The design brief “Personal Rain Protection Device” challenges the design team to minimize the negative effects of rain with a portable device. First, the design team assessed the brief, reframed it to ensure divergent conceptual designs and defined a complete set of metrics. Second, four conceptual designs were developed, assessed in relation to the metrics and compared them to each other. As a result of this comparison, a preferred conceptual design was chosen.

The brief clearly identified the challenges caused by rain and outlined a list of desired improvements on existing solutions. Although relatively concise, it may be improved upon in how it addresses existing solutions, identifies stakeholders, prioritizes objectives and includes certain constraints and criteria.

A. Existing solutions

While clearly outlining the flaws of the basic umbrella and raincoat design, it does not fully recognize existing improvements. For example, umbrellas have been designed to be wind-resistant with air flaps and unique shapes and to be hands free, such as the Brella bag. Likewise, many new raincoats have stiff visors to protect one’s face from the rain, draw strings in the hood in case of strong winds and ample room to wear several layers of warm clothing underneath.

The existing solutions were identified to recognize where the basic designs had already been improved and for the design team to understand the focus of the improvements.

B. Problem Statement

The wording “prevents the negative effects of rain” calls for a solution to solve several rather than one problem and restricts compromises between the primary function of a device and considerations such as portability and cost. Changing the word “prevents” to “minimizes”, the problem statement now allows the design team to optimize primary objectives with secondary ones. Furthermore, this change allows the design team to focus on one or several negative effects of rain to create a more divergent design space.

The problem statement identifies the user as the primary stakeholder, but does not specify whether the device is intended for those biking or on foot and whether they are outside briefly or if they are outdoor workers. To address this concern, the user is defined as an individual who is temporarily exposed to the rain for less than 30 minutes one or more times a day in order to travel by foot or bicycle. The list of stakeholders will be expanded to other pedestrians, the design team and the manufacturer, which were considered in the design stage, but will not necessarily be focused on in this report.
C. Objectives

A clear list of objectives is given in the design brief, but the prioritization is unclear and the first objective narrows the design space significantly. By specifying the need to protect the user from the rain rather than the problem statement’s “prevent the negative effects of rain”, the objective decreases the size of the design space. Furthermore, without a clear prioritization, it is unclear whether the brief is aiming to improve storage, wind resistance and overall rain protection or if one is more important. To address this concern, the objectives were ordered from the highest priority to the lowest. Furthermore, the first objective is divided into four divergent objectives for different negative effects of the rain. They are as follows:

1) One or more of:
   - **Design for protection: Minimize contact between rainfall and a user’s skin and clothing**
     The objective aims to come up with a novel rain protection device or improvements on existing for personal protection.
   - **Design for Protection: Minimize contact between rainfall and a user’s personal belongings**
     This objective considers solutions that will protect a user’s belongings from water damage due to rain.
   - **Design for storage: Ease of rain gear storage after use**
     Opens up the design space to secondary solutions whose primary purpose is not improving rain protection, but to address storage issues of rain gear.
   - **Design for versatility: Improved rain protection while using a bicycle as a means of transportation**
     This objective is aimed at solutions that would not necessarily apply to a user on foot.

2) **Design for comfort: Be hands free during exposure to rain**
   Any protection from the rain cannot require hand use while the user is exposed to the rain. This is the primary problem of a traditional umbrella. During rain exposure is specified because even raincoats require your hands while putting them on and taking them off.

3) **Design for portability: Portable when not in use**
   Although many exist, solutions that decrease size and increase the convenience of carrying will be considered.

4) **Design for weather extremes: Remain effective in high speed winds**
   For a typical commuter in Toronto, wind is a common occurrence especially around large buildings¹, however, it a relatively low priority for design considerations because many existing raincoats and umbrellas already address this problem.

D. Constraints and Criteria

A number of the constraints and objectives are difficult to interpret in the context of the problem statement. For example, the temperature constraint includes a range with snow, which is not within the problem statement. It will be interpreted instead by how well the device allows the user to wear a range of clothing. Also, the reference to the Health Canada guidelines is vague and does not include a formal citation. Nonetheless, specific safety considerations will be left to the detailed design team. Finally, many of the tests specified in the criteria are relevant for designing a new raincoat material, which is outside the scope of this design course and will therefore not be focused on.

¹ Toronto has a humid continental climate.
The constraints and criteria were reviewed and combined into a list of metrics for evaluating a design. To ensure the design space includes a divergent set of objectives, specific and general metrics were created. The metrics are grouped under a parallel set of headings to the objectives with a few changes. Durability was added as a general criteria because the original design brief had emphasized it.

If designed to ... it should:

- **Minimize contact between rainfall and a user’s skin and clothing**
  - Decrease the body’s exposure to rain
    (Metric: Surface area not covered by rain gear, where less is better)
  - Decrease the face’s exposure to rain
    (Metric: Increased weight of a cloth stretched 1 inch behind hood opening during a 20 minute exposure period where less is better)
  - Decrease water absorption by clothing
    (Metric: The increase in weight of clothing after a 20 minute exposure period to rain where less is better)
  - Allow the user to wear a range of clothing
    (Metric: Volume of free space within the protected area)
  - Be comfortable in terms of breathability and weight
    (Metric: the amount of moisture build up on user, where less is better the weight of the device, where less is better)

- **Minimize contact between rainfall and a user’s personal belongings**
  - Decrease water absorption by personal belongings
    (Metric: The increase in weight of personal belongings after a 20 minute exposure period to rain where less is better)

- **Ease of rain gear storage after use**
  - Decrease water left on rain gear after use
    (Metric: additional weight of coat due to water where less is better)
  - Decrease seepage and dripping from stored rain gear
    (Metric: volume of water dripped in 20 minutes where less is better)
  - Be fast to use

All designs aim to:

- **Be portable when not in use**
  (Metrics: dry weight of the device, after use weight of the device, size of the device, longest axis of the device where less is better in all categories)

- **Be hands free**
  (Metric: hands needed or not, where none is better)

- **Be durable**
  (Metric: amount of uses before replacement is required, where more is better)

- **Not hinder the user’s normal movement while exposed to rain**
  (Metric: time to move around a given object, such as a doorway or street sign, with the device compared to without, where less is better)

- **Remain effective in high speed winds**
  (Metric: the wind tunnel test, where a higher wind speed endured is better²)

**IV. Conceptual Design Solutions**

Four conceptual designs will be presented in this section. For each design, its motivation will be stated, its physical structure and function described, its unique advantages outlined and its possible problems identified.
IV. A. The Pull Dry

Design Motivation:
The Pull Dry aims to minimize the difficulty of storing wet rain gear after use. Despite countless existing raincoat and umbrella designs, there is little innovation in how to handle wet gear when you come in out of the rain. Wet rain gear can take a long time to dry and the dripping water can damage other belongings, for example a wet coat stored in a book bag can damage electronics. The pull dry increases a user’s personal efficiency by decreasing the time it takes to store rain gear and preventing damage to personal belongings.

Structure and Function:
The Pull Dry offers a cheap, fast and efficient method to dry a raincoat or umbrella. A wet coat or umbrella is pulled through a circular plastic frame approximately 20 cm across. Pointing inwards from the frame are two offset layers of rubber flaps that “squeegee the water off the coats surface. They act in a similar way to the straw hole in the lid of a fast food pop squeezing most of the pop off as you pull the straw out. They are offset so a flap will be above the split in the flaps of the first layer. Two inches across of space is left open in the middle of the circle to allow the coat to be grabbed and pulled through. Above the rubber layer is a thick-er layer of absorbent sponge material. A thin wire strap running along the inner surface of this sponge can be pulled to squeeze the sponge against the frame, removing the water.

To use the device, a rain coat is draw through the circle, entering on the side of the rubber flaps. As it pulls through, the flaps brush and squeeze off the majority of the water. As the coat passes past the flaps, the sponge material absorbs the remaining moisture. Once the coat is drawn through, the strap is pulled from the side of the frame, squeezing the absorbed water out of the sponge.

Advantages
This solution is an improvement to existing rain gear storage techniques where they stay wet until air dried. It is small and portable within a backpack and dries itself off after use.

Possible Problems:
Three central problems will need to be addressed in this design. First, it may get caught on the coat’s pockets and zippers. Second, folds in the coat may leave portions of the coat still wet. Third, the sponge material would have to be designed for reuse as replacement could be difficult.

Additional Notes:
The solution focuses entirely on increasing the ease of storage of rain gear rather than designing a new rain protection device. Although not meeting the original design brief’s first objective, it was included primarily for its divergence from other designs. With this in mind, it can only be judged based on how much easier it makes rain gear to store, its portability, durability and speed of use.
**Design Motivation:**

The Strollbrella protects a user and his or her personal belongings against the rain. Raincoat hoods may be uncomfortable, flatten hair and the coat does not protect a backpack; an umbrella fixes these problems, but must be held. The solution protects a user’s head, backpack and shoulders from the rain. This increases personal efficiency because both hands remain free during use, it allows a user to remain presentable and it prevents damage to personal belongings.

**Structure and Function:**

The canopy of the Strollbrella resembles the roof of a convertible: it unfurls from the base of a user’s bag up and over the head. The pivot point of the canopy is attached to both sides of the straps of the bag. When not in use, it hangs as a U-shaped bar, which allows full access to the bag's top and side compartments (Figure B.2.b,c).

The canopy is supported by a series of thin hollow rods or ribs made of aluminum alloy to provide rigidity, be lightweight and prevent corrosion. In the event of high speed winds, the ribs are able to sustain maximum wind gust of 50km/hr. The canopy has downward angled air vents that prevent gusts of wind from throwing the user back. The rods rest closely together when the canopy is stored by securing them with a strap.

The canopy will be made of a thin layer of breathable, waterproof material, for example one of the materials described by the European Patent Application No. 89301438.1.

**Advantages of the design:**

The Strollbrella combines the hand free convenience of a raincoat with the overhead user and bag protection of an umbrella. First, two hands are available compared to one with an umbrella. Second, it offers a higher level of protection for personal belongings, such as a laptop, inside a backpack than an umbrella.

**Possible Problems:**

This product only covers the user’s head and backpack hence a shortcoming of this design would be that it does not provide complete protection from the rain for the rest of the body. The user may have to wear a raincoat in conjunction with this device to ensure that parts of the arms do not get wet.
**IV.C. Rain Belt**

**Design Motivation:**
The device is an alternative to carrying around a traditional raincoat as a precaution against possible rain. It is aimed at users who would be going somewhere, such as a restaurant or bar, but do not intend on carrying a rain coat or for users who want a lightweight option while travelling. It increases personal efficiency by making it more convenient to carry a raincoat in case of rain, removing the need to carry a backpack if the coat isn’t be worn.

![Image of Rain Belt](image)

Figure B.2. This diagram displays the folded up raincoat in the form of a belt. One end will be slipped through the buckle end in order to secure the belt.

**Structure and Function:**
The rain belt is a disposable rain poncho worn as a belt around the waist. It protects the head, body and clothing from becoming wet. It is thin enough to be worn under a traditional belt, but can be designed in different colors and patterns for aesthetic purposes. The dimensions are shown in Figure B.2. Once folded 6 times, one time for the arms, it is approximately 3 cm in height to fit most belt loops. The poncho raincoat is folded and attached to a buckle so that it acts like a belt. When rain-ing, a user would remove the belt, tear the buckle off, unfold it and wear it. It is designed for one use as an emergency measure.

**Advantages:**
The device is advantageous because it incorporates the existing advantages of disposable rain ponchos while making it more convenient to carry. First, existing disposable ponchos are lightweight, very cheap and can be made out of biodegradable materials, such as Bio-Ponchos seen in Figure B.3. Modified polyethylene is an example of a material that does this. Second, folding it into a belt provides a bag-free and hands-free method to carry it. Third, a rain poncho’s bulky design would allow full backpacks and other bags to be worn underneath it.

**Possible Problems:**
It may take more time to unfold and put on than a regular raincoat.

If one is using the rain belt to hold one’s pants up, one will have to hold them up by hand in case of rain.
The Rain Vest aims to maximize the benefits of a raincoat and rain pants while storing them conveniently in the form of a vest. It is designed to offer partial or full body protection for a pedestrian or a cyclist.

**Structure and Function:**

The rain vest is a traditional vest with roll-up sleeves, pant legs, and hood that are concealed at the arm openings, the base, and the collar of the vest. These additional parts are made up of a thin, light, and waterproof synthetic material.

In case of rain, the sleeve pocket is unzipped and the sleeves rolled down to the wrist. Elastic drawstrings at the cuffs of the sleeves secure them in place against high winds. The circular arm opening pocket has a waterproof material between it and the skin, but a breathable material facing outwards, allowing some evaporation of the sleeves if stored wet.

Similar to the sleeve pocket, there is a semicircular pocket placed on either side of the base of the vest. This stores the rolled-up pant leg, which is a rectangular section of waterproof fabric that wraps around the leg, leaving the inseam open. Velcro straps at the upper thigh, knees, and ankles secure the partial pant leg in place. This open design allows full motion and the straps prevent the fabric from blowing in the wind.

The hood pulls out of a hidden pocket in the collar of the vest. It has an elastic drawstring to hold it in place in case of wind.

Pockets will be added to this design to provide protection to personal belongings.

**Advantages:**

First, the key advantage of the design of the rain vest is the full body rain protection it provides while decreasing the size of the raincoat when not in use. Second, it allows the user the option of only using the hood and arms in case of light rainfall. Third, the vest can be worn in a variety of temperatures and it has space for a sweater or hoodie to be worn underneath. Fourth, it addresses the problem of wet legs for bikers.

**Possible Problems:**

The product may be difficult to fold up after use because of the time to dry and roll up the arms, legs, and hood. However, drying the coat would be no more difficult than drying a regular raincoat by leaving it hung up.

The inseams of the user’s pants may not be fully covered, leaving some clothing exposed.
The four conceptual designs will be judged using a Weighted Decision Matrix table. Listed in this table are the metrics previously discussed, each of those paralleling a main objective includes a sublist of corresponding criteria and metrics. The four designs are judged based upon how well the design team believes the device would do on the metric tests. Without a developed prototype, these metrics cannot be checked quantitatively. The average of their rankings (from ‘0’ being inadequate to ‘4’ being excellent) will then be averaged for the score of their relevant objective. Lastly, the total score of each of the designs will be calculated by summing the weighted scores of each objectives. The metric for hands-free usage was not included in this table because all designs satisfy being hands-free during rain exposure.

Weighting:
The weighting was mostly decided by the significance attributed to each reframed objective in the original design brief:

- The objective for user protection was given a 0.3 weighting because it was the first objective of the original design brief, whereas the improved rain protection for a user on a bicycle was only weighted at 0.05 because it was added during reframing by the conceptual design team. Although, it could be argued that the bicycle objective should be removed at such a low weighting, the design team has chosen to include it based the unique user perspective it provides and its emphasis on versatility.
- Ease of rain gear storage after use was weighted at 0.2 above portability at 0.1 because the design team believes there has been less innovation with wet storage after use than portability.
- Protection of personal belongings was weighted at 0.1 because it was an objective extended from the personal protection in the original design brief and it was a negative effect clearly identified by the design team.
- The effectiveness in high speed winds was only weighted at 0.05 because many solutions have already been found for this problem. Also the design team did not take it as a high priority because of its solutions tend to be minor improvements to existing designs.
- Durability was weighted at 0.1 because it was included in the criteria of the design brief. It is an important factor because raingear is constantly subjected to windy and wet conditions.

- Ease of movement was also weighted at 0.1 because it was well defined by the design brief and is an important consideration on crowded sidewalks.

Important Factors for Consideration:
- The Pull Dry design only satisfied one of the primary objectives: the ease of storage after use. It was not considered for rain protection of personal belongings because it does not prevent rain damage during exposure to the rain. Consequently, it will not be considered for the proposed prototype because it only partially addresses the original design brief.
- The Rain Vest was considered for how it protects personal belongings because it could include pockets.
- The Rain Belt was not considered for ease of storage after use because it is for one-use only.
- The Rain Belt was not considered for cyclists because a large loose poncho could endanger a cyclist in winds and could catch on gearing. The new hazard this presents indicates it is not an appropriate design for this objective.
<table>
<thead>
<tr>
<th>Metrics</th>
<th>Weight</th>
<th>Pull Dry</th>
<th>Stroll-brella</th>
<th>Rain Belt</th>
<th>Rain Vest</th>
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</thead>
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<tr>
<td>Minimize contact between rainfall and a user’s skin and clothing</td>
<td>0.3</td>
<td>0</td>
<td>2.2</td>
<td>3.2</td>
<td>3.2</td>
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<tr>
<td>(Average Score)</td>
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<tr>
<td>Decrease the body’s exposure to rain</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>(Metric: Surface area not covered by rain gear, where less is better)</td>
<td></td>
<td></td>
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<tr>
<td>Decrease water absorption by clothing</td>
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<td>1</td>
<td>3</td>
<td>3</td>
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<tr>
<td>(Metric: The increase in weight of clothing after a 20 minute exposure</td>
<td></td>
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<tr>
<td>period to rain where less is better</td>
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<tr>
<td>Allow the user to wear a range of clothing</td>
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<td>4</td>
<td>4</td>
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<td>(Metric: the amount of moisture build up on user, where less is better)</td>
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<td>Be comfortable in terms of weight</td>
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<td>4</td>
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<td>(Average Score)</td>
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<td>Decrease water absorption by personal belongings</td>
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<td>minute exposure period to rain where less is better)</td>
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<td>Ease of rain gear storage after use</td>
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<td>Decrease water left on rain gear after use</td>
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<td>1</td>
<td>0</td>
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<tr>
<td>(Metric: additional weight of coat due to water where less is better)</td>
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<tr>
<td>Decrease seepage and dripping from stored rain gear</td>
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<td>3</td>
<td>1</td>
<td>0</td>
<td>1</td>
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<tr>
<td>(Metric: volume of water dripped in 20 minutes where less is better)</td>
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<tr>
<td>Be fast to use</td>
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<td>3</td>
<td>0</td>
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<tr>
<td>(Metric: average time it takes to put rain gear away where less is</td>
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<td>better)</td>
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<td>Improved rain protection while using a bicycle as a means of</td>
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<td>How little it hinders normal biking movement</td>
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<td>the device compared to without the device where more is better)</td>
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<td>Secondary Objectives</td>
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<td>Be portable when not in use</td>
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<td>(Metrics: dry weight of the device, after use weight of the device,</td>
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<td>all categories)</td>
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<td>Be durable</td>
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<td>better)</td>
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<td>street sign, with the device compared to without, where less is better)</td>
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<td>Remain effective in high speed winds</td>
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<td>(Metric: Wind tunnel testing’)</td>
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<td>Total</td>
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</table>

*All rankings are based on the expected metrics performance of the devices based on the personal judgement of the design team. Rankings: 0: Inadequate/Inapplicable 1:Weak 2:Satisfactory 3:Good 4: Excellent
V.I. Candidate Solution

The metric table ranked the conceptual designs based on the weighted metrics. The Rain Vest at 2.90 was the highest rank and the Strollbrella ranked second with a lower score of 2.35.

Beyond the large ranking difference between the Rain Vest and other solutions, the Rain Vest was chosen as the preferred design solution for three reasons. First, the Rain Vest increases the portability of a raincoat while extending its body coverage. Second, it can be worn casually as a regular rain coat in light rain, as full body coverage in heavier rain or on a bicycle. Third, when there is no rain, it can be worn as a light vest, increasing its portability. The basic vest can be designed for a variety of weather conditions and looks to appeal to a variety of users.

Regardless of the metric rankings, the Rain Vest is the solution that addresses the design brief’s problem and objectives the most holistically.

V.II. Conclusion

The conceptual design process resulted in several divergent solutions, but the Rain Vest addressed the original problem statement the most directly.

Despite not being chosen as the candidate solution, the other conceptual designs took unique approaches to the problem statement and have their own merits. The Strollbrella addresses the problem of flattened hair and protects personal belongings. The Rain Belt increases the convenience of disposable ponchos, expanding their market beyond campers and travelers. The Pull Dry is an example of a divergent solution addressing a specific problem with few existing solutions. Nonetheless, the design team recognized the importance of addressing the specific objectives of the design brief, therefore the Rain Vest was chosen.

VIII. References


Research of existing products


