Product design and development of a reading aid for the visually impaired

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Abstract. One of the main hurdles for the blind are to read, easily and there by learn and graduate. Various researches are happening to reduce the effort required for the blind to read in terms of aids which can speak out the written data. The current research targets to design and fabricate a reading aid for the visually impaired. This device will help them to identify the text written in any book or page by scanning the text and speaking it out to them with the help of a mobile application called KNFB reader which helps to read anything to blind or dyslexic people. This project utilizes the fact that majority of the people use smartphones, which can be used for the advantage of the blind people. Based on a survey conducted among the blind people with the help of an NGO Anuprayas all the criteria for the design of reading aid, in the current project were selected. Four sample designs were prepared after taking the criteria for reading aid into consideration. Forced Decision matrix (FD) analysis and Decision alternative ratio System (DARE) analysis, which are tools to rank the properties based on the priority, were conducted to identify the most influential parameter for the design. The parameters were ranked based on these analyses. The ergonomics, cost and durability were the most important properties desired in the product. This product can be deployed for the effective utilization by public at railway stations, bus stations, libraries etc. This will enable the blind to be self-independent and have the information available for them whenever they need it.

Keywords: Blindness, Reading aid, visually impaired, Forced Decision matrix method, Decision alternative ratio System

1. Introduction

According to WHO 2017 statistics, about 285 million people are visually impaired worldwide. Only 27 percentage of blind and partially sighted people of working age are in employment and 39 percentage of blind and partially sighted people of working age say they have some or great difficulty in making ends
meet according to the Royal National Institute Of Blind People. There are many more aids for visually impaired to help track their movements (Electronic travel aids), know about their surroundings (Position locator devices), read texts (Optical character reader) etc [1]. The need for a design that is flexible to compensate for changes in human condition is essential. Principles like affordability and emotional durability is important when it comes to designing an aid for the visually impaired [2]. The path of technological development is difficult to predict but they should be focused in making the tools more cost efficient, portable and light [3].

Consumer involvement during designing is an area that needs further research [4]. Further switching between sketching and CAD modeling had a huge impact during concept design and development of the tool [5]. There is a need to understand product design typicality in order to know about the market potentials of any tool [6]. Additive manufacturing gives an element of freedom when comes to designing and manufacturing over traditional methods [7]. Research done to help visually impaired goes in vain due to the aid being too expensive for the masses to use[8][9].The purpose of our study is to provide a solution to social problem faced by visually impaired.

2. Methodology
2.1. Criteria Identification
A survey was conducted among the visually challenged population to identify some of the most desirable properties for them in a reading aid. The aim of the project and the vision was explained to them and their inputs on the design were collected and a chart was made which contained all the identified parameters of the design.

2.2. Sample Design Creation
Several designs were made on CAD which can accommodate a book and phone in such a way that the phone can scan a whole page on the book.

2.3. Prioritization of Requirements
The parameters that were identified are prioritized using a scale in ascending order using the help of FD analysis and DARE analysis.

2.4. Selection of Design
The designs that were made are rated according to the prioritized parameters and the highest rated design is selected for optimization and modification.

![Flow Chart of the experimental procedure](Image)

Figure 1. Flow Chart of the experimental procedure
2.5. Modification and Optimization
The selected design is modified to make it more customer friendly and Design Study is conducted using the software to make the design lighter and stronger and also to make sure less material is used to manufacture it.

2.6. Fabrication of Model
The final optimized design is manufactures using 3D printing.

2.7. Customer Feedback
The fabricated model is put to test by the customers and the feedback is taken to consider modifications. In the end, after the complete process, the final model is obtained which meets the expectations of the customer and is also an optimized model.

2.8. Customer Survey
Customer surveys help in development of a product to an extreme extent as these products are made for these customers. From customer surveys one can understand the needs or requirements of the consumer. All the details are stored in Table-1 and these details are further used to analysis.

**Table 1**: List of required feature from the point of view of the customer

| No. | Requirement           | Description                                                                 |
|-----|-----------------------|-----------------------------------------------------------------------------|
| 1   | Setup                 | The amount of effort required for the initial assembly of the scanning tool should be minimal. |
| 2   | Cost                  | The amount at which the scanning aid will be available on the market should be affordable. |
| 3   | Weight                | The tool should be light in weight                                           |
| 4   | Size/Compactness      | The scanning aid should be portable                                          |
| 5   | Surface Quality       | The tool should have a good design aesthetically and should have a good finish |
| 6   | Durability            | The tool should be strong enough to withstand ill usage and shocks due to drops. |
7 Compatibility with Phones
The scanning aid should be able to accommodate different aspect ratios of different phones

8 Ergonomics
The tool should be comfortable to handle and should have good grip

3. Results and Discussion

3.1. Sample Design Creation
This design in model A as shown in Figure 2(a) consists of no moving parts and can be assembled like a puzzle.

![Figure 2](a) Model-A (b) Model-B

The book is placed on part-3 and the phone on part-1. Part-2 provides structural strength and also helps maintain a minimal distance from the book for the phone to focus and scan the book. This design satisfies durability criteria as well as cost effectiveness. However, since the movement is limited, thicker books can’t be focused on by the phone making it more suitable for single page scanning which gives this design a downside on ergonomics and flexibility. The model B shown in figure 2(b) is an upgraded version of Model-A. It includes moving parts and is foldable making it more portable. Part-3 and part-4 constitute an adjustable phone holder. Part-4 can be removed and inserted in several slots to change the size of the holder making it possible to accommodate bigger phones. The book to be scanned is placed on part-1. Part-1 folds into part-2 and can be carried around like a box. This design is cost effective and portable but less ergonomic than Model-A and also less durable as movable parts tend to have lesser life. The distance between the phone and the reading material still can’t be adjusted.
This model C as shown in figure 3(a) contains more parts and also moving parts than the other three models. The phone can be placed on part-3 and the height can be adjusted from the book to help focus thicker books. The book is placed on part-4 and the phone can be moved along x and y axes using rollers (part-5) and the phone holder can be locked in place using part-1. The design C is flexible and slightly less durable than models A and B. This model C is not portable and not very ergonomic as a visually impaired person will not be able to judge if the phone is focusing on the book or not. In the model D as shown in figure 3(b) there are several design changes that have been made keeping Model-C as the initial design. To increase the ergonomics, guide-rods (part-3) have been incorporated on the phone holder (part-2). This makes sure that the phone always maintains a fixed distance from the book to ensure clear focus. Slots have been made in side supports (part-1) to help the blind user to hold and move part-1 along the x-axis with the help of the linear guide bearings (part-5). The y-axis movement is made possible using linear bearings (part-5). The weight of the model is also less as optimization is done to remove unwanted material without compensating on safety. This model is flexible, cost effective, ergonomic and durable. There are only few things the model compensates on, and they are, size, portability and setup. The design of part-2 enables it to hold phones of almost any size.

3.2. Prioritization of the Customer Requirements

The Prioritization of customer requirements is done to determine relative importance of each feature. It is done in two stages:

3.2.1. FD Analysis. is used to determine the importance of the features. In this method, items are compared in pairs as in a league tournament. [8] Of the pair, the item having the higher value to the customer is given a rating of 1 and the other 0. When all the pairs have been compared, the total scores given to each of the items are summed in the total column. Priority is given to each item according to its total points, as shown in the column titled Ranking. Table 5 shows the FD analysis of the Scanning aid.

Inference of the aforementioned FD analysis suggests that ergonomics of the design has number one priority when compared with other qualities. Even though most of the customers prefer to put the quality of weight above ergonomics, the latter earned the highest rank as it is highly preferred over most of the other qualities.
Table 2: Forced Decision Matrix

| Function Description               | T | R |
|-----------------------------------|---|---|
| **Comparative Study**             | O | A |
| **T**                             | T | N |
| **A**                             | A | K |
| **L**                             | L | |

| | A | B | C | D | E | F | G | H | L |
|---|---|---|---|---|---|---|---|---|---|
| A | Setup       | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| B | Cost        | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 5 |
| C | Weight      | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 4 |
| D | Size/Compactness | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 4 |
| E | Surface quality | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 2 |
| F | Durability  | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 5 |
| G | Compatibility with phones | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| H | Ergonomics  | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 6 |

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3.2.2. DARE Analysis. is an abbreviation for Decision alternative ratio System. DARE is the method to quantify the degree of importance. Once the priorities have been determined by the FD method, it is relatively easy to compare the importance of two functions which are adjacent to each other in priority. Beginning with the item highest in priority ranking, it is determined how much more important that item is to the item that is directly below in priority ranking. The item lower in priority is given the factor 1, & the higher priority item, a number higher than 1 depending on how much more important it is to the function below it in ranking. From the DARE analysis, as shown in table 3, one can understand the importance of a quality over the quality positioned below it from the FD analysis conducted above.
Table 3: DARE Analysis

| Function Description | Comparative Scores | Score | Cumulative Weight | Weightage % |
|----------------------|--------------------|-------|-------------------|-------------|
| Ergonomics           | 1.2                | 1.2   | 12.71             | 23.94       |
| Cost                 | 1                  | 1.7   | 10.63             | 19.94       |
| Durability           | 1                  | 1.7   | 6.24              | 11.73       |
| Weight               | 1                  | 1.2   | 3.67              | 6.90        |
| Size                 | 1                  | 1.5   | 3.06              | 5.75        |
| Surface Quality      | 1                  | 1.2   | 2.04              | 3.84        |
| Setup                | 1                  | 1.7   | 1.7               | 3.20        |
| Compatibility with phones | 1            | 1     | 1                 | 1.88        |
| Total                |                    |       | 53.1              | 100         |

Total number of people surveyed was regarded as 100% and their individual answers were used to determine how important a quality is over the next one. The weightage of the qualities can now be used to decide which model can be selected for further modification and optimization.

3.3. Selection of Design
Model-D as shown in figure 4, satisfied most of the customer requirements. As per FD and DARE analysis Ergonomics and cost were main criteria that people looked for. The final design was not only relatively cheaper but also more ergonomic. Major advantage of this design is the phone holder which takes care of position of the camera and the guide rods make sure the required amount of distance is maintained between the surface to be scanned and the camera.
3.4. Modification and Optimization of Design

Changes were made to the initial design of the side supports by removing material in the load bearing elements and making them of a T-type cross section. A T-cross section beam exhibits qualities of good stiffness and low weight. Fillets were added to sharp corners to enhance the durability and cycle life. The changes in the design after design optimization are shown in the figure 5.

![Figure 4. Model-D](image)

![Figure 5.(a)Optimization of the model. (b)Optimization of the part.](image)

The modified design performed well in all the loading conditions with very small resultant displacement and stress values much below yield point. The applied load ranges between 30N to 40N per item. The modified design was found to be structurally resilient and able to survive the load applied.
Figure 6(a) and (b) shows the analysis of the parts which was done for optimization of the design. Since all the parts performed well under the application of load and the design optimization was achieved for all the components of the hearing aid. The part 2 and 3 design optimization and the analysis is shown in the figure 6.

![Figure 6](image)

**Figure 6.** (a) Optimization of the part 2. (b) Optimization of the part 3.

Figure 7 depicts the selected design after undergoing part level modification and analysis, an optimized model which is durable, can withstand major loading conditions, light in weight and has good stiffness properties was achieved without compensating on the ergonomics. This design satisfies all the criteria adapted for the design development process and was found to be most ergonomic.

![Figure 7](image)

**Figure 7.** Final Optimized Design.
3.5. Fabrication of the Product

In order to accommodate the side supports over the small print bed of the 3D Printer it had to be divided into two parts as shown in figure 9, which were later printed in PLA and joined together using stainless steel bolts. The Parts of the Phone holder were also 3D Printed in PLA. The parts were then saved and converted to STL file format for the subsequent fabrication of the product.

The components were then 3D printed with the PLA material and was assembled together to obtain a well performing device. The mobile phone was successfully held in the slot and with the KNFB reader the text was easily readable. The device worked efficiently and is expected to be of great service to the blind people in reading books and any texts they feel to read.

![Figure 8](image1)

Figure 8 (a) Final Optimized Part Model for Part 3 (b) Final Optimized Part model for Part 2

![Figure 9](image2)

Figure 9. (a) Final Optimized Part Model for Part 1 (view 1) (b) Final Optimized Part Model for Part 1(view2)
For the base a 3 mm plywood (500 mm×650mm) was used as its sturdy and reduces the cost. Linear bearings and guide ways were used to provide linear motion for the side supports (X-Direction) and the phone holder (Y-Direction). The Hearing aid for visually impaired was successfully designed and optimized. This optimized design was fabricated by fused deposition modeling and was successfully assembled. The product was found to be fully functional and was tested for its functionality. The KNFB reader app installed in the mobile phone captured the text and converted it into speech for the visually challenged person. The Minimum requirement for the Smartphone camera is 5 Mega pixel resolutions. The focal distance for most Smartphone is 22-28 cm which has been considered while designing the apparatus. The scanning methods available in the market are complex and most of the designs are similar to the Model-B of the paper; which has rotational DOF which the visually impaired may find difficult to operate. The current design is neither complex nor has unwanted DOF. Furthermore, the FD and DARE analysis helped the design to be catered to the people. The user-friendly design of the product and the cost effectiveness are some of the important factors which were considered while designing the apparatus. The entire setup was manufactured under 5,000 rupees which for a prototype is comparatively cheaper. The KNFB READER app is a freeware and is available in the play store. The hearing aid will be a valuable addition to the public places such as library, railway stations and bus stations where the blind people could make use of the this product to get proper information read out to them without any external help.

4. Conclusion
The product, hearing aid for visually impaired, was successfully designed, optimized and fabricated. This product was designed keeping in mind various difficulties the blind people have to face in order to get information from written literature. This problem was taken up as one of the primary concerns for the design and development of this product. In order to understand various design considerations, a survey with the blind was conducted by which the important aspects for the aid were identified. Further by Forced Decision (FD) matrix method and Decision alternative ratio System (DARE) analysis the most important/relevant property required in the product was identified. Sample designs were made by taking these parameters into consideration. From the available sample designs an optimized design was selected, which satisfies all the condition/criterion of FD and DARE analysis. All the CAD models were compared and the model in which the highest ranked properties are getting satisfied was selected as the optimized design. The selected design prototype was fabricated with fused deposition modeling and was fabricated parts of the product.
successfully tested for the functionality. The design is ergonomically designed to be handled easily. It has a mobile platform which can be moved up and down to adjust the scanning range of the mobile application. It is not electrically powered and has to be handled by the person himself. The final design was fabricated using additive manufacturing and with the help of smartphone camera and KNFB reader mobile application text from books were scanned and converted to speech. This Product will serve as a helping hand to the blind in public places such as libraries and bus stations and is a first step towards helping the blind people become independent.

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