanied with the data found from further analysis, the next iteration of the device should have significantly improved accuracy.

Conclusion

The initial goal of the design as stated by the situation impact statement was to design a device to be used by wheelchair-bound individuals with any severity of a spinal cord injury to track and manage their weights in a home environment with minimal assistance that is easy to access and user friendly. Based on this statement, specific constraints and requirements were established to measure success. These requirements concerned device efficiency, safety, configurability, cost, and accuracy. Measured against these metrics, the device was not successful. Engineering analysis has shown that the current iteration of the device cannot reasonably be predicted to fall within the requirement bounds set during needs assessment. The team is not currently equipped with the technical skills needed to assess the optimal sensor placement based on weight distribution. For this reason, to meet the accuracy requirement the design requires sensors along the entirety of the seat cushion, and single strain gauge load cells on the footrests. This significantly raises production cost. The seat measures 18” by 16” and is fully covered by an array of 0.5” by 0.5” sensors. This results in 1,152 sensors costing $7.50 each [17], bringing the cost of sensors alone to at least $8,640. Following the bounds set during needs assessment, this estimate causes the device to fail requirement 4. Therefore, the current iteration of the device is not successful. However, production costs can be reduced with further research on materials and sensors. Manufacturing costs can also be difficult to judge at the current stage of the design process. Although the product appears costly, there is an inverse relationship between cost and the remainder of the requirements. For example, the product design met requirement 1, which evaluated design efficiency and convenience. The cushion design provides user comfort and can be used efficiently, with a one-time installment procedure. In conclusion, the current design concept is promising, but will benefit from further research, technical skill development, and iterations.

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Appendix

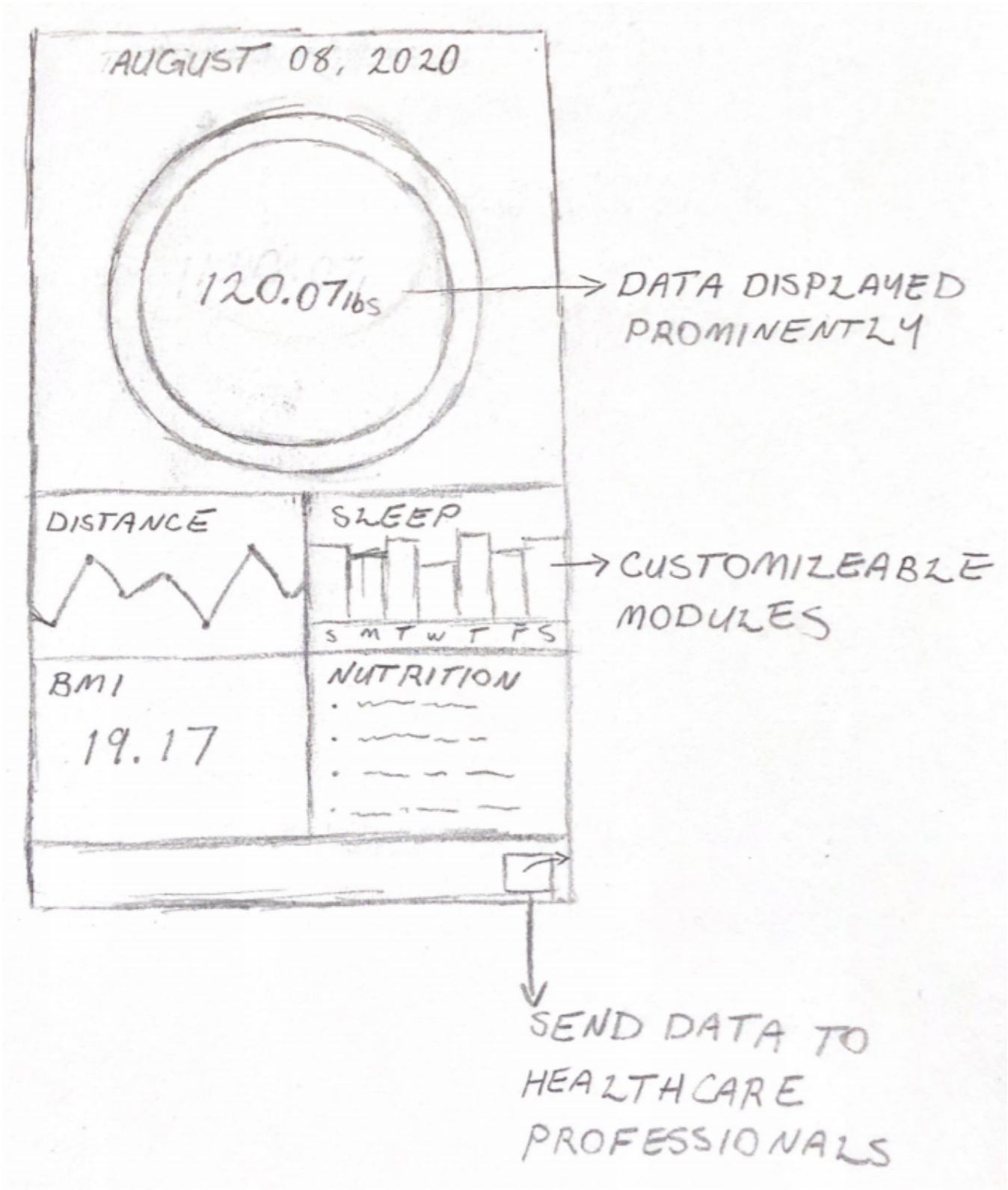

Figure A1: Basic layout of the app interface.

Engineering Analysis 1:

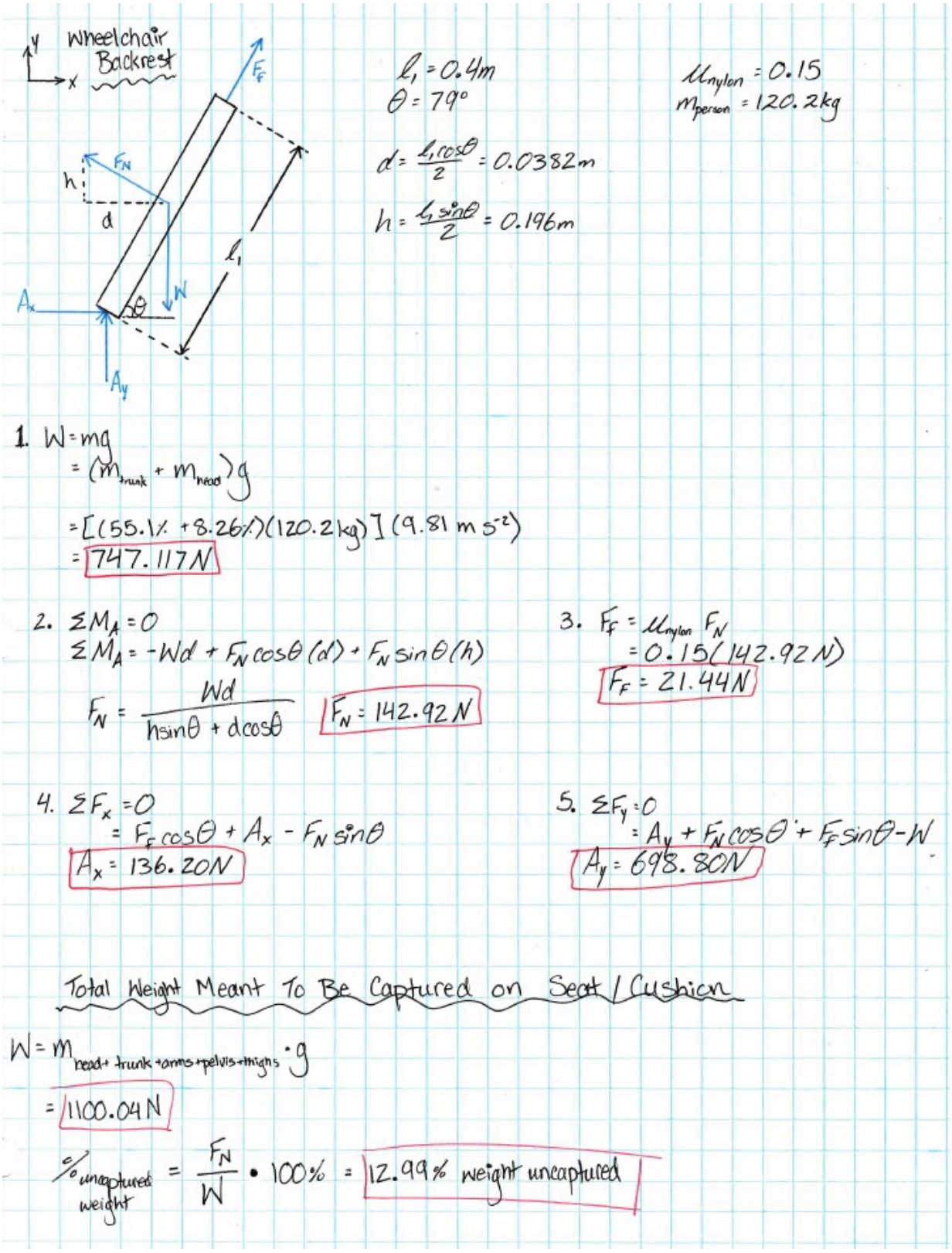

Figure A2: Engineering analysis of the wheelchair backrest and percentage of uncaptured weight by the cushion [8] [18][19].

Engineering Analysis 2:

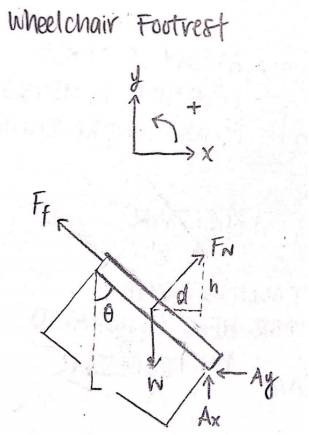

Figure A3: Free body diagram of footrest.

Table 1A: Calculations of given values for engineering analysis on the footrest [8][10][19].

Total weight of shank and foot	Distance (d) from F_N to A	Distance (h) from F_N to A	Force of Friction
$W = 2(m_{shank} + m_{foot})g$ $= 2((120.2*0.0475) +(120.2*0.0143))*9.81$ $= 145.7N$	$d = (L*\sin70°)\ 2$ $= (0.3048*\sin70°)/2$ $= 0.1432m$	$h = (L*\cos70°)/2$ $= (0.3048*\cos70°)/2$ $= 0.05212m$	$F_f = \mu_{Polyester}F_N$ $= (0.80)F_N$

Table 2A: Equilibrium equations and calculations of engineering analysis on the footrest.

Normal force if front frame angle is 70° from seat	Normal force if front frame angle is 90° from seat
$\Sigma F_x = 0$ $= A_x + F_N\cos70° – F_f\sin70°$ $= A_x + F_N\cos70° – 0.8F_N\sin70°$ $\Sigma F_y = 0$ $= A_y + F_N\sin70° – W + F_f\cos70°$ $= A_y + F_N\sin70° – W + (0.8)F_N\cos70°$ $\Sigma M_A = 0$ $= Wd – F_N\sin70°(d) - F_N\cos70°(h)$ $= (145.7*0.1432) - F_N\sin70°*0.1432 - F_N\cos70°*0.05212$ **$F_N = 136.9N$, $A_y = -20.40N$, $A_x = 56.09N$**	$\Sigma F = F_N – W$ $F_N = W$ **$F_N = 145.7N$**

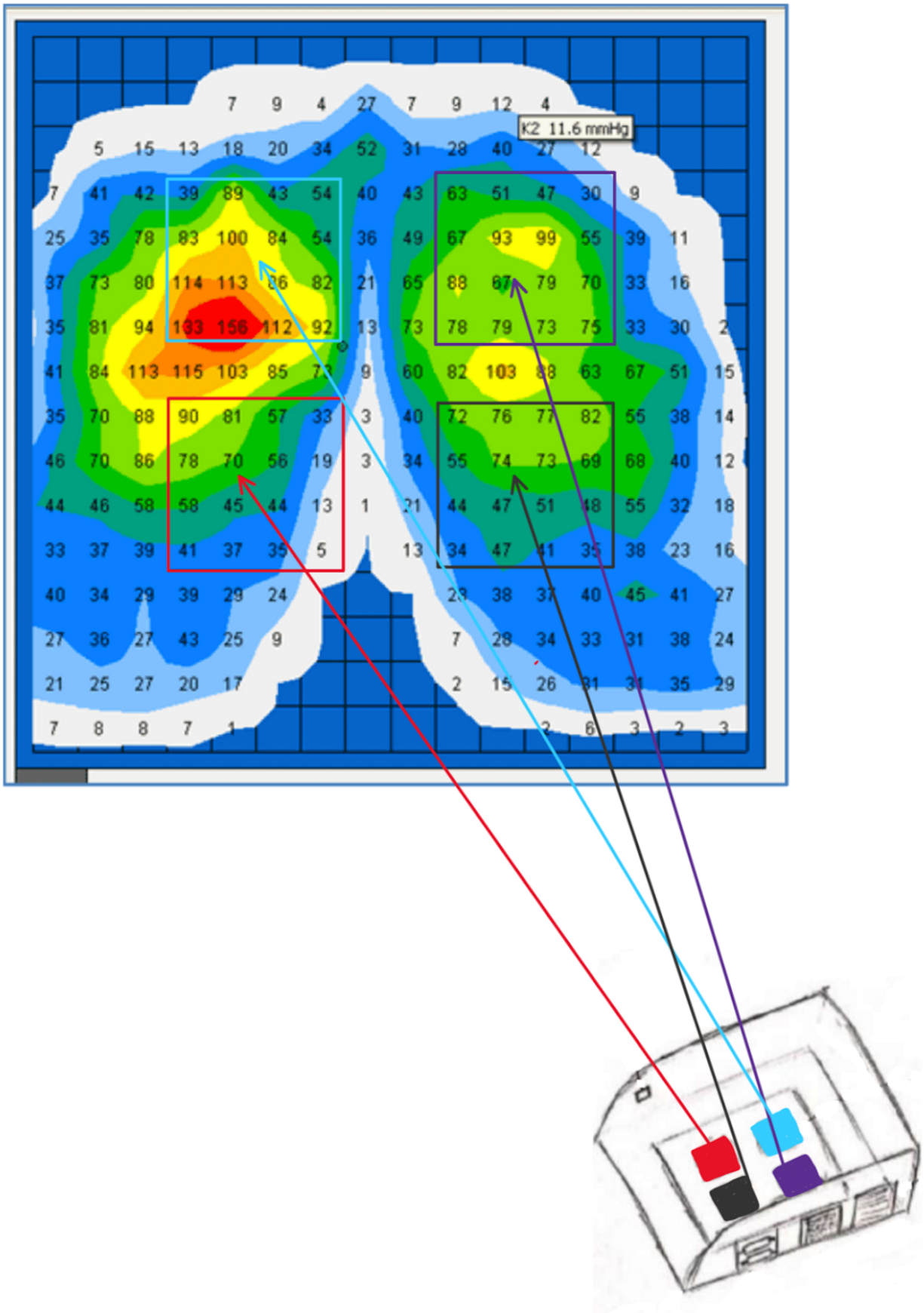

Figure A4: Pressure map and location of sensors relative to the pressure map [13].

Full List of Assumptions:

- The total weight of the feet and shank are meant to be captured by the foot cushion scales
- The total weight of the thighs, trunk, pelvis, head, neck, and arms are meant to be captured by the seat cushion
- The height of the backrest is the average height of offered backrests lengths
- The width of the footrest is the average width of offered footrest widths
- The mass of the user is the maximum mass that the wheelchair can handle; therefore neglecting the mass of the scale and other wheelchair accessories that may be present
- The backrest material is nylon with $\mu = 0.15$
- Both cushions are encased with polyester with $\mu = 0.8$
- Point A is treated as a pin joint
- The total weight force acting on the backrest is comprised of the head, neck, and trunk mass, and treated as a point force, rather than as a distributed force
- The normal force is assumed to be acting on the backrest as a point force at the center of the backrest height, rather than as a distributed force
- The weight of the backrest is negligible
- The weight of the footrest is negligible
- The seat of the chair is parallel to the ground
- The force of friction has a line of action passing through point A
- The user is male

Table 3A: Table to be used to collect data during testing for requirement 2:

Sensor Position	**Trial #**	**Force Reading (N)**	**Observations**
Centre	1		
	2		
	3		
	4		
	5		
Front Centre	1		
	2		
	3		
	4		
	5		
Left Centre	1		
	2		
	3		
	4		
	5		

Right Centre	1		
	2		
	3		
	4		
	5		
Back Centre	1		
	2		
	3		
	4		
	5		
Front Left Corner	1		
	2		
	3		
	4		
	5		
Front Right Corner	1		
	2		
	3		
	4		
	5		
Back Left Corner	1		
	2		
	3		
	4		
	5		
Back Right Corner	1		
	2		
	3		
	4		
	5		

Final observations	

Questionnaire for Testing Requirement 1:

User Experience Questionnaire:

1. Location of Spinal Cord Injury: _____

2. Can you use this product independently in your home?
   - ❑ Yes
   - ❑ Somewhat
   - ❑ No

3. If answered 'Somewhat' or 'No', who could/does assist you and where?
   - ❑ The regular health professional I see (ie. family doctor) in a medical environment
   - ❑ The caregiver that sees me in my home
   - ❑ Someone (relative/friend) who lives with me in my home
   - ❑ Other: (please specify) _____

4. How long did the product (device and app) take you to **set up** for the first time?
   - ❑ < 1 minutes
   - ❑ < 2 minutes
   - ❑ < 5 minutes
   - ❑ < 10 minutes
   - ❑ > 10 minutes (please specify time in minutes) _____

5. On average, how long does the product take to use each time (ignore set-up time)?
   - ❑ < 1 minutes
   - ❑ < 2 minutes
   - ❑ < 5 minutes
   - ❑ < 10 minutes
   - ❑ > 10 minutes (please specify time in minutes) _____

6. How often would you use this product (ie. measure and check your weight)?
   - ❑ Multiple times a day
   - ❑ Once a day
   - ❑ Once a week
   - ❑ Bi-weekly (every two weeks)
   - ❑ I would never use the product again
   - ❑ Other: (please specify) _____

7. Rate your ease of navigating the mobile application?

Terrible (1) Neutral (5) Excellent (10)

○ ○ ○ ○ ○ ○ ○ ○ ○ ○

8. What feature do you navigate to most often on the mobile application?
   - ❑ Current Weight and BMI Viewer

- ❑ Logbook Overview (Graphical Representation)
- ❑ Logbook Detailed View (Date/time of reading, weight from respective scales and total weight)
- ❑ Medical Professional Inputted Details

9. How would you rate the physical comfort of the product?

Terrible (1) Neutral (5) Excellent (10)

○ ○ ○ ○ ○ ○ ○ ○ ○ ○

10. Select any pressure points/areas of discomfort you had from using the product.
    - ❑ Upper Back
    - ❑ Lower Back
    - ❑ Arms
    - ❑ Buttocks
    - ❑ Tailbone
    - ❑ Hips
    - ❑ Pelvis
    - ❑ Thighs
    - ❑ Shank
    - ❑ Feet
    - ❑ Other (please specify location) _____

11. How would you rate the ease of use of the product?

Terrible (1) Neutral (5) Excellent (10)

○ ○ ○ ○ ○ ○ ○ ○ ○ ○

12. How would you rate your overall satisfaction with the product?

Terrible (1) Neutral (5) Excellent (10)

○ ○ ○ ○ ○ ○ ○ ○ ○ ○

13. How likely are you to recommend this product to another wheelchair-bound individual?

Very Unlikely (1) Neutral (5) Very Likely (10)

○ ○ ○ ○ ○ ○ ○ ○ ○ ○

14. Please provide any other feedback or concerns you have on the product:

_____

_____

_____

Thank you.