GNG 1103: Deliverable I

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1. Introduction

Our client, Sandra Cocea, set out a task for our team to create an economical bed frame for domestic violence victims who need a temporary place to live while the government finds a more permanent solution. Our team was instructed to create the bed frame out of cardboard and we were limited to a budget of 100 dollars. Our team was instructed that the bed frame has to hold a minimum of 250 pounds. This deliverable highlights the design process our team went through to finish our final product, the design criteria of our bed frame, and issues we had to deal with to create a desirable product and feedback given by our client.

2. Problem Statement

To provide the domestic violence victims in the city of Ottawa a safe place to sleep, a bed frame that can hold at least 250 pounds, be easily compacted, transported and set up, while being made entirely out of cardboard needs to be made.

3. Our Solution

The final iteration of our solution consists of four legs and a series of slats that lay across them. The legs have a square base and the tops of them are corrugated in one direction. A 'box' is inserted inside each leg to increase their rigidity. The four legs are split into two pairs, with each pair consisting of a larger 'outside' leg and a smaller 'inside' leg which can be nested inside the larger one. The top slats are bent into an 'A' shape to fit over the corrugated parts of the legs. The slats are also paired, with a longer slat that covers slightly less than three-quarters of the bed length and a shorter slat that covers one half of the bed length, overlapping slightly. To compact the bed for storage or transport, the legs. Our bed frame features a water-resistant coating on the lower half of the legs.

4. Design Process

4.1 Stage One

The first step in our design process was to meet with the client and extract as much pertinent information as possible, such as the client's needs. From there we developed our problem statement and a list of prioritized criteria. At this stage we also brainstormed design ideas and selected a single design for the first prototype, which we presented at the second client meeting where we received feedback.

4.1.1 First Client Meeting

Our first meeting with the client took place during class, with all design teams present. We took notes on the important points of her presentation and asked questions to clarify on specific points. By the end of the meeting we learned that she wanted a bed frame with the following features: made entirely of cardboard, the size of a single mattress, capable of supporting one adult, can be folded or made smaller for ease of transport, costs less than \$100.

4.1.2 Problem Statement and Design Criteria

Based off the client's needs we obtained from the first meeting, we formulated a list of criterion for the bed frame. We then refined the list to create a list of prioritized criterion.

Design Criteria (In Ranked Order from Greatest to Least):

- 1. To be able to support a 250 pound full grown adult without issue
- 2. It needs to be stable enough to not rock or fall apart when in use
- 3. It should be foldable or break down for easy transport
- 4. It should support the bed at least 60cm off the ground
- 5. It should be durable against liquid spills

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4.1.3 Ideation

Our ideation process began with a group brainstorming session. The whole team sat around a table together and went over the problem statement and design criteria to ensure everyone understood the project. We then spent several hours discussing ideas and doing research as a group, developing a better understanding of different design ideas. After the group session we broke off to work individually for several days. Are We reconvened to compare ideas, eliminating duplicates, and compiled them into a single document.



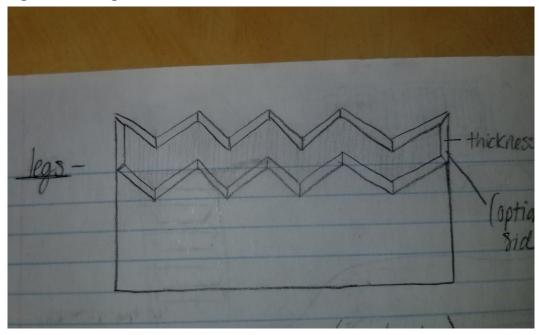


Figure 2. Design Idea 1

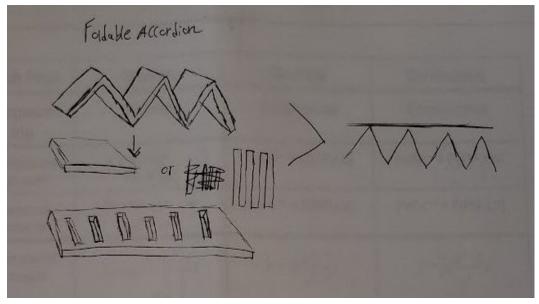
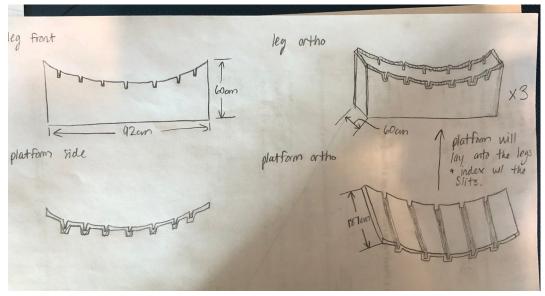


Figure 3. Design Idea 11



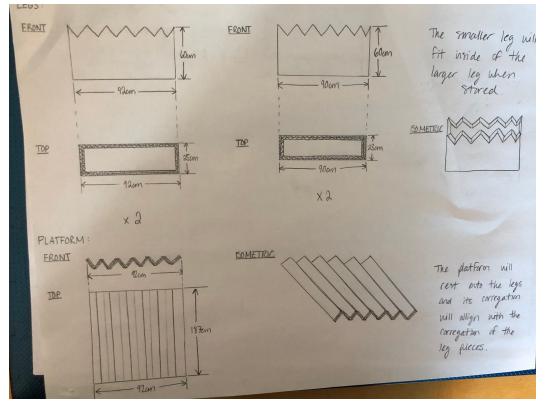
4.1.4 Idea Selection

We started this process by comparing each of our potential solutions to our established design metrics, setting out how well each idea satisfied them. We also benchmarked current products from the market against the same metrics and criteria. We took the most promising design solutions and the best products from the market, and put all of them in a decision matrix (**Table 1**). From this we determined our top three designs, which beat out the currently available products. We decided that the winning designs could be improved upon however. Thus we worked as a team to take characteristics from each of the top-three designs and combine them into a single better solution. This was the solution we eventually moved forward with.

Design Criteria (weighting)	ldea 7	ldea 1	Idea 11
Strength (5)	<mark>2</mark>	1	3
Longevity (3)	<mark>2</mark>	1	2
Compactness Ratio (3)	2	<mark>3</mark>	1
Dimensions (3)	2	2	2
Ease of Assembly (3)	3	2	1
Stability(5)	3	1	3
Cost(2)	1	<mark>3</mark>	1
Score	54	40	50

Table 1. Decision Matrix with Top 3 Design Ideas

Figure 4. Final Design Solution



4.1.5 Prototype One

The first prototype was a scale model produced from PLA on the 3D-printers in the makerlab. We produced a 3D-model of our best design solution using Solidworks. This was the first time anyone in our team had used CAD software before so it presented several challenges. It took a large amount of time to learn the basics of using it, and we were very slow in creating simple models, which significantly delayed the first prototype. After we had our models we used Cura to prepare them for 3D-printing. This was where we hit another delay, someone cancelled our first print partway through, wasting eight hours of work. On our second attempt we succeeded in printing an 8% scale model of the legs, the slats unfortunately failed. We did not manage to get a successful print of the slats in time for our next client meeting and were forced to go with just the Solidworks models.

4.1.6 Second Client Meeting

The client seemed to approve of our first prototype, the client cleared up some factors that could be ignored and suggested that we include something to prevent the mattress from sliding off. The client also questioned how we planned to waterproof the bed frame in order to improve the longevity of the product, to which we provided her with our two options: applying a coat of wax or a waterproof spray, which was the cheaper option. We cleared up that although the client valued longevity of the bed, given the tight budget, she was fine if we went with the cheaper waterproofing option.

4.1.7 Issues / Lessons Learned / Next Steps

An issue with the design was that we had neglected how the frame would prevent the mattress from sliding off. We acknowledged the importance of this feature and decided to take this aspect into account moving forward.

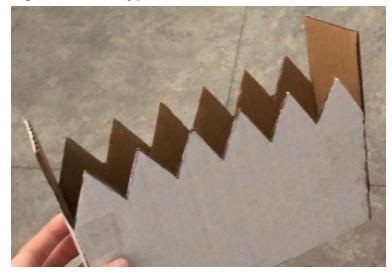
4.2 Stage Two

The second step in our design process was to use the feedback from the first prototype in order to improve upon our initial design. Using these improvements we created our second prototype design, and brought them to life with the program Solidworks, to be presented to the client at the third client meeting.

4.2.1 Prototype Two

From the second prototype we made an adjustment to add raised sides for the larger set of legs. On the full size model we designed to have this raised side be an additional 10cm. Our second prototype was made from scrap cardboard boxes and tape. It was approximately 1/8 scale, and allowed us to do some preliminary strength and stability testing.

Figure 5. Prototype 2



4.2.2 Client Feedback

Overall, the client and the supervisor were satisfied with the design and were extremely pleased with the strength our second prototype. A suggestion the client and the supervisor made was to include something to reinforce the legs as they were weak to torsional loads.

4.2.3 Issues / Lessons Learned / Next Steps

The physical prototype of the leg was strong, but we discovered that the legs were very weak to torsional forces. To stabilize the legs we decided we should add reinforcement within the legs near its base. We also realized that using a single sheet of cardboard as the top was not the most compactable design. Finding a cardboard sheet the size we needed would also be very difficult to find, not to mention very expensive if we were able to find a sheet of that size. We saw improvement in the design by using individual slats to be laid on the legs instead, which would solve all these issues.

4.3 Stage Three

For this final stage, using the design created in stage two, as well as the feedback that we received during the second client meeting, the final design and prototype was created.

4.3.1 Prototype Three

Design: We improved upon prototype two by adding the the design feature of having sheets with exact dimensions of the insides of the legs fit inside right at the base, followed by 10cm tabs that would be attached to the inside walls, then another sheet laid horizontally onto the tabs. We also changed the design to have individual slats instead of a single sheet. Due to the limitations of the dimensions of the cardboard sheets we ordered, we planned to have 10 slats that were 120cm long and 10 slats 80cm long, which would overlap.

Construction: Our group began with ten sheets of cardboard, each sheet was 4'x4'. To begin we sketched an outline the legs on the cardboard, with the longer sides having slots on both ends and the shorter sides having 5cm tabs. Once the sides of the legs were cut out, we slid in the tabs into the slots and used wood glue to glue the tabs down. Once the glue set, we reinforced the triangular parts of the larger panels by gluing the triangular cardboard cutouts to the inside edges of the triangles. To create the corrugated top of the bed, 22cm wide cardboard pieces of different lengths (120cm and 80cm) were cut out and partially sliced through down the middle to enable them to bend and fit on the pointed tops of the legs. To Reinforce the legs, sheets with exact dimensions of the insides of the legs were cut out and glued inside at the base, followed by 10cm tabs that were glued to the inside walls, then another sheet laid horizontally onto the tabs.

4.3.2 Client Feedback

The response to this prototype was quite positive, although, one suggestion was made to improve upon the design. The larger outside legs had longer vertical sides that would act as a fence to keep the mattress in place. However this side was only one sheet thick and were prone to bending if an outward pressure was applied.

4.3.3 Issues / Lessons Learned / Next Steps

In the construction phase of prototype three, we learned that we had underestimated how long it would take to layout and cut the parts of the bed frame. If we were to do it again we would be sure to plan out our process much better and be more efficient with our use of time. We also made a mistake in cutting two of the long sides of one of the smaller legs with the direction of the ridges running the wrong way. We originally did not think it would matter much, but it turned out to significantly weaken that side of the leg. An issue that was addressed was the raised sides of the bed frame, which was that they were prone to being bent. To make up for this weakness, another sheet of cardboard could be added to strengthen this side. The slats were also splitting down the middle. This was not an issue we realized until we tested the physical prototype. Moving forward we could use some type of hinge at the bends.

5. Conclusion

Our team provided an effective solution to the task set out by the client, Sandra Cocea. The bed frame we constructed satisfied the criteria that we defined. Through the process of multiple meetings, brainstorming sessions and thoughtful feedback, the bed continued to improve until the final design came to fruition. Overall, the client was very pleased with what we managed to build. A future change our team plans to make to the design of the bed frame are increasing the strength of side panels which helps to fence in the mattress, by adding another layer of cardboard onto it.