Design of an Economical Medicine Dispenser using design thinking methods

Bliss Pereira

Abstract

The cost of healthcare is increasing every year making it difficult for majority of families incapable of affording costly inpatient care. Hence these families have to rely on home care where the caretaker has insufficient training in administering medicine. A family's bread earner must step outside almost everyday to feed the family, hence the patient must be left at home unattended by a suitable caretaker. Hence an effort is made in the current project to help the caretaker administer prescribed dosage to the patient on time over the day. The device is designed to dispense the desired medicine in correct quantity and time interval and sound a alarm which the caretaker (and patient) can turn off after manually activating a button on the dispenser. The device is intended to be designed to send data over the internet to a mobile device which enables it to be monitored by a suitable individual who can take corrective action in case the medicine is not dispensed by the caretaker. This paper highlights the design and development process of this device.

Table of Content

List of figures

List of Tables

1. Aims and Objectives

The aim of this work is to improve patient care economically at both the healthcare facilities and in home alike. The need is realised by the author after observing poor patient care for most of the population in a developing country like India. The main objective of this work hence is to design a product which can dispense the prescribed medicine at appropriate time interval for the patient. The product should be simple enough for an uneducated worker to operate, after it has been initially set up by a educated and well-informed individual. The device should be able to be monitored via an app along with the possibility to change dispensing time using the app itself. Also, the device must have some battery backup so it will function also if the power is lost even for a few days.

2. Introduction and literature review

India's healthcare sector comprises of public and private components. Public sector involves the government institutions which also focus on rural areas additional to institutes on national important like AIIMS at various locations in tier-1 and tier-2 cities. Although the cost of healthcare in India in approximately one tenth compared to western countries, it is still now reachable for a majority of population especially the inpatient care and surgery requirements. The CPI-C (Consumer Price Index Combined) inflation arrived at 5.2 percent in 2021-22 as compared to corresponding period in previous year [1]. As per the economic survey of the year 2021-22, the country's public health expenditure was reported to be 2.1 percent of the GDP compared to 1.8 percent in 2020-21 [2]. Although this looks like an improving trend, some experts are not satisfied with it and contend the healthcare sector is not made the priority in the annual budget in the year 2022 [3] [4]. This is due to the fact that the annual allocation of funds to the healthcare sector rose only meagrely compared in 2022-23 (86,606 crores) compared to the previous year (85,915 crores). As can be seen in Figure 1, the per capita spending on healthcare in India keeps rising whereas the public funds spending on healthcare by the government keeps reducing [5]. This spending is among the lowest when compared to other Asian countries let alone the western countries.

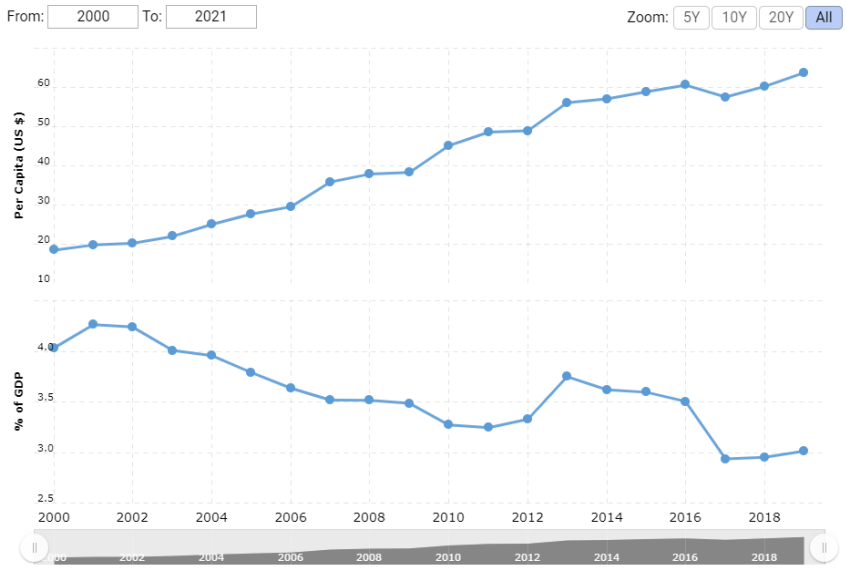

Figure 1. Per capita spending in India on healthcare compared with GDP over the years [6]

The cost of healthcare is increasing day by day and the recent pandemic made the entire nation realise the cost and state of healthcare. The Indian government needs to spend 3.8 percent of GDP on healthcare if quality healthcare is to be provided to all citizens across the country. The standard for quality healthcare are set by Indian Public Health Standards (IPHS) [7]. The cost of inpatient care in private hospitals is skyrocketing with respect to the per capita income in India. Still, majority of rural and urban household cannot afford private hospitals and end up endangering their lives due to this. A large percentage of population still have to resort to inhouse care where an inpatient care at a hospital is essential [7]. Still, even at a home, proper medicine can not be dispensed at prescribed duration due to insufficiency of education among poor household. Even at economically and educationally sufficient household there is frequent negligence on part of the caretake to administer appropriate medicine at the appropriate time interval. Even cautious individual finds it hard to timely administer medicine and frequent lapse happens which negatively affects the patient. Hence efforts are made to address this need in the society.

3. Methodology

3.1 The Double Diamond method

To design and develop a device which can administer suitable medicine at desired time, design thinking methods are used to generate ideas. The popular Double Diamond method of problem solving is utilized to find a reliable solution for the problem at hand. In the discovery stage suitable work is done to find the root of problem at hand. Appropriate market surveys and user study is done to approach the root of issue. Solving a personally invented problem can lead to sure failure resulting in poor market adoption.

Hence personal interviews were done although the same problem was also observed in the author's own home. Timely administration of medicine is practically a universal problem.

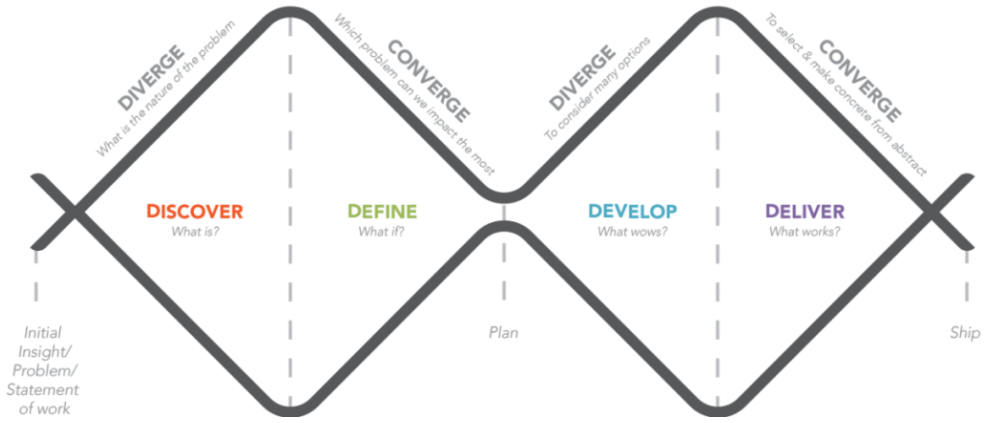

Figure 2: The double diamond method of problem solving

3.2 Market research

Some design thinking methods greatly help in discovering the problem namely Ethnography and Empathy mapping. Ethnography is the study of local culture to understand their needs and desires. It helps us study how prevalent and intense the need is in the population being studied.

3.2.1 User survey

An online survey questionnaire as shown in Table 1 was prepared and 115 responses were collected to get some realistic data. It can be seen in Figure 3, that almost half the people surveyed forgot to administer the prescription to a sick person, and 71 percent forgot to take medicine themselves, at some point of time which could have had detrimental effect on their state of health clearly indicating the need for a product which can address this matter. It is also concluded from the survey conducted that every 3 out of 4 people suffers from a chronic illness which require regular medication and almost half have someone who is dependent on someone else to administer medicine to them. The survey provided realistic data which demonstrated a definite need for a solution.

Table 1: A survey questionnaire prepared for the user research

1. What is your age group?
2. Does your family have a car
3. Does your family rely on domestic help when someone gets sick in your family?
4. How often do you forget to take medicine to the sick person at the right time?
5. Which medium do you adopt for buying medicine?

6. Have you forgotten to take a medicine dosage at the specified time?
7. What is your family income bracket?
8. Have you accidentally repeated a medicine dosage due to forgetfulness?
9. Do you have elderly at home?
10. Do you have an ill patient at home?
11. Do you forget taking medicine?
12. Does someone at your home has chronic illness and is bedridden?

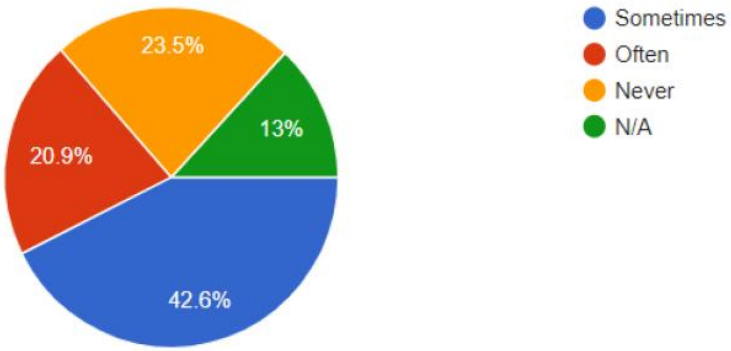

Figure 3. A snippet from the survey data showing how often people forget to take the prescription.

3.2.2 Persona

Persona is a representational image of the probable user for the product which is being designed [8]. The persona highlights the age, educational level, economical class, geographical location, interests, priorities of the probable user of product [9].

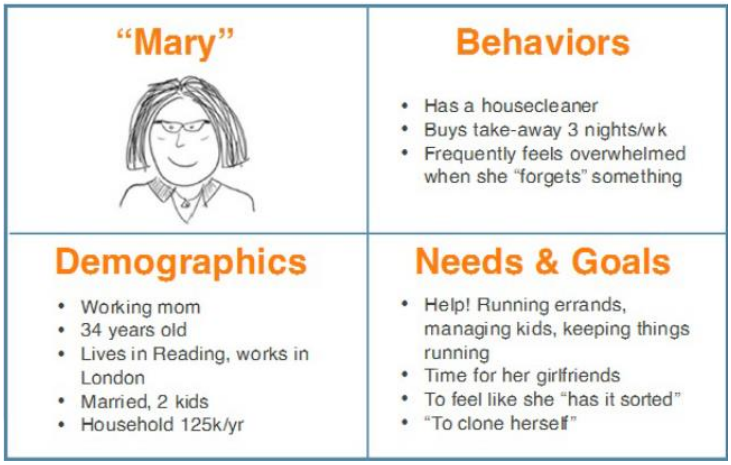

Figure 4: An example of a rough persona [10]

An example of a preliminary persona can be seen in Figure 4, where rough details of a would-be user is listed. A persona helps choose the product features which increase the chances of it being adopted by the personality of the user of whom the persona is created. It helps in articulating the needs, wants, desires and goals of the market/user for whom we are creating the product thereby reducing the likelihood of choosing an unsuitable user.

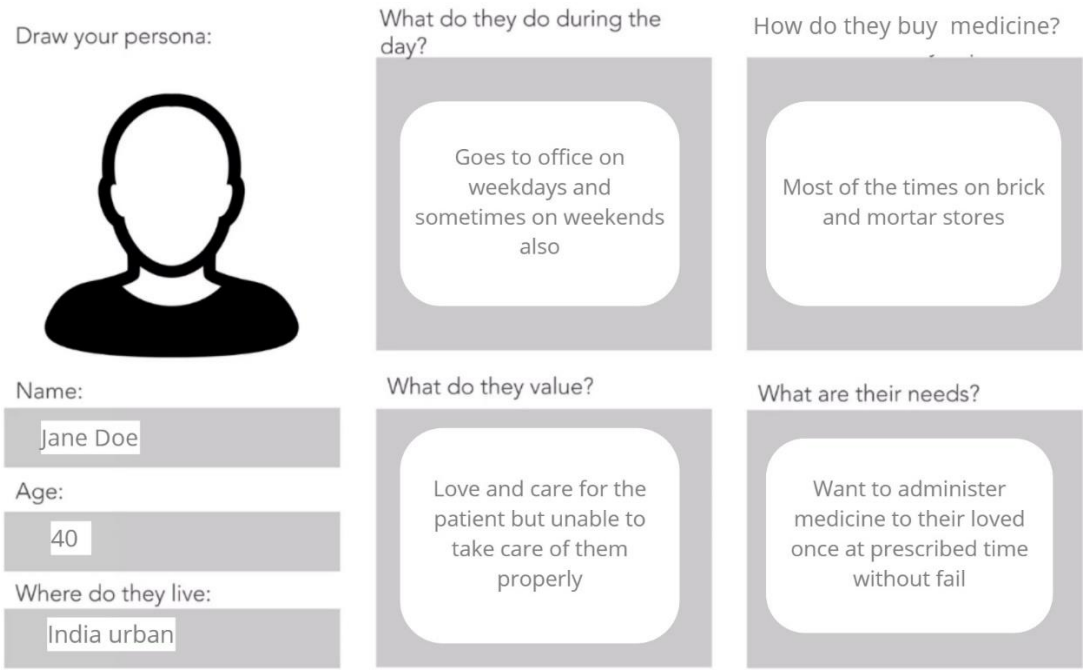

Figure 5: A user persona created for the current product

A typical target market for this product is a household where both adults are working and have senior citizen at home who are either not educated sufficiently to take appropriate medicine or forget to take them. The user (who will decide to take to buy the product) works at an office or owns a business and has to stay outside his/her home most of the days and even night if necessary. Taking care of their loved once (who need regular medicine) is crucial for them. Their family income does not allow them to hire a nurse or a well-educated caretaker and hence need a solution which can solve the problem of administering medicine to the concerned person.

4. Problem Definition

4.1 PDS

Not every problem which is discovered can be solved by the design team in the available time and resources. Neither the market is ready for some features which are undesirable at the current mindset and economical conditions of the market to be addressed. The specific requirements of the project at hand are segregated in this stage. It is crucial to make the product design specifications (PDS) since this

document guides the decision make process throughout the product development process. All decisions are governed by the PDS and the factors which are important are listed below in the current product

4.1.1 Sustainability

Sustainability is crucial for the current product since environmental impact of non-eco-friendly product is significant and the author does not want to contribute to greenhouse gasses (GHG). Attention should be paid early in the design stage itself to predict the lifecycle of the product which includes disposal and recycling. This product is designed keeping the well being of society in mind and having a healthy environment is essential part of it. Ply made of recycled bio waste are used in the current product for enclosure manufacturing.

4.1.2 Ergonomics

Ergonomics (ease of use) determines the user-friendliness of a product. The intended user and even possible misuse is accounted for in ergonomics study of a product. This field is vast and necessary study is done to improve the usability of the product keeping in mind the probable user. The user in this case is minimally educated possibly domestic help workers who handle daily chores in a household, like dish-washing, cleaning etc. These domestic workers are generally not educated even up to high school and cannot read English which is generally the writing language on medicines. Hence a qualified and educated person must setup the medicines in the device and subsequently it can be operated by a worker. Also, it is kept in mind the minimal responsibility and supervision is required on the part of worker for the device to operate. Hence, only the alarm to be turned off physically once it activates by the worker which happens if the time for administering medicines has arrived. The worker only needs to collected the medicine which are dispensed from the device and turn off the alarm by pressing a button on the device. Also, a timer is provided on the device so a worker can be informed about the time after which the medicines are to be given so they can manage their other chores accordingly. The worker only needs to collect the medicine and turn the alarm off which most domestic workers can handle.

4.1.3 Cost

Since the household in question are economically weaker, all efforts are made to keep the device cost low as long as it does not compromise the reliability of the device. Standard parts are used to reduce the cost and the body/enclosure is designed to be built using recycled wood.

4.1.4 Portability

The device should be compact enough to be carried conveniently by an individual. The device size is governed by the amount of medicine which it must carry and its ergonomics. It should be a tabletop device which can be conveniently operated by an uneducated person, hence the buttons and displays are to be large and simple enough for these to be easily understood.

4.1.5 Reliability

Since patients are supposed to rely on this device for critical purpose like dispensing medicine, failsafe are to be employed to make sure the medicine is administered at the specified time. Also, notifications are to be sent to a supervisor if the device has malfunctions. Standard and reliable components are to be used which provide dependability.

5. Concept Development

Concepts are developed which satisfy the PDS and time-tested techniques are used to develop numerous concepts and ideas early in the design stage. Some of these methods are product research, SCAMPER, morphological chart which can be readily adopted in the current work. These methods enable rapid idea generation especially when done in a team and can drastically alter the pace of product development cycle.

5.1 Product Research

Once the need is recognized, product research is done to find out how the said problem is being solved currently in the market. This serves multiple purposes including finding current competitors, pros and cons of their products. Thought must be put into finding out what better can be provided in our product which none of the existing product provides in terms of quality, quantity, price, aesthetics, customization etc. Product research also helps get the knowhow of the current market benchmark which intimates about what the current users expect to be present at the least. The products features can be categorized as a requirement, performance, pleasers, exciters. The requirement features are bare minimum considering the current market and must be known if the users are to be satisfied. The performance features improve the functionality of the product compared to the existing product in the market. Both of these features are important as these come into the “already expected” category of user’s expectations and if are unmet, can lead to poor customer reviews. The pleaser and exciter features can be provided based on the price point at which the product is kept. Since this is a niche product as can be seen from the market research done, hence not much benchmarking data is available except from what is collected using the user research done by the author.

5.2 SCAMPER

SCAMPER is a technique developed for rapid concept development by incorporating the ideas from existing products in the market and hence the “product research” stage serves as the input to this stage. The existing products in the market may have numerous useful features and the data available on the user perspective on this can provide valuable information on weather it is considered important or not by the user. This data is concrete since it is no longer a predication or speculation on the part of the design team. SCAMPER is an acronym from Substitute, Combine, Adapt, Modify, put to other use,

Eliminate, and Reuse. As the word meaning suggest, “substitution” leads to the product being replaced completely and the need it satisfies be satisfied by the product being designed. “Combine” method fuses different product to form a new product class and multiple needs be met by the designed product. “Adapt” methods stimulates customization of the existing product to the current demand to satisfy it better. “Put to other use” line of thinking enables the use of an existing product to satisfy a different need for which it has not been used before. “Eliminate” focuses out attention to stripping down some features which are not needed as per the PDS formulated. These “forced creativity techniques” enable rapid concept development as compared to our natural thought process.

Figure 6: SCAMPER technique and its components [11]

Multiple aspects of SCAMPER can be employed instead of just one and in this product the substitution, adaptation, modification aspects can be employed. There are a few manual compartmentalized medicine carriers are available but these have the probability of wrong medicine being administered which can be critical for the patient. Hence automating the process and have it been setup by a qualified personal reduces the possibility of mistakes. Adaptation and modification aspects can be employed keeping in mind a coffee machine and modifying it for our application.

5.3 Morphological chart

Table 2: Morphological matrix for generating concepts

Functions	**Form**	**Syrup dispensing**	**Solid dispensing**	**Powder dispensing**	**Material for enclosure**

Option 1	**Cuboid**	Gravity	**Plunger and cavity**	Plunger and cavity	Plastic
Option 2	Cylindrical	Impeller pump	Screw	**Screw**	Sheet metal
Option 3	Oval	Peritectic pump	Air flow	Air flow	**Recycled wood composite**
Option 4	Disc	Piston pump	Shutter	Shutter	
Option 5	Cube	Vane pump			
Option 6		**Tube and roller**			

Morphological matrix provides a structured way of developing numerous concepts early in the design cycle. First the features/functions are selected which are to be provided in the product and then as many ways as possible are thought of to provide the same. This reduces the possibility of ignoring the obvious for generating the ideas for satisfying the design criteria. In our product medicines are to be dispensed, which is the main function of this product. The medicine come in different form factor namely liquid, powder, solids in some standard forms.

For the overall form, due to ergonomic and aesthetic reasons, cuboid shape scores better. For materials use in the device body, composites based on recycled wood scores better considering the sustainability in mind. For syrup dispensing, due to the price considerations, a tube and roller pump which is well known in dosing applications is used. This pump has the a few advantages over other pumps including the no contact delivery of the liquid. This feature, combined with its lower price tag has made this pump popular in dosing applications in the medical and chemical industry.

For the power dispensing function, a screw is used which is a positive displacement mechanism, hence is well suited in this application. This mechanism comprises of a screw rotating in a tunnel through which the power is dropped which is kept above the screw so gravity supports the power flow. Also, to keep the powder flowing steadily, a vibration motor is employed and is mounted on the container which stores the powder. The vibrations do not allow to powder particles to stick to each other and form lumps which can prevent its effective flow into the screw.

For the solid medicine in pallet form, a plunger and cavity mechanism are used. The plunger is activated by a solenoid which pushes it forward to dispense the medicine. The is a reliable choice this a screw can lead to multiple pallets being dispensed which can have serious implications for the patient.

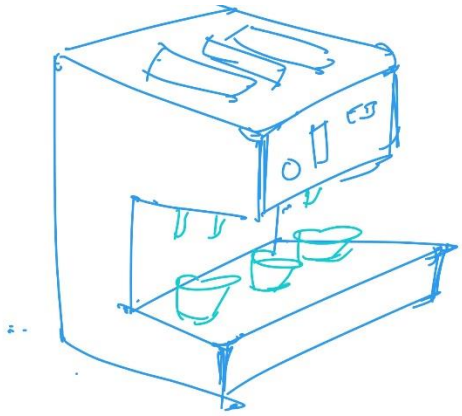

Figure 7. Concept 1

Figure 8. Concept 3

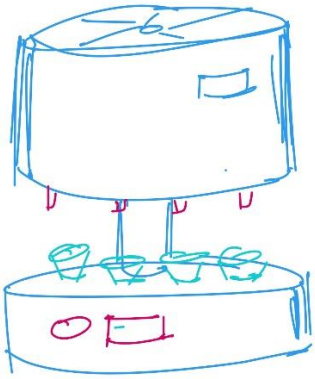

Figure 9. Concept 2

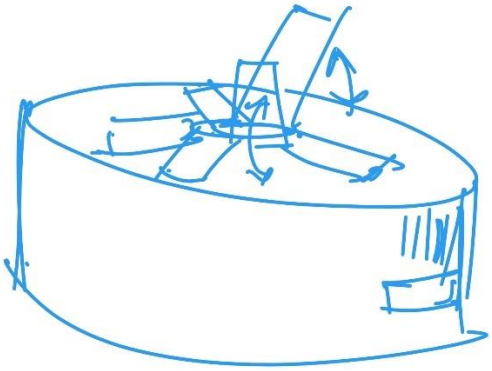

Figure 10. concept 4

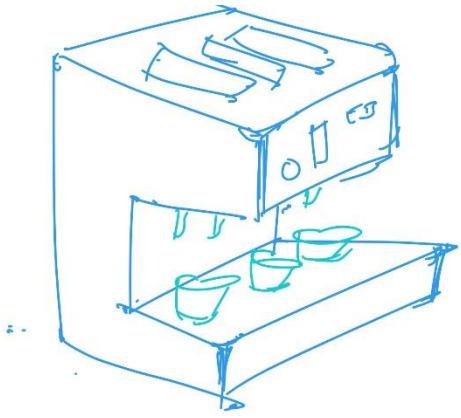

Figure 11. Selected concept based on the concept ranking matrix

6. Concept Selection

Table 3: Criteria ranking matrix for the product

Criteria	**Cost**	**Reliability**	**Ease of use**	**Sustainability**	**Portability**	**Total**	**Rank**	**Weight**
Cost	0	0	0	0	1	1	3	0.1
Reliability	1	0	1	1	1	4	1	0.4
Ease of Use	1	0	0	0	0	1	3	0.1
Sustainability	1	0	1	0	1	3	2	0.3
Portability	0	0	1	0	0	1	3	0.1
					Total	10		

Table 4: Concept ranking matrix for the product

	Criteria	**Cost**	**Reliability**	**Ease of Use**	**Sustainability**	**Portability**	**Total**	**Overall Rank**
	Weight	**0.1**	**0.4**	**0.1**	**0.3**	**0.1**	**1**	
Concept 1	Rank	80	85	90	90	90		
	Rank*Weight	8	34	9	27	9	87	1
Concept 2	Rank	75	80	70	75	75		
	Rank*Weight	7.5	32	7	22.5	9	78	3
Concept 3	Rank	70	70	75	80	70		
	Rank*Weight	7	28	7.5	24	7	73.5	2
Concept 4	Rank	40	50	70	75	80		
	Rank*Weight	4	20	7	22.5	8	61.5	4

The components must be selected at the beginning of parametric design although even in concept development, a basic understanding of components prove useful to generate a functional concept. The pump used for liquid medicine is a tube and roller type which is easily available in in India from Robu.in [12].

Figure 12. A silicon tube pump selected for dispensing liquid medicine [12]

Figure 13. An electromagnetic solenoid selected for dispensing solid medicine pallets [13]

This pump can supply 55 ml/min of liquid and is rated at 12 V, 0.25 A and produces noise levels under 40 dB which are suitable specifications for the current application. Also, this is a non-contact type of pump which ensures that no mechanical part of this pump touches the medicine thereby avoiding any possibility of contamination.

A solenoid is used for forcing the solid pallets of medicine which can be round, oval, and long oval. An electrical solenoid is a linear motion electrically operated actuator. Generally, it only has two positions which can serve as open/close function. A spring keeps the solenoid in open (or close) position depending on the type of solenoid. When electrical potential difference is applied across its terminals, the plunger moves into other position opening or closing a valve.

Figure 14. Vibration motor using to facilitate medicine movement [14]

Figure 15. Stepper motor used to drive the lead screw [15]

In this application, the linear motion provided by this actuator is used to push the medicine pallet out of the cavity in which it is held. The pallets drop into the cavity under gravity and is also assisted by a vibration motor mounted on the container in which all the pallets are held. The solenoid [13] selected can provide a displacement of 15 mm and a force of 50 N which is suitable for current application [13]. For driving the screw to dispense medicine in the form or a powder, a low-speed motor [15] is used having 15 rpm. This motor is 28BYJ-48 which is widely available along with its driver ULN2003. This is driven on 5VDC and has a gear head with a reduction ration of 64:1. The motor drives the lead screw which rotates in a tunnel pushing the powder forward predictably. Just so the powder does not stick together affecting its free flow a vibration motor [14] is used with the container which houses the powder medicine. The vibration motor is driven at high rpm (15000 +/- 2500) at 2.7 V and 80 mA max.

The micro-controller used to control the device and enable its connection with the internet is ESP8266 based NodeMCU CP2102 [16]. This is a SOC (system on chip) microcontroller which provide WIFI connectivity right out of the box and is very cheap considering what it offers in terms of functionality. The board provides easy access to its I/O (input/output) pins using Arduino IDE which offers easy programmability. It has an on-board voltage regulator and a USB to serial converter to directly connect it to the PC for programming.

Figure 16: A NodeMCU ESP8266 based microcontroller [16]

7. Parametric Design

Parametric design incorporates designing the actual files using which the parts will be manufactured considering the manufacturing and functionality aspects. In the beginning of this phase, the components

can be laid out in 3D inside a CAD (computer aided design) program which gives an understanding about the special limitations of the design. After the basic layout any possible reorganization can be made to make the design more effective in serving its purpose. There can the 2 approaches in making the digital 3D design.

One is the top-down approach where first the inside components are assembled digitally and the functionality aspects are analysed. Possible rearrangements are done to enable better serving the underlaying purpose of the design. Another is the bottom-up approach where the interface and enclosure are designed first and then the inside components are conceptualized and selected. Both approaches serve a purpose and are not entirely exclusive, as there is an overlap in the principles used to in both approaches. Since the products have to be functional, even in top-down approach some understanding of the technology to be used must be held otherwise the concept may not be functional, since it can't be realised physically. After functional part assembly is made, the enclosure is designed considering the ergonomics and aesthetics of the design. The intended user is considered primarily in designing the interface of device including the location, size and shape of button and display. User interaction and experience design principles are used to design the enclosure of the product.

Material selection is another crucial part of product design and online catalogues [17]–[19] which are parametric in nature provide great help in making the top 10 choices quickly. After the top materials are finalized material charts (Figure 17) can be employed to make the final selection. MDF (medium density fibre) board, practical board, wood-plastic composite, oriented strand board (OSB) are a few top choices for the enclosure material, since sustainability is and important factor although the cost of production is also contending with the factor since this product must be affordable by poor households.

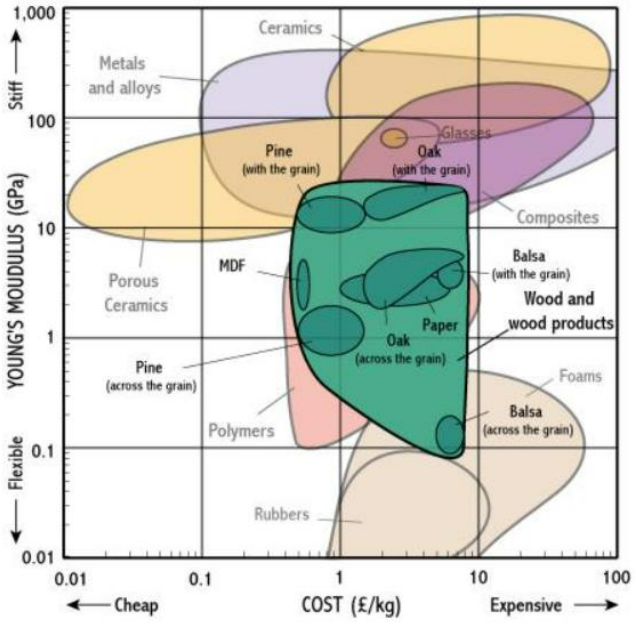

Figure 17: Young's modulus vs cost chart highlighting the wood class [20]

For the body panels, particle board is used as these are sustainable as these are produced from recycled and repurposed wood. Particle boards are fabricated by combining wood fibres, chips, dust with resin and pressing it together under pressure [21]. These are popular in furniture, countertops, flooring, and interior fabrication [22].

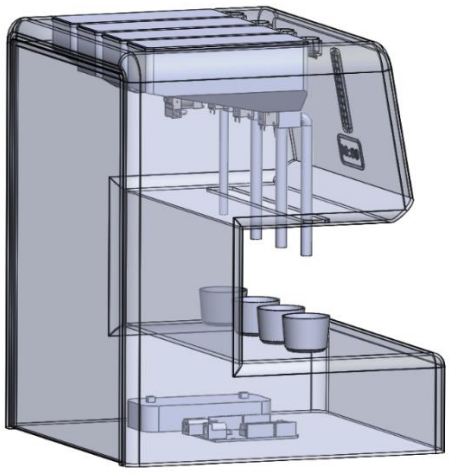

Figure 18. CAD design showing the inside arrangement

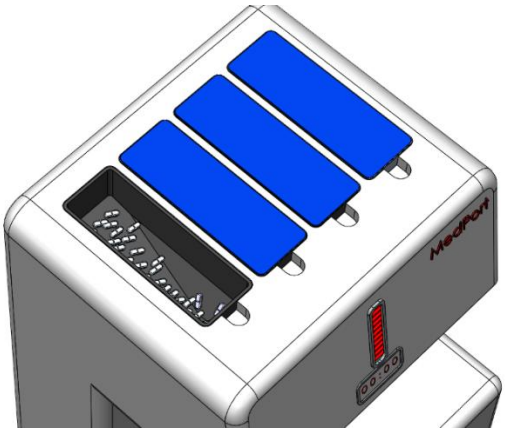

Figure 19. CAD design showing medicine compartments

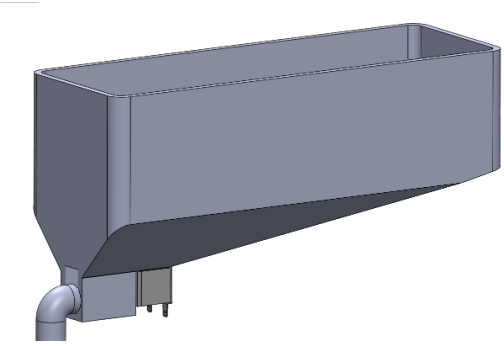

Figure 20. CAD design showing solenoid and cavity

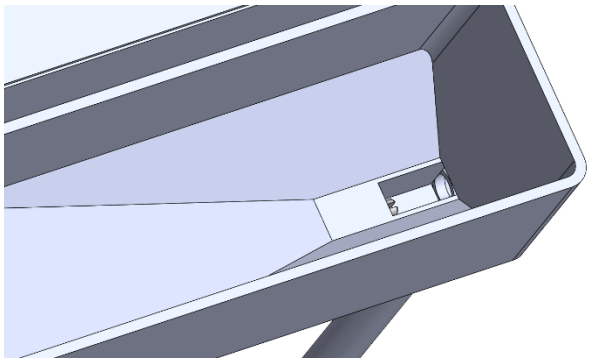

Figure 21. CAD design showing compartment and cavity

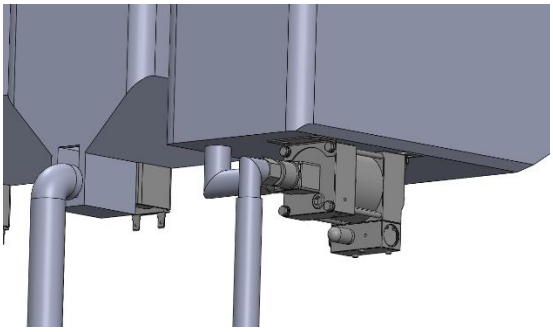

Figure 22. CAD design showing the liquid dispenser pump arrangement

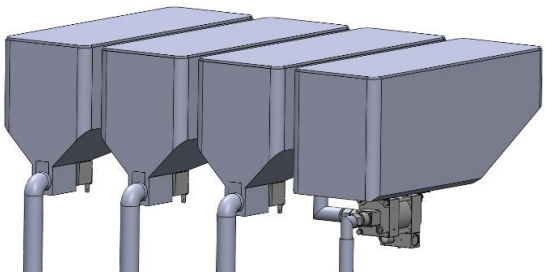

Figure 23. CAD design showing the arrangement of compartments

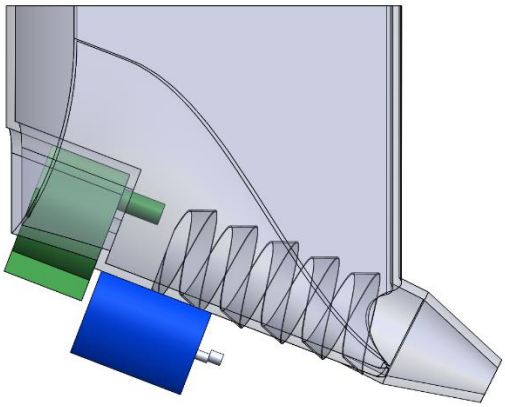

Figure 24. Screw mechanism to dispense powder medicine

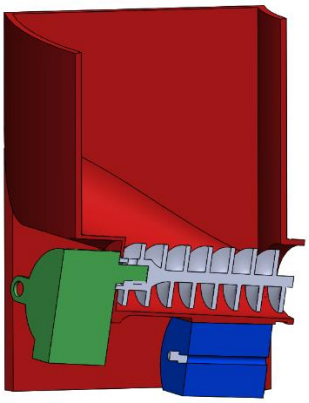

Figure 25. Screw mechanism and vibration motor shown

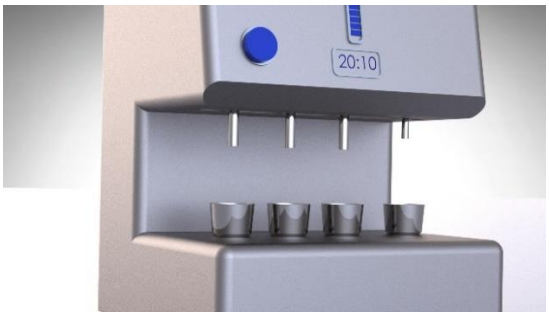

Figure 26. Rendered view 1 showing the device rendered in metallic appearance

Figure 27. Digital rendering view 2 in metallic theme

Figure 28: View 3 in metallic theme

Figure 29: View 4 in metallic theme

8. Results and Conclusion

A need is recognized to administer medicine without a dedicated trained personal, hence performing the task economically. A device is designed considering this need to administer medicine to the patient at specified time intervals without fail. The design elements and respective standard components were

chosen to satisfy the chosen criteria namely reliability, economy, ergonomics, sustainability, and portability. Components were chosen also considering the economic aspects and availability in India. In all future versions of this design, all the findings and data collected are to be kept in mind if optimal use of resources is to be made. Design for functionality was a key concept learned which must be kept in mind at all stages, which ensures that a product works once it is put to service. Errors initially made during the parametric design were corrected with multiple iterations as the digital design served well in that stage. The components were modelled using CAD without actually considering which components are going to be finally selected and hence is a useful lesson for future work. Also design for manufacturing was later considered after initially just modeling the parts which were not fit for manufacturing.

Parametric design is done and 3D printable files are generated for further testing and optimization. Once a functional prototype is developed, appropriate testing can be done which is a future scope of this work.

References

[1] "Economic Survey." https://www.indiabudget.gov.in/economicsurvey/ (accessed Oct. 31, 2022).

[2] "Healthcare System in India, Healthcare India - IBEF." https://www.ibef.org/industry/healthcare-india (accessed Oct. 31, 2022).

[3] "Lack Of Care For Healthcare: Budget 2022." https://www.outlookindia.com/business-spotlight/lack-of-care-for-healthcare-budget-2022-news-122164 (accessed Oct. 31, 2022).

[4] "Budget 2022: Despite Covid pandemic, health no longer the highlight | Business Standard News." https://www.business-standard.com/budget/article/budget-2022-despite-covid-pandemic-health-no-longer-the-highlight-122020200049_1.html (accessed Oct. 31, 2022).

[5] "Cost of Healthcare In India: Factors, Cost of Treatment & Benefits." https://www.godigit.com/health-insurance/health-guides/cost-of-healthcare-in-india (accessed Oct. 31, 2022).

[6] "India Healthcare Spending 2000-2022 | MacroTrends." https://www.macrotrends.net/countries/IND/india/healthcare-spending (accessed Oct. 31, 2022).

[7] S. Prinja *et al.*, "The Cost of Universal Health Care in India: A Model Based Estimate," *PLoS One*, vol. 7, no. 1, Jan. 2012, doi: 10.1371/JOURNAL.PONE.0030362.

[8] "Define personas - IBM Garage Practices." https://www.ibm.com/garage/method/practices/think/practice_personas/ (accessed Oct. 17, 2022).

[9] "What are Personas? | Interaction Design Foundation (IxDF)." https://www.interaction-design.org/literature/topics/personas (accessed Oct. 17, 2022).

[10] "How to design lean personas for your UX strategy | by Justinmind | UX Planet." https://uxplanet.org/how-to-design-lean-personas-for-your-ux-strategy-921ef635e275 (accessed Oct. 17, 2022).

[11] "A Complete Guide of SCAMPER | EdrawMind." https://www.edrawmind.com/article/what-is-scamper.html (accessed Oct. 29, 2022).

[12] "Buy Kamoer 12V 0.25A 55ml/min Silicone Tube Liquid Pump | Robu.in." https://robu.in/product/kamoer-12v-0-25a-55ml-min-silicone-tube-liquid-pump/?gclid=Cj0KCQjwnvOaBhDTARIsAJf8eVOQfH7zbQi9ROv4zX7OJeyQqONlw_bONdq5CpzGlIvNO64Do_hV4PwaAsKAEALw_wcB (accessed Oct. 30, 2022).

[13] “Buy DC12V 50N 15mm Push Pull Solenoid Electromagnet Online in INDIA | Robu.in.” https://robu.in/product/dc-12v-50n-15mm-push-pull-solenoid-electromagnet/ (accessed Oct. 30, 2022).

[14] “SMD type Vibration motor H3.0*W4.0*L11 with 15000 ± 2500 RPM - Robu.in | Indian Online Store | RC Hobby | Robotics.” https://robu.in/product/smd-type-vibration-motor-h3-0w4-0l11-with-15000-%c2%b1-2500-rpm/ (accessed Oct. 30, 2022).

[15] “Buy 28BYJ-48 Stepper Motor with ULN2003 Motor Driver Online.” https://robu.in/product/28byj-48-stepper-motor-and-uln2003-stepper-motor-driver-good-quality/?gclid=Cj0KCQjwwfiaBhC7ARIsAGvcPe4sn3HrcHmyjNz-zBWcw4KRlD9_1Ro_bZFAUK7EpNtpVXTtXlPFebUaAuIzEALw_wcB (accessed Oct. 30, 2022).

[16] “Buy ESP8266 NodeMCU CP2102 Board at Lowest Price In India | Robu.in.” https://robu.in/product/nodemcu-cp2102-board/ (accessed Oct. 30, 2022).

[17] “Ansys Granta Selector | Materials Selection Software.” https://www.ansys.com/en-in/products/materials/granta-selector (accessed Oct. 30, 2022).

[18] “Find Materials and Suppliers - Matmatch.” https://matmatch.com/ (accessed Oct. 30, 2022).

[19] “Online Materials Information Resource - MatWeb.” https://www.matweb.com/ (accessed Oct. 30, 2022).

[20] “Young’s Modulus - Cost.” http://www-materials.eng.cam.ac.uk/mpsite/interactive_charts/stiffness-cost/NS6Chart.html (accessed Oct. 30, 2022).

[21] G. Nemli and G. Çolakoğlu, “The influence of lamination technique on the properties of particleboard,” *Build Environ*, vol. 40, no. 1, pp. 83–87, Jan. 2005, doi: 10.1016/J.BUILDENV.2004.05.007.

[22] D. L. Grebner, P. Bettinger, J. P. Siry, and K. Boston, *Introduction to Forestry and Natural Resources*. Elsevier, 2021. doi: 10.1016/B978-0-12-819002-9.01001-4.