GROWTH MONITORING DEVICE FOR INFANTS

PRODUCT DESIGN PROJECT III

BY
SOHINI GUIN
136130001

GUIDE: PROF. G.G.RAY

INDUSTRIAL DESIGN CENTRE
INDIAN INSTITUTE OF TECHNOLOGY BOMBAY
2015

PROJECT 3

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Submitted by:
Sohinl Guin
136130001

Guide: Prof. G.G.Ray

IDC
IIT Bombay

Declaration

I declare that this written document represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources.

I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any iea/data/fact/source in my submission.

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Sohini Guin,

136130001

Industrial Design Centre,

Indian Institute of Technology, Bombay

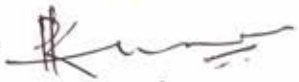
May, 2015.

Approval Sheet

The project titled 'Growth Monitoring Device for Children' by Sohini Guin, is approved for partial fulfilment of the requirement for the degree of 'Master of Design' in Industrial Design.

Guide: 

Chairperson: 

Internal Examiner: 

External Examiner: 

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Abstract

45% of global infant deaths are from nourishment issues. Such problems can be monitored and diagnosed from Growth monitoring of children. Growth monitoring of children is a standard practice followed all over the world from birth till the age of 18. It allows detection of growth problems, nutrition deficiencies and endocrin diseases. Endocrine problems at a young age manifest into serious problems as an adult. These problems can be monitored and detected at a young age. Parent scan be given information baout nutrition, or referred to doctors in case of a problem.

The various equipment available for Growth monitoring are often not used by Health workers who set up health camps in remote locations due to various usability issues. The current scenario, use of these devices or lack thereof has been studied. Concepts for easier use, accurate measurements and data recording of growth monitoring systems were explored. The final concept was a portable product that is simple to use, has data recording capabilities and is affordable for use in health camps and rural hospitals.

Fig 1.1: Growth monitoring

Introduction

Growth Monitoring

Growth Monitoring is a screening tool to diagnose nutritional, chronic systemic and endocrine disease at an early stage *(Kaldilkar et.al., 2007)*

Children are weighed and measured at regular intervals after they are born to keep track of any growth abnormalities or endocrine diseases. It is strongly supported by health care professionals all over the world. Measurements are taken at regular intervals after birth. In the first one year after the baby is born, the measurements are taken every month. The frequency of these tests reduces as the child grows up. The growth of the child is plotted on growth charts which are standardized by WHO. This allows doctors to check if the growth of the baby is normal or not. Growth monitoring can continue even through the teenage years as this is the pubertal age when the secondary sexual characteristics of the adolescent are checked. However, most people do not adhere to the monitoring done at this age.

Routine growth monitoring is widely accepted and strongly supported by health professionals *(Hall, 1996)* and is a standard component of community pediatric services throughout the world.

Growth monitoring comprises a package of activities:

- Regularly measuring the weight of children as shown in Fig 1.1;
- Plotting the information on a growth chart to make abnormal growth visible;
- If growth is abnormal (usually faltering), the health worker does something, in concert with the mother;
- As a result of these actions, the child's nutrition improves, the child receives appropriate medical support; doctors are able to diagnose early serious disease.

Image Sources: http://www.han-sl.org/images/2014/10OCT/FOCUS%201000%20participates%20in%20growth%20monitoring%20in%20Tonkolili.jpg as on 16-04-2015

Aim of growth monitoring

Growth monitoring is a useful tool for detecting nutritional, endocrine diseases at an early stage. It can be beneficial in one primary and two secondary ways.
Primarily, it can be used to prevent disease, malnutrition and even death. It then also helps in medical referrals and further action.
Furthermore, the mother gets information about nutrition and reassurance about health and wellbeing of the child.
It also sensitizes pediatricians to use growth charts for analyzing growth of the children.

Prevention of endocrine diseases

Growth monitoring can inform doctors about any endocrine diseases that the infant may be suffering from.

The endocrine system includes eight major glands in the body. These glands make hormones which act as chemical messengers. They travel through your bloodstream to ti ssues or organs. Hormones work slowly and affect body processes from head to toe. These include:

- Growth and development (Fig 1.2)
- Metabolism - digestion, elimination, breathing, blood circulation and maintaining body temperature
- Sexual function
- Reproduction
- Mood

(Medline Plus, 2014)

Endocrine diseases can be related to nutrition, metabolism and environment. If your hormone levels are too high or too low, you may have a hormone disorder. Hormone diseases also occur if your body does not respond to hormones the way it is supposed to. Stress, infection and changes in your blood's fluid and electrolyte balance can also influence hormone levels.

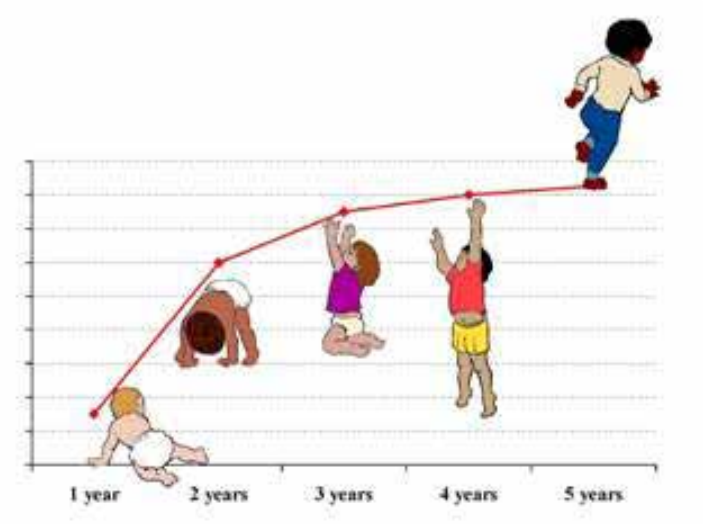


Fig 1.2: Growth monitoring stages

Image Sources: http://hetv.org/resources/childgrowth/cover_mgrs_whitesm.jpg as on 16-04-2015

Fig 1.3: Growth chart in a village health camp

Current scenario

Even though growth monitoring of children right from birth is important, it is often ignored or not done properly because it does not have immediate consequences. However, it proves to be very useful in detecting and taking immediate action if the child is suffering from any endocrine diseases. Fig. 1.3 indicates the growth monitoring chart in a primary health clinic helping in understanding the growth status of a child.

Most hospitals are equipped with infantometers and weighing scales. However, hospitals which have a large footfall often fail to record this data regularly. They often use a measuring tape to measure the infant, and this isn't accurate data. In rural hospitals, a spring balance with a harness is used to weigh the babies. They often use vegetable weighing scales too. For measuring the length of the babies, they are made to lay down, while their parents and nurses hold them in position, one nurse or doctor takes the measurement with a measuring tape.

Image Sources: http://www.wotr.org/sites/default/files/Growth-Chart-500.jpg as on 16-04-2015

Literature Review

A healthy, adequately nourished and emotionally secure child grows at an optimal rate *(Stanhope 1994)*. Growth measurements encompass the measurement of height, weight and head circumference. The relationship of all these measurements will identify the need for further monitoring or investigation; ie a small head circumference with a low weight needs a different approach, compared to a small head with a normal weight.

The various measurements that are currently taken are:

- Height or length: One of the primary data for growth monitoring is the length or the height of the child. This measurement is useful in detecting any kind of endocrine abnormalities in a child.
- Weight: Weight is also a very important parameter and gives information about nutrition and endocrine diseases.
- Head Circumference: The measurement of a child's head circumference is part of the growth assessment.
- MUAC: The Mid Upper Arm Circumference is useful in detecting the extent of malnourishment in a child.
- Chest measurement: This measurement is important for new born babies and for checking extent of malnourishment.
- Abdomen measurement: When a child is malnourished, his chest contracts and abdomen expands. Thus, the abdomen measurement is also taken to detect malnourishment.

Products currently being used for Growth Monitoring

Infantometers

An infantometer is a height measuring device for infants. The baby is placed on this device in the supine position to measure the length. This is usually used for infants upto 1.5 years of age. Once the baby can stand up and be stable by itself, they can be measured using stadiometers. The following types of infantometers are most commonly used:

Fig 2.1: Robust infantometer

The infantometer shown in Fig 2.1 are usually found in big hospitals. Most often, these are purchased and then fixed at a location in the hospital. They are accurate and comfortable for the infant. The V shaped holder allows the child to be cradled properly. The doctor usually holds the legs of the infant down so that the correct length can be recorded. The sliders have a push button which needs to be pressed for it to move. By doing so, they make sure that the sliders don't move without the doctor meaning to. Thus, errors are minimized.
The weight of these infantometers is fairly high and they prove to be fairly expensive.

Fig 2.2: Lightweight Infantometer

Infantometers which are less robust, lightweight and cheaper are also available. These are used by hospitals and clinics. The infantometer in Fig 2.2 is a folding paper infantometer with two flat plates which act as references.

Fig 2.3: Makeshift infantometer

Some rural set-ups use makeshift infantometers such as the one shown in Fig 2.3. These are made of wooden planks etc. Two or people are usually required to get a reading from such a setup.

Image Sources: Fig 2.1: http://www.sellesmedical.co.uk/system/images/data/000/016/053/original/SECA416_3.jpg?1401014997 as on 16-04-2015, Fig 2.2: http://www.hopkinsmedicalproducts.com/images/products/bigGraphic/680210.jpg as on 16-04-2015, Fig 2.3: https://s-media-cache-ak0.pinimg.com/236x/1a/4c/44/1a4c446c5ba53afb00d8660df926c56f.jpg as on 16-04-2015

Measuring tape

Most rural hospitals use a measuring tape to measure the length of the infants. This data is usually inaccurate as the start and end points of the infant's body are not referenced properly. A measuring tape is also used to measure circumferences of the body. It is used for head circumference (Fig 2.4), MUAC, chest circumference and abdomen circumference measurement.

Coloured measuring tape: The measuring tape shown in Fig 2.5 is a colour coded throwaway tape made from paper. The colour reference to the reading helps the health worker or parent know if the reading is in a safe zone or that the child needs medical attention.

Fig 2.4: Measuring head circumference

Fig 2.5: MUAC using coloured tape

Weighing scales

Many kinds of weighing scales are used for weight measurement. Spring balances with a harness as shown in Fig 2.6 are used in rural hospitals and PHCs. Hospitals and clinics use electronic weighing scales as shown in Fig 2.7 . Infant weighing scales like the one in Fig 2.8 have a tray attached to the weighing scale onto which the infant can be laid down. Children who can stand up and be stable are measured using stadiometers as shown in Fig 2.9

Fig 2.6: Spring balance

Fig 2.7: Electronic weighing scale

Fig 2.8: Infant weighing scale

Fig 2.9: Stadiometer

Image Sources: Fig 2.4: http://www.ox.ac.uk/sites/files/oxford/styles/ow_content_width/public/media_wysiwyg/baby%20growth.jpg as on 16-04-2015, Fig 2.5: http://www.worldvisionmagazine.org/sites/default/ as on 16-04-2015, Fig 2.6: http://www.thehindu.com/multimedia/dynamic/01736/30THANGANWADI_1736930e.jpg as on 16-04-2015, Fig 2.7: http://img.weiku.com/waterpicture/2011/10/19/5/ electronic_bench_scale as on 16-04-2015, Fig2.8: http://kellymom.com/bf/normal/weight-gain/ as on 16-04-2015, Fig 2.9: http://www.pedsalex.com/pediatric-services.php as on 16-04-2015

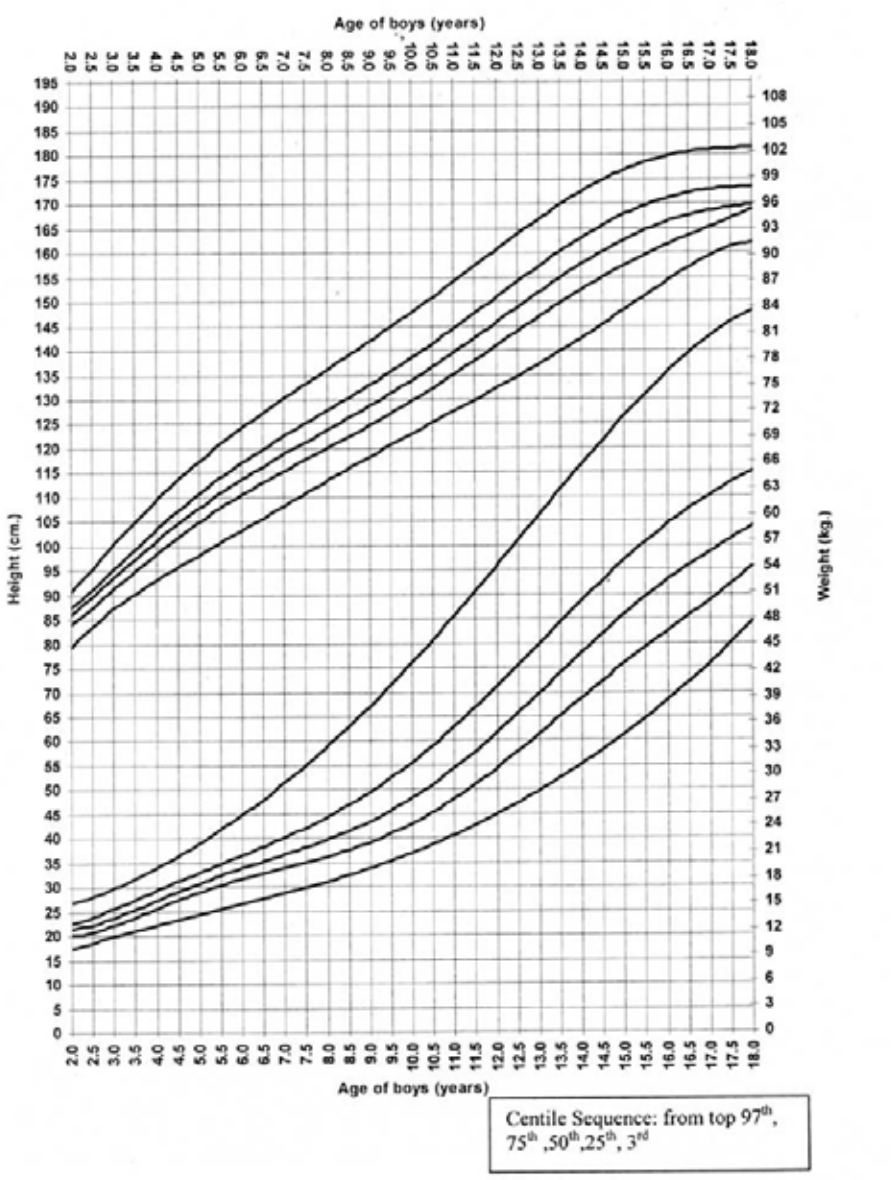


Fig 2.10: Growth chart

Image Source: Fig 2.10 IAP Growth Monitoring Guidelines for Children from Birth to 18 Years, Indian Pediatrics

Growth charts used

Children around the world have different growth patterns due to ethnic, geographic and regional factors giving different rates of nutrition. Thus for assessment, a national representative sample of population data are ideal as growth standards. The Indian Council for Medical Research (ICMR) undertook a nationwide cross sectional study during 1956 and 1965 to establish Indian reference charts. *(Khadilkar, 2014)*

WHO standards

In 2007, the World Health Organization released new international growth charts, a sample of which is shown in Fig 2.10, depicting the optimal growth of children from birth to age five years and charts for monitoring the growth of older children and adolescents *(British Columbia, 2013)*

Field Study

For observing how growth monitoring is done and the various instruments used, a children's hospital or a pediatric ward had to be visited.

First, the Well Baby Clinic of IIT Bombay hospital was selected. However, the footfall of children in the baby clinic was very low for any proper observation. It was suggested that a government hospital be selected for this purpose so that there is a large number of children. Wadia Children's Hopsital (Fig 3.1) was the next stop for the study. Here, the crowd was extremely large. However, these children were mostly under-nourished and thus the growth measurements were all lower than standard. The next hospital visited was Tata Memorial Hospital. All children admitted here are diagnosed with cancer of some form, thus there growth measurements are strictly done for specific purposes pertaining to their ailment only. Lastly, multi specialty hospital Holy Spirit Hospital (Fig 3.2) was selected for observation and discussion. The Pediatric OPD of this hospital had the various growth monitoring devices, and every child that came in had some sort of monitoring done and recorded.

Fig 3.1: Wadia Children's Hospital

Fig 3.2: Holy Spirit Hospital

Image Sources: Fig 3.1: http://www.magicbricks.com/Parel-in-Mumbai/photos/Hospitals-Pharmacy-in-Parel/Nowrosjee-Wadia-Hospital-photoId-4d42323138373537 as on 16-04-2015
Fig 3.2: http://www.holyspirithospital.org/contact.html as on 16-04-2015

Doctors were interviewed in both Wadia Children's Hospital and Holy Spirit Hospital. The OPD sections in both the hospitals were also observed. The insights from both sets of observations are listed below.

At Wadia Children's Hospital...

The OPD section was extremely crowded with approximately 50 patients in the waiting area and 10 doctors checking them out throughout the day. The children who were brought in here were mostly suffering from some ailment. The OPD section had a running wooden table and bench with doctors sitting on the other side of the table. The entire area was extremely crowded with children, their parents, doctors and nurses.

1. Parents walked in with their infants and sat at the first available spot with a doctor on the wooden bench.
2. The infant was then placed on the wooden bench in supine position and the doctor examined the infant.
3. Due to the crowd, only rare cases were weighed or measured. There was an infant weighing scale for children less than the age of 1.5 years.
4. A wooden infantometer was kept in one corner of the hall, and was not used.

At Holy Spirit Hospital...

The Pediatric ward OPD in Holy Spirit Hospital was selected for observations. Every child that came into the OPD section was first weighed, some were measured and then they were sent to the doctor for consultation.

1. Child was brought in by the parent. Usually the child was carried by the parent. Most of these children were slightly unwell such as fever, cold, etc.
2. Some of the children easily stepped onto the weighing scale when asked to.
3. Some of the children started crying very loudly when they were asked to step onto the weighing scale. They did not want to step down, out of their parent's lap. It was difficult to get a weight reading in some cases since the children kept crying.
4. The doctor on-call, noted down the weight of the child on the notepad.
5. Some of the children were also measured. The child was made to lie down on the bed, one doctor held down the baby's head and oriented it correctly while pressing down the knees to get the full length of the child. Another doctor used a standard measuring tape to measure the child. The starting point of measuring the child was taken as the top of the head and end point as the base of the foot.
6. Children above the age of 1.5 years were measured using stadiometers. This OPD had one attached to a door frame.

Devices used in the Hospitals

Weight measurement

There are two kinds of weighing scales available in all hospitals. One is for weighing infants as shown in Fig 3.4. It consists of a tray to lay down the infant as the infant cannot stand up. Once they can stand up by themselves, an electronic weighing scale such as the one in Fig 3.3 is used.

Fig 3.3: Electronic weighing scale

Fig 3.4: Infant weighing scale

Height measurement

For measuring height, an infantometer and a stadiometer were available. However, The infantometer shown in Fig 3.5 was rarely used. It requires a lot of assistance and the nurses prefer to take the measurement using a tape instead of using an infantometer. The stadiometer shown in Fig 3.6 was used for children who can stand up steadily, i.e. usually above the age of 1.5 - 2 years.

Fig 3.5: Infantometer

Fig 3.6: Stadiometer

Data recording

Each patient is given a booklet which has all infant's information, details of doctor's visits, immunizations, vaccinations, growth monitoring measurements and growth charts.

Fig 3.7: Follow Up Card

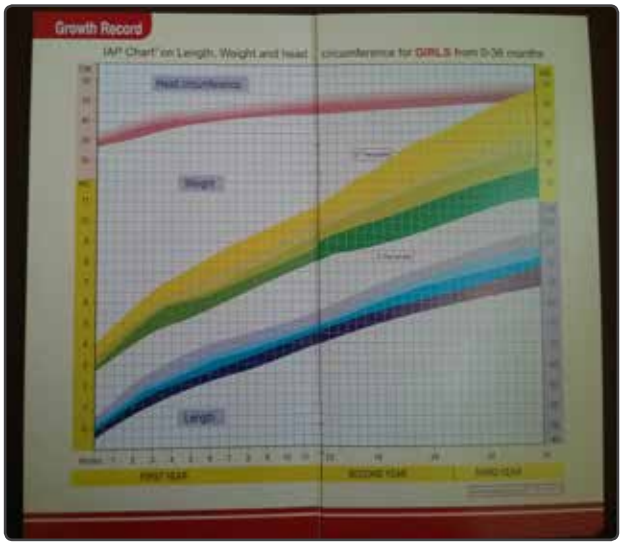


Fig 3.8: Growth chart for Girls 0-36 months

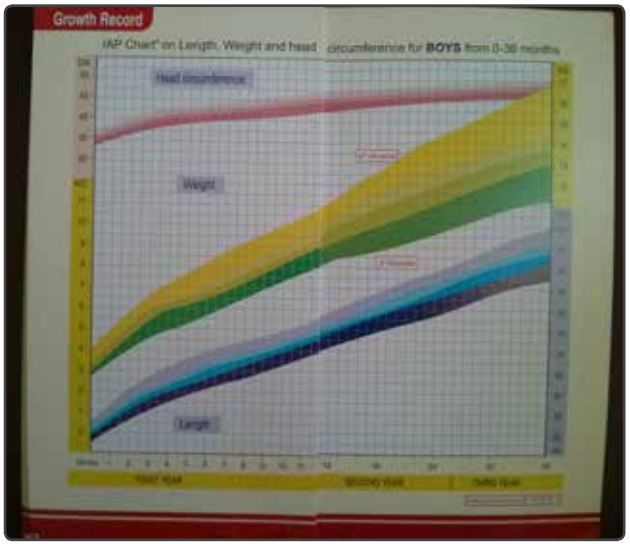


Fig 3.9: Growth chart for Boys 0-36 months

Fig 3.10: Immunization Record

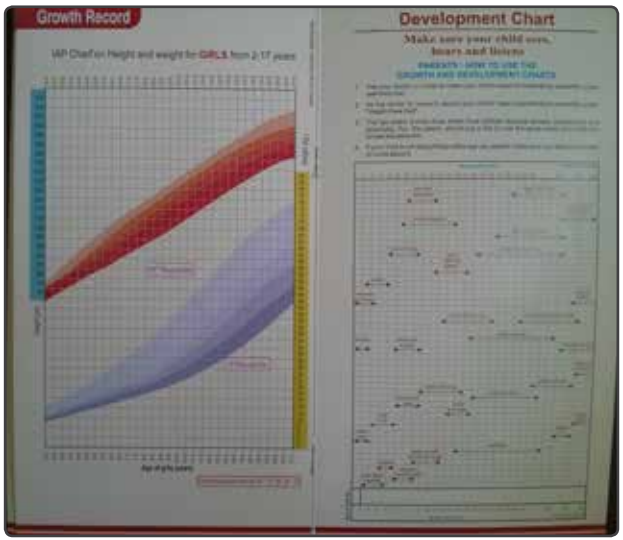


Fig 3.11: Growth chart for Girls from 2-17 years

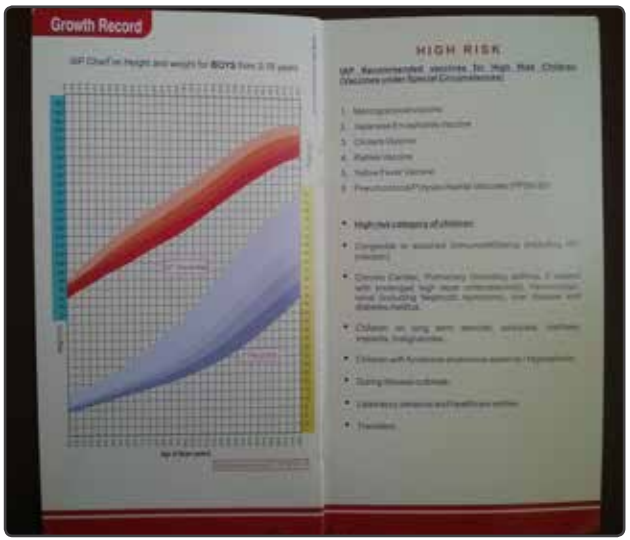


Fig 3.11: Growth chart for Boys from 2-17 years

Insights

Use of infantometer

- In case an infant is sleeping, movement will be less. However, most infants move a lot when placed on such devices. In all this movement, they may also move from the references or roll over the surface of the infantometer.
- The surface is a hard, plastic, flat surface which is uncomfortable.
- Sterilization of the surface is necessary after every baby is measured.
- For measuring new born babies, it must be taken to the maternity wards, operation theatres etc. and thus must be sterilized.
- Since an infant usually lies down with bent knees or with their legs up, the legs need to be held down and the head needs to be positioned properly. Thus, it still takes more than one person to take the reading using the infantometer, thereby adding to effort.

Accuracy

- There is a lack of accuracy in the measurement of height or length. This is mainly because most often, a tape is used for measurement instead of an infantometer. The reference points of the baby are thus not necessarily correct.
- The weighing scales used in such scenarios is usually any weighing scale available such as a vegetable vending scale.Thus, over time, they may need to be caliberated properly if the reading to be taken from them must be accurate.

Safety

- Newborn babies and babies under the age of 6 months are put on the weighing scale. It is necessary to ensure their safety.
- Children between the age group of 1-3 are afraod to get onto the weighing scale.

Hygiene

- The measuring devices are used on several babies a day. It is necessary that the device is hygienic and easy to clean.
- The devices are also used on newborn babies outside operation thetares etc. Thus, it must be sterile.

Time

- The total time taken in doing all the measurements must be less.
- It should be hassle free and easy to record and maintain

Portability

- It must be made portable so that doctors can easily carry it to rural areas, PHCs etc. to take measurements there.
- Installation must be simple, and the device must be easy to use
- The energy source of this product must also be independent of the facilities provided in the village.

Data Storage:

- Study the need for data storage, analysis of trends, levels of malnourishment, growth patterns in different parts of the country etc.

Project Brief

Fig 4.1: Growth for All campaign

Image Source: http://growthforall.org/2008/08/ as on 16-04-2015

Scenario

Several clinics need growth monitoring systems. Weight, height and head circumference of infants is regularly monitored. These must be done responsibly and regularly for proper counseling and diagnosis in case any problems arise. Growth monitoring charts help in detecting problems and correcting them at the earliest. Often, organizations set up health camps in villages or remote locations. One such Growth for All campaign is shown in Fig 4.1. Such situations also require portable, robust, safe and accurate growth monitoring systems.

User

The growth monitoring system may be used by nurses, doctors, and partially trained health workers in a rural health camp or clinics. The system should be easy to carry, set-up, use and dismantle.

Design Objective

To allow for easier, faster and more accurate growth monitoring procedures

Design Brief

To design a growth monitoring device which allows for measurement of height (cm), weight (Kg) and head, chest and abdomen circumference (cm) and adhere to the following features:

1. Requires less number of people to take readings
2. Portable for easy transportation and use in rural areas
3. Generates fairly accurate and repeatable data up to first place of decimal.
4. Allows for easy sterilization between uses
5. Ensures safety and security of the infant

Ideation

After having the Scenario and Design Brief in place, ideation was started. Based on secondary and primary research, some directions for ideation were listed.

- Control the movement of the infant
- Sterilization methods
- Making it as one person's job
- Technology available for measurements, such as sensors, scanners etc.
- Analogies from existing measuring devices in the market
- Safe looking product
- Play value for children
- Portable - Detachable, Collapsible etc.
- Support provided for the head
- Non-contact type

A market study was done of existing measurement related products to find analogies or technology which is already being used.

Based on all the insights, a mindmap was made and then ideation sketches were started.

Mind map

After a list of insights to ideate were listed out, a mind map was generated to bring out all the related points to consider and possible design directions. This mindmap allowed for several points to be collected in one place for ideation.

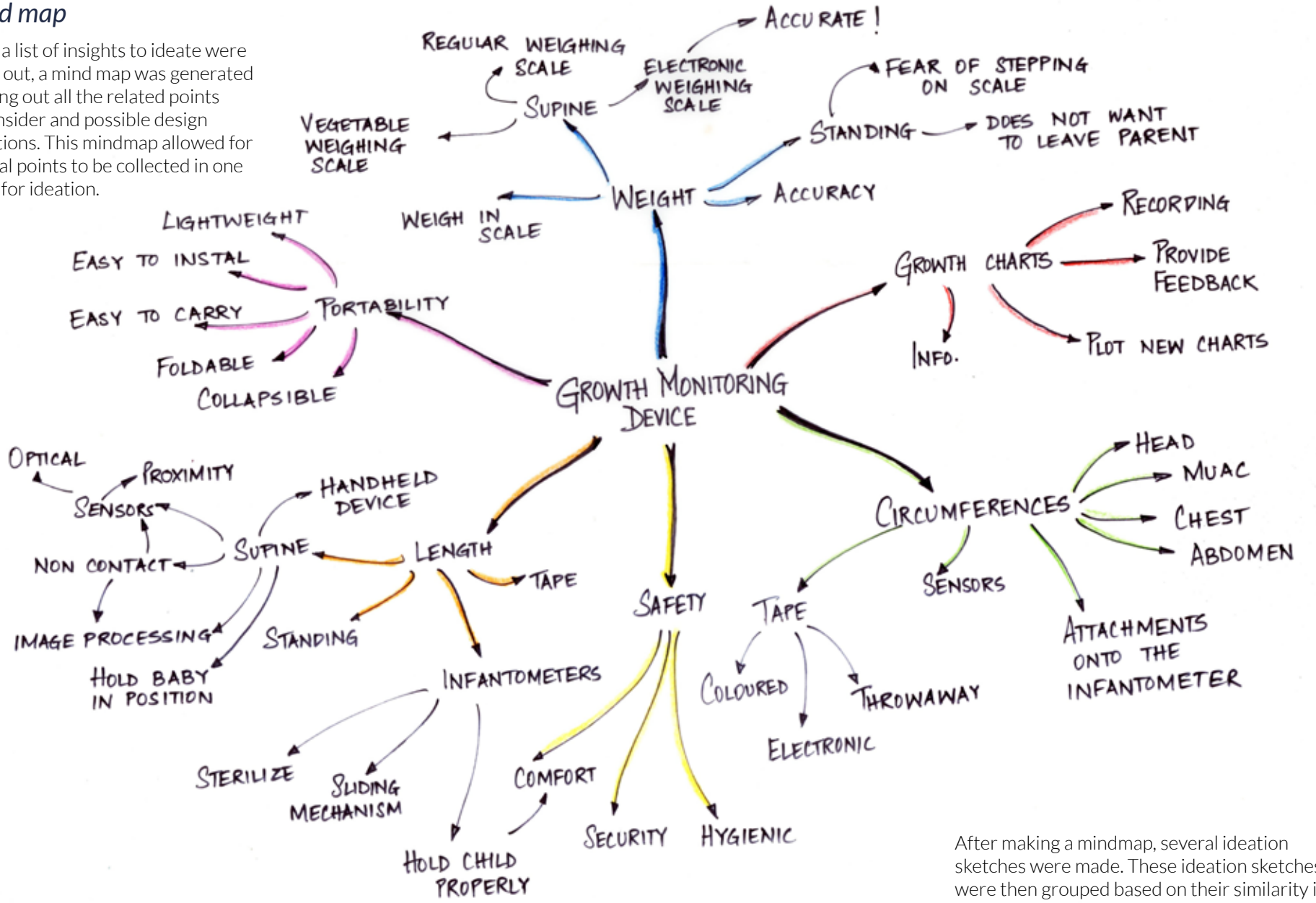
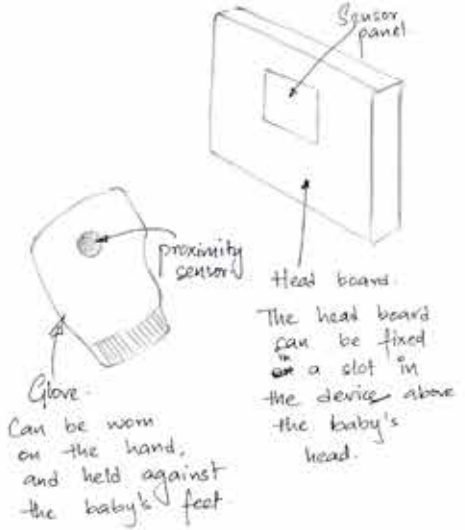


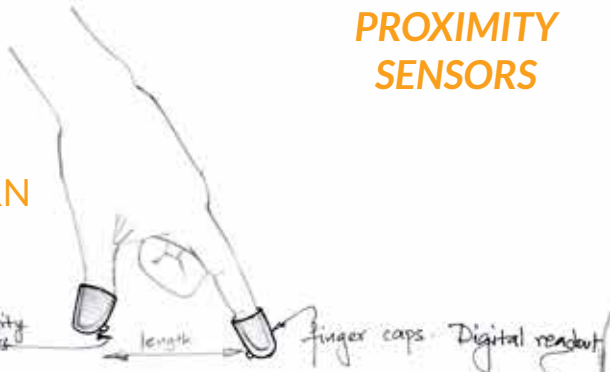
Fig 5.1: Mind map

After making a mindmap, several ideation sketches were made. These ideation sketches were then grouped based on their similarity in features or technology used.

PALM WORN



PROXIMITY SENSORS



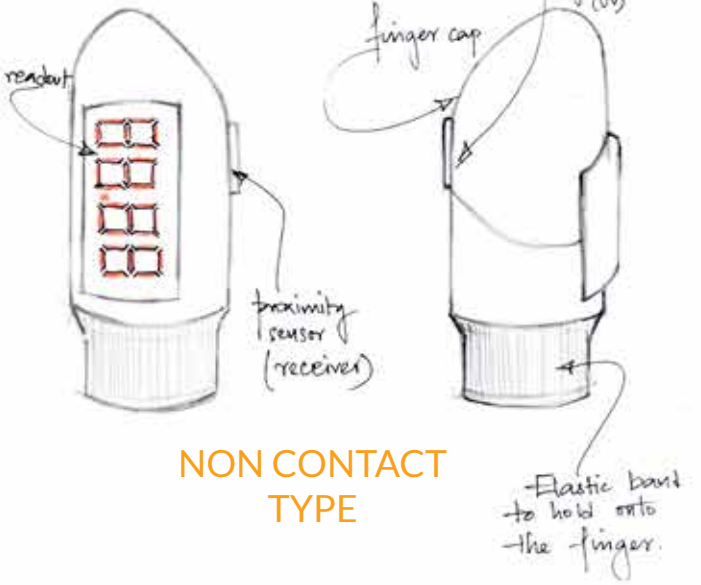
FINGER WORN

Pros
- *Easy use*
- *Convinient readings*
- *Comfortable for the infant as there is no restricted movement*
- *Infant can be laid on any surface*
-

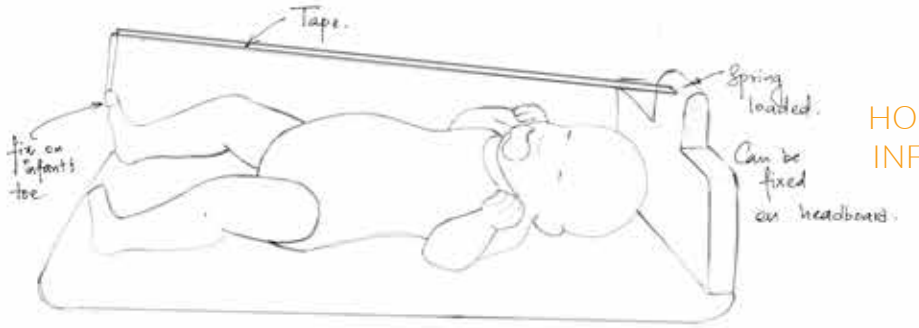
Cons:
- *High maintenance*
- *Battery source is required.*
- *Might not be very accurate since finger movements may vary*
- *Might take contours into account thereby making length longer than it is*
- *Requires a learning curve*

Bulges at various locations for supporting the

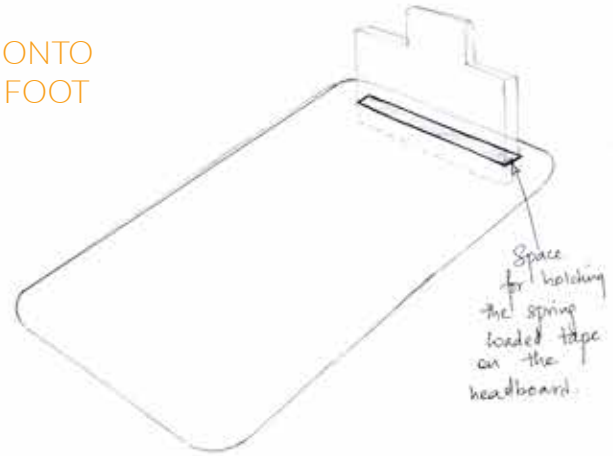
SMALL ROLLERS ON FINGERS. ROTATIONS CAN GIVE THE LENGTH



NON CONTACT TYPE



HOOKED ONTO INFANT'S FOOT

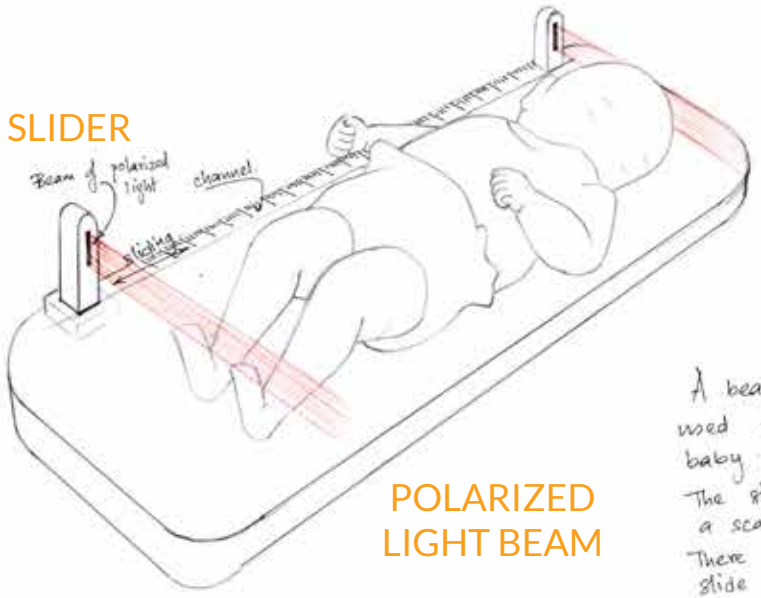


Can be one small unit that can be fixed onto the weighing scale [which in turn can have provision for a holding it].

This can reduce bulk & weight drastically.

CONTACT TYPE

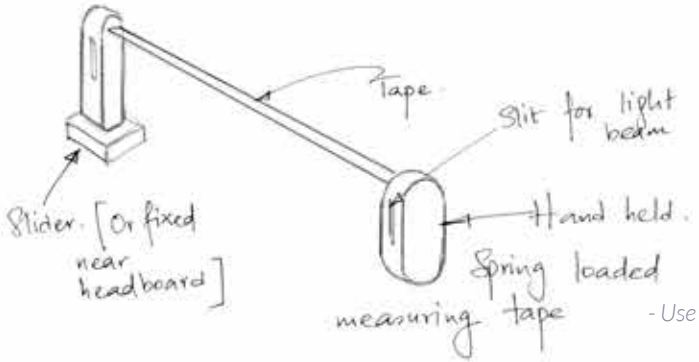
SLIDER



POLARIZED LIGHT BEAM

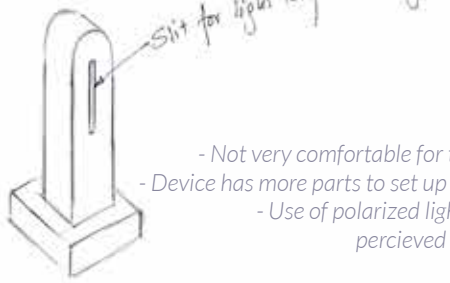
A beam of polarized light can be used to mark the extremities of the baby.
The side of the device [the edge] can have a scale.
There are two sliders [or one] which slide on the scale for the measurement.
Once the head has been adjusted, the legs can be made straight.

MEASURING TAPE



Pros

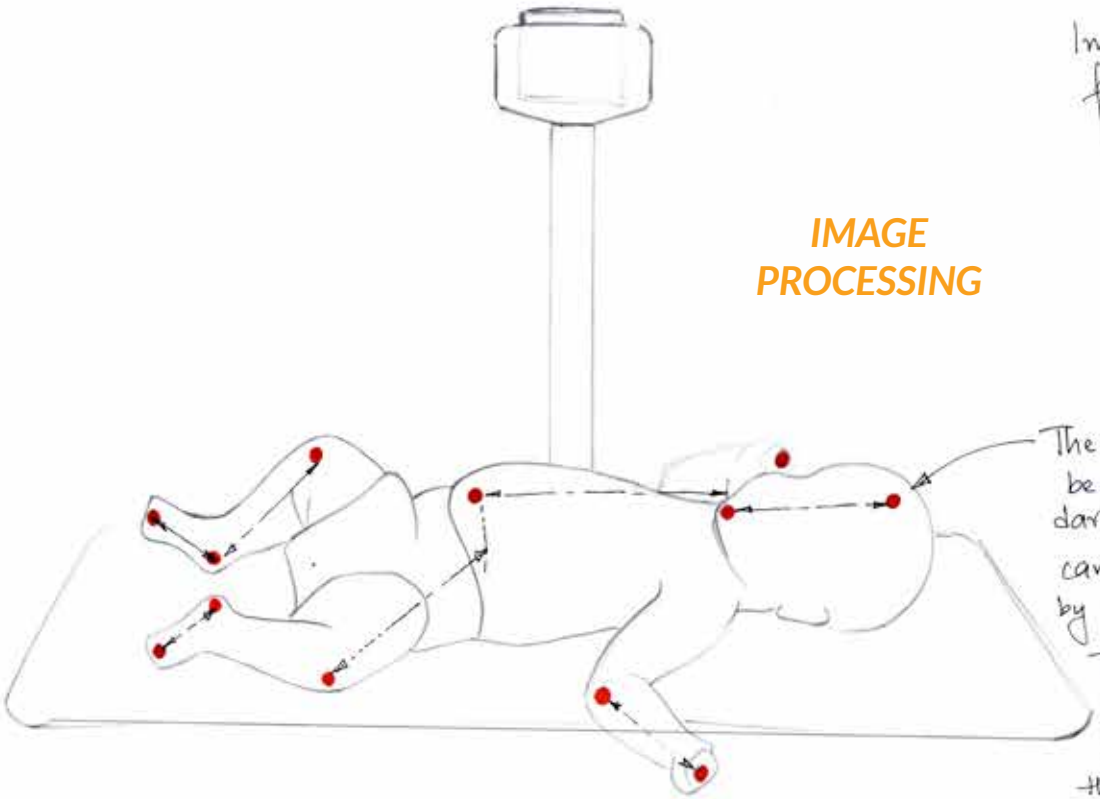
- Simple method
- Use of existing measuring tapes makes the product frugal
- Less learning curve
- Accurate



Cons:

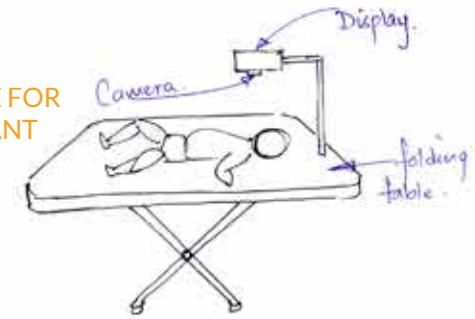
- Not very comfortable for the infant
- Device has more parts to set up and store
- Use of polarized light may be percieved as unsafe

IMAGE PROCESSING

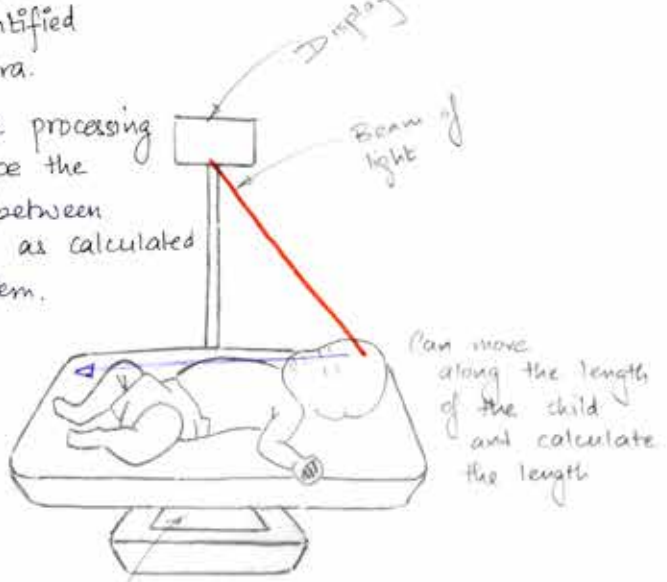


SPOTS ON INFANT'S BODY TO PROCESS

CAMERA SET UP



FOLDING TABLE FOR PLACING INFANT



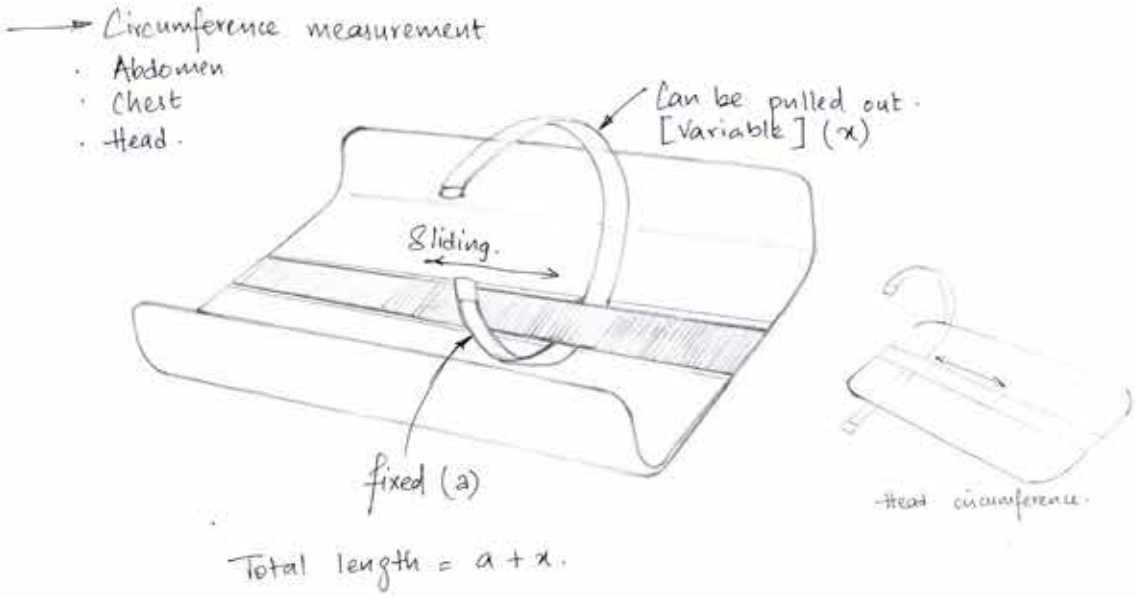
SCANNING THE BODY

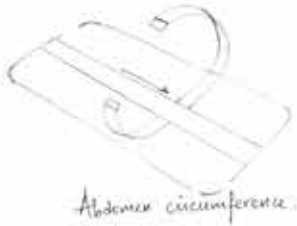
SAND SCANNING

Pros:
- *Highly accurate*
- *Can provide data about all limb lengths as well*
- *Fast*
- *No restriction of movement for the infant*

Cons:
- *Has a high learning curve*
- *May be percieved as intimidating and high-tech*
- *May be percieved as unsafe for infant*
- *Expensive*
- *High maintenance*
- *Device is not robust*
- *Will require a power source*

CIRCUMFERENCE MEASUREMENT





Pros

- Simple method
- Use of existing measuring tapes makes the product frugal
- Less learning curve

Cons:

- Infant's weight on the tape makes alignment difficult
-May require assistance of parent

FOLDABILITY / COLLAPSIBILITY

Pros

- Makes product more compact
- Easy to carry
- Allows for larger surfaces to be incorporated

Cons:

- Hinge details may fail

MATTRESS CONTOURING

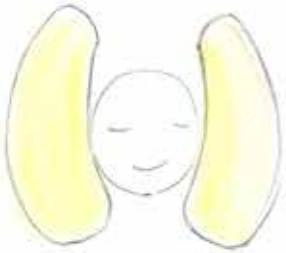
Pros
- *Integrated with the mattress*
- *Comfortable for infant*
- *Restricts movement*

Cons
- *Will make the product bulky*
- *Maintenance is required*

HEAD SUPPORTS

Head & Neck supports of various shapes.

→ These can be placed around the child, once the child is laid down so that the head is placed correctly & there are no measurement errors.

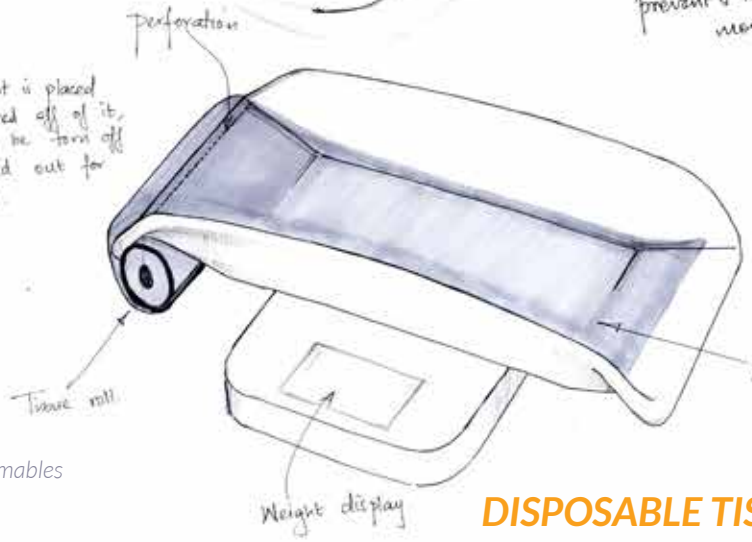


Two or three sizes of these head & neck supports can be made available for various head sizes.

Pros
- *Comfortable for the child*
- *Can be made colourful and playful*
- *Restricts movement comfortably*

Cons
- *Will make product bulky*
- *Add more elements to the kit*
- *One size may not fit all*
- *Would require a range which would be expensive*

DISPOSABLE TISSUE ROLL FOR HYGIENE



Pros
- *Easy use*
- *Disposable*

Cons
- *Increases use of consumables*

Brainstorming and Idea Evaluation

A brainstorming session was held to get a large number of varied ideas in a short span of time. These were useful for exploration and better understanding; It also increased the number of directions which could be considered for making the device. All ideas irrespective of suitability were considered and then evaluated post the brainstorming session. After the brainstorming session, concept clusters were created from all the ideas evaluated.

IDEA	PLUS POINTS	CONCERNS	NEW IDEAS
IMAGE PROCESSING	• Highly accurate • Can fit all shapes and sizes Can give lengths of various limbs	• Baby staying still ?? • Bending body ? • Prototype time frame ? Possible in P3? • Protect child's eyes	• Instead of put marker • Hanging stuff, play • Have a scanner
POLARIZED LIGHT BEAM	• Nice minimalist aesthetics • Height measurement seems promising	• Child movement is a major concern Material for hygiene Cost factors ? $$ • Safety of babies' delicate skin	• Can the baby be checked standing? CLOTHING for measurement ??
PROXIMITY SENSORS	Neat measurement technique Sliding sensor — fixed sensor	• Caps on fingers — Accuracy? How to make sensors align properly?	• Like WACOM - INKLINK pen. Draw straight line, it measures length • Roller on finger - count rotation - move finger
CIRCUMFERENCES	Tape sliding good	More wearable ideas needed Protect head, eyes	• Inflatable air pillows - All contours can be measured. • Check circumference or curvature measurements used for clay sculpting Inflatable rubber ring like ?
TAPE	• Throwaway tape Cheap Hygiene	• Bends, curves will get added • Inaccurate	Disposable cute tape for baby
HYGIENE	• Roll of tissue — good idea.		Roll of paper could have pre-printed scale
COMFORT, SAFETY	• Soft contouring for baby's body for safety - good	• WHACKYNESS !!	Inflatable products Air / Sand / Water ? • Heating element — To attain/maintain body temp
SPRING LOADED TAPE	• Good for frugal solution One hand hold, one leg side Pull — record.		• Piggyback idea - Add flags, play values, sound etc
EYE PIECE	• Calibrated scale • No extra instrument	• Maybe expensive • May have a learning curve ? Tech support ?	
GLOVE FOR WEIGHT	• Hold in hand • Does not need to leave lap • Reduces crying	Expensive ? Execution ? Big children ? Tech support ?	Weight + height in VEST like design Pressure cuff type cloth - with sensors ?
HEAD SUPPORTS	• Comfort • Safety		
PLAY VALUE	• Children won't be scared to leave parent	— Might not be priority — It does not take too much time	• Sandpit, changing things • Game for the kid?
SCANNING	3D scanning Photograph baby — process later	Expense ? Execution Tech support ??	Barcode type scanner • Sand Image Processing • Scan baby - move ba • LIVESCRIBE - tech solution • Sand KINECT - contours

Fig 5.2: Idea Evaluation

Conceptualization

After evaluating all the ideas,some key points that came acrss were the following:

- The product had to be affordable to be used in smaller health clinics and rural hospitals.
- Ease of use was important so that the doctors used it and did not ignore growth monitoring procedures.
- The product had to be portable and easy to set up in health camps, etc.

Three types of concept clusters were seen being formed:

Attachment type:

One type was such that it could not take all the measurements required, but different concepts in this cluster were very good for some measurements.

Portable products:

The second cluster considered all types of portable products. These used principles such as foldability, collapsibility, detachability etc.

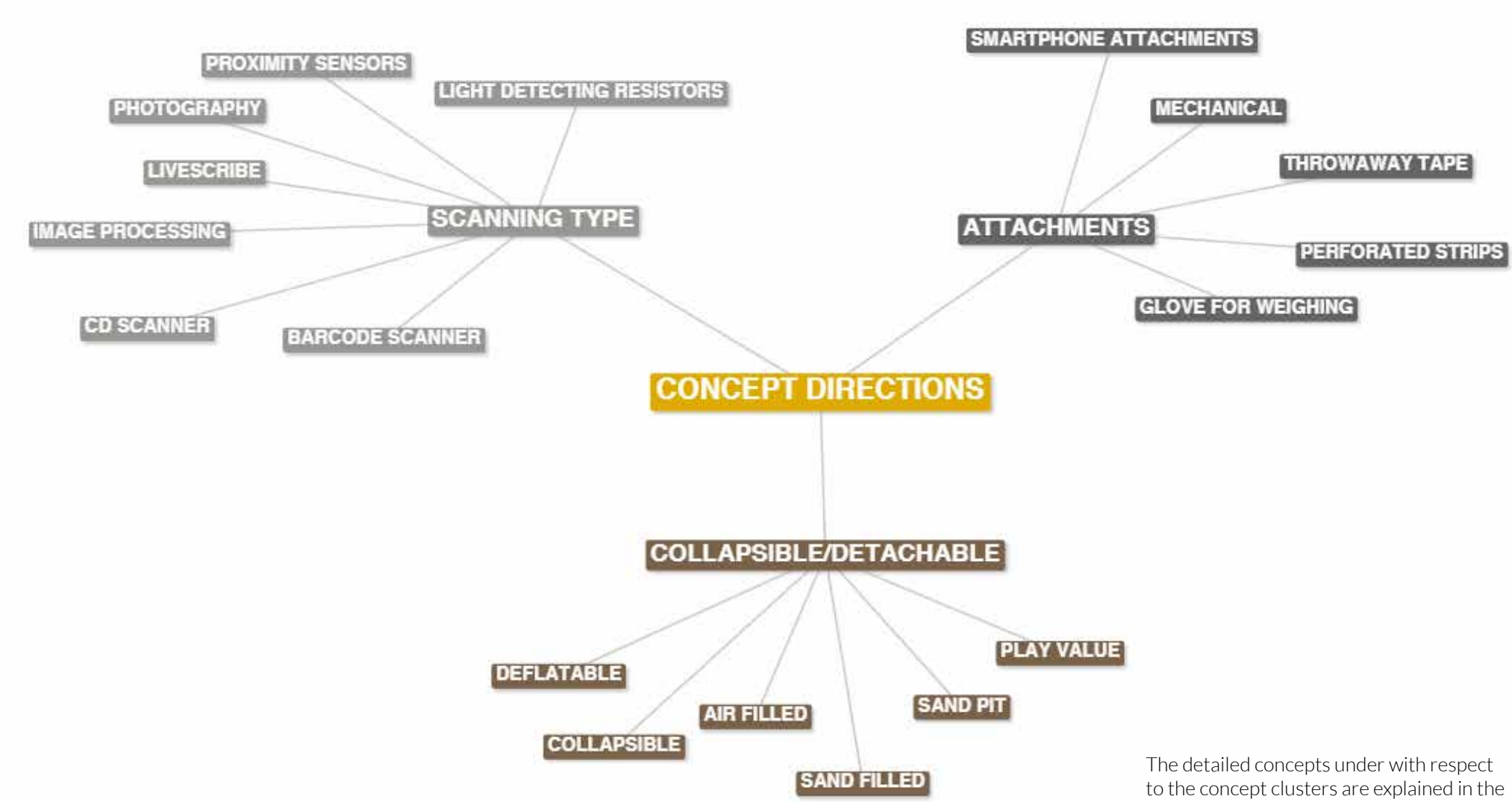
Scanning devices:

Various types of scanning methods could be used for the device. However, most 3D scanning techniques would not be feasible. Thus, simpler scanning methods such as Barcode scanners, CD ROM scanners could be used for finding the length.

The following page shows the sorted out ideas grouped under the three concept clusters.

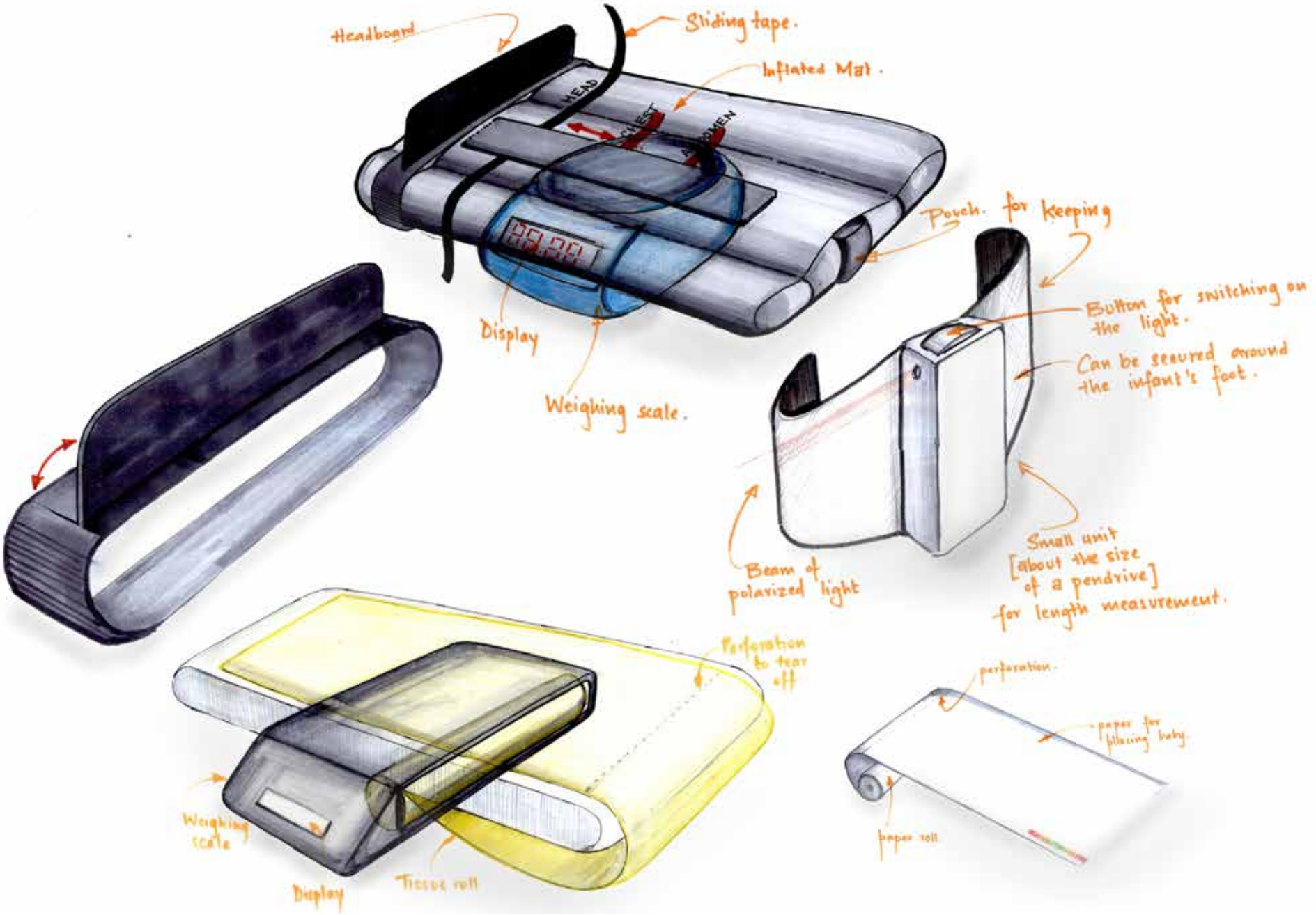
Concept Clusters

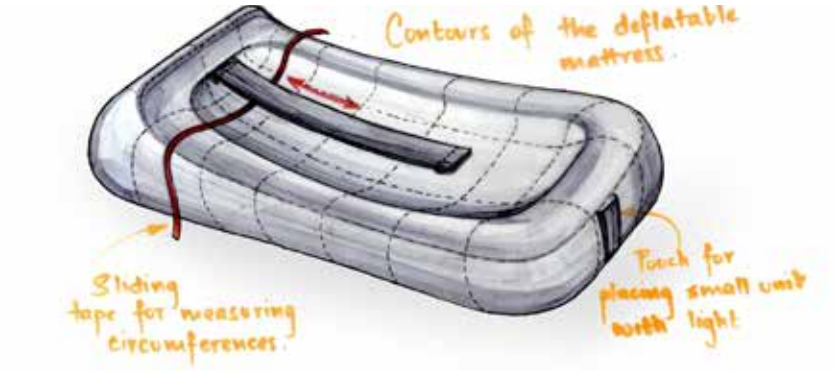
The three concept clusters shown in the following Fig 6.1 are Scanning type, Attachments and Collapsible type.



The detailed concepts under with respect to the concept clusters are explained in the following pages.

Fig 6.1: Concept Clustering


Headboard
Sliding tape.
Inflated Mat.
HEAD
CHEST
ABDOMEN
Display
Weighing scale.
Pouch for keeping
Button for switching on the light.
Can be secured around the infant's foot.
Beam of polarized light
Small unit [about the size of a pendrive] for length measurement.
Perforation to tear off
Weighing scale
Display
Tissue roll
perforation
paper for placing baby
paper roll



Pros:

- Comfortable for the infant
- Restricts movement of the infant
- The mattress can be deflated and folded.
- Lightweight
- Easy to carry
- All the measurements can be taken with this concept. Thus, one product would serve all purposes.

Cons:

- The head support can deform since it is soft material and the infant can be pushed further than needed.
- The mattress may buckle under the weight of the infant and not give the correct reading.
- The slider would give a small error in the circumference reading which would have to be considered.

Concept cluster 1: Portable device

In this concept, portability is the primary feature. Collapsible, foldable, inflatable products were studied.

Weighing scale:

An electronic weighing scale is used for weighing the infant. It has a LCD display and a power button. It is battery operated and houses a rechargeable battery. It could be used in camps, etc and then recharged when not in use. It would have another larger surface on it for the child to be placed on and weighed.

Inflatable mattress:

An inflatable mattress is used for holding the infant to be measured and weighed. It is contoured to cradle the baby safely so that the baby does not roll off. Since an inflatable mattress is used, it would be far more comfortable for the child. The contouring of the mattress would also accommodate for a head support. This would act as the reference for length measurement of the infant.
The inflatable mattress would also have the scale impressed on to the side of the mattress so that the length reading can be taken easily. A small unit for length measurement would be held in a small pouch on the foot-side of the mattress. Once the mattress is deflated, it can be folded and wrapped around the weighing scale.

Slider for circumference measurement:

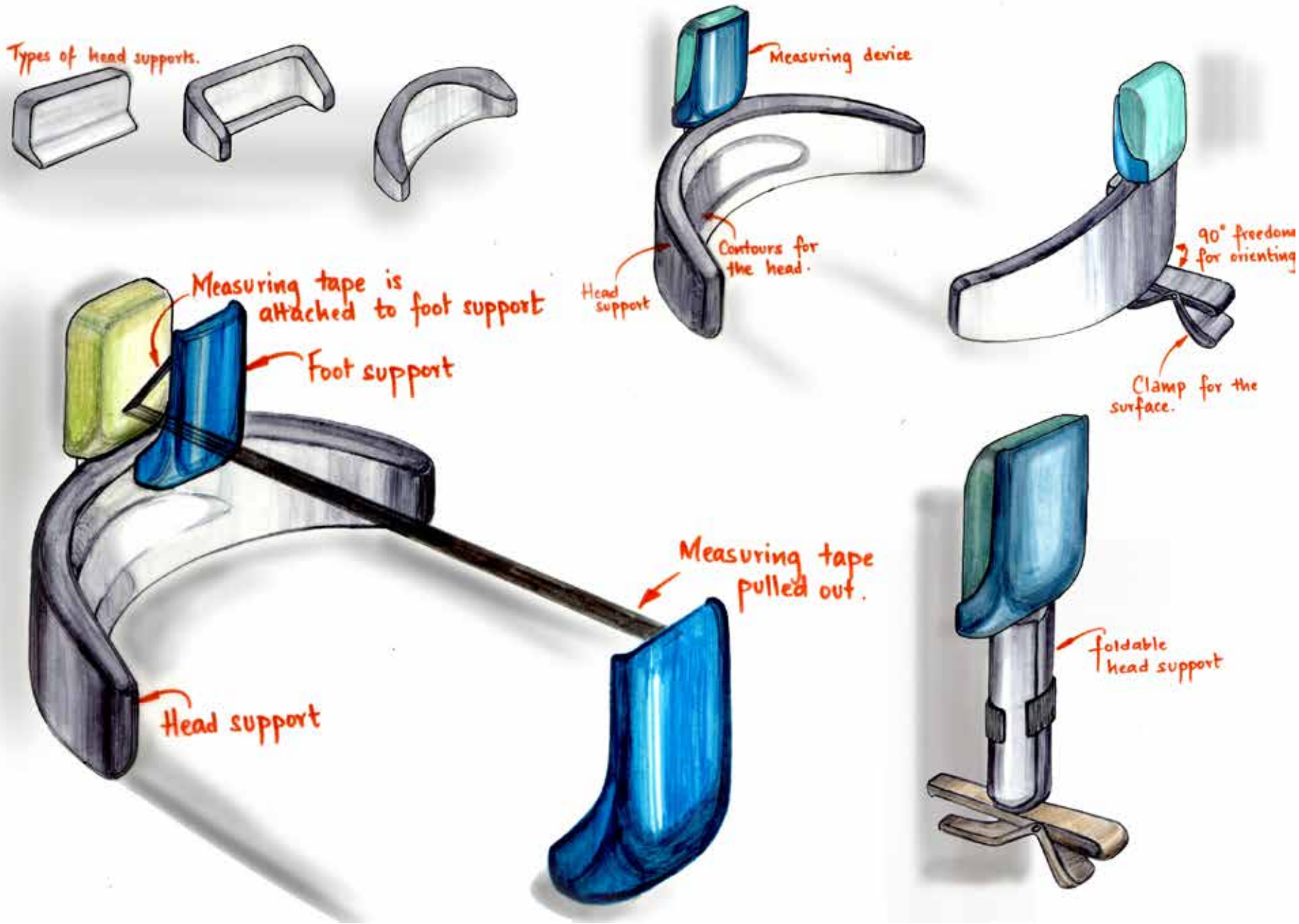
A measuring tape is placed under another strip of plastic on the inflatable mattress so that it can slide from head to abdomen to measure the head, chest and abdomen circumferences. Since all these are measured in one axis only, it can be placed under one strip for easy usage.

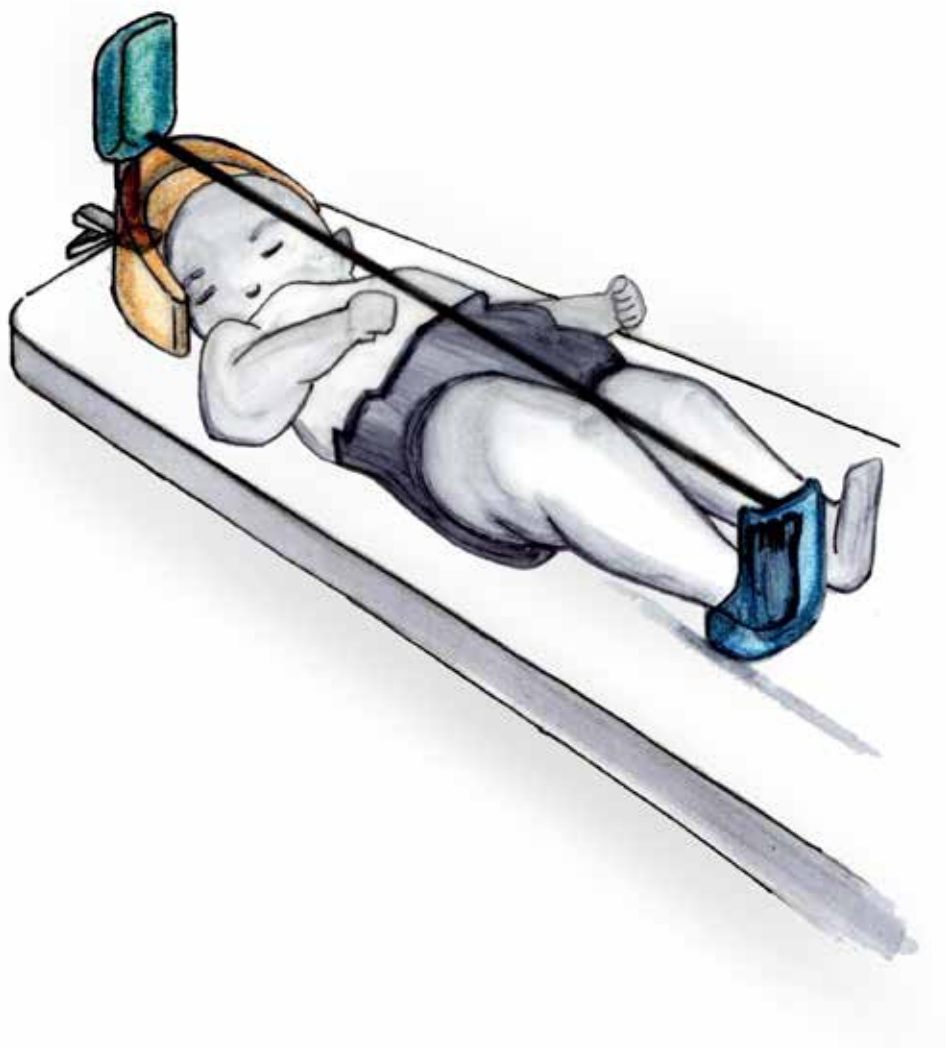
Unit with a light beam pointer:

A small unit which has a beam of light can be used to point at the length that needs to be recorded on the scale which is impressed on the mattress. This unit can be a small unit which is battery operated and strapped onto the foot of the infant. Once the infant's legs are stretched out, the pointer would point at the correct length reading.

Tissue roll:

A tissue roll can be housed in a slot in the weighing scale. This tissue roll can have perforated sheets which can be used on the mattress for making sure it is hygienic. After each baby, the sheet can be ripped off and disposed.


Types of head supports.
Measuring device
Contours for the head.
Head support
90° freedom for orienting
Clamp for the surface.
Measuring tape is attached to foot support
Foot support
Measuring tape pulled out.
Head support
foldable head support



Concept Cluster 2: Attachment type

This concept consists of an attachment that can be latched onto any surface such as a table or a bed. This attachment would help in accurate length measurement of the infant with minimal effort in terms of holding the baby in position.

Head reference:

The head support in this product acts as a head reference or as the point from where the measurement begins. It also supports the head of the infant and has a hard surface for supporting the head. Even though a soft surface would be comfortable, it cannot be used as it may yield if the infant is pushed upward and give an error in measurement.

Heel reference:

A heel reference is needed at the foot end so that the measurement of the baby is accurate. This is attached to the spring loaded tape and can be pulled out to measure the length of the baby.

Spring loaded recoiling measuring tape:

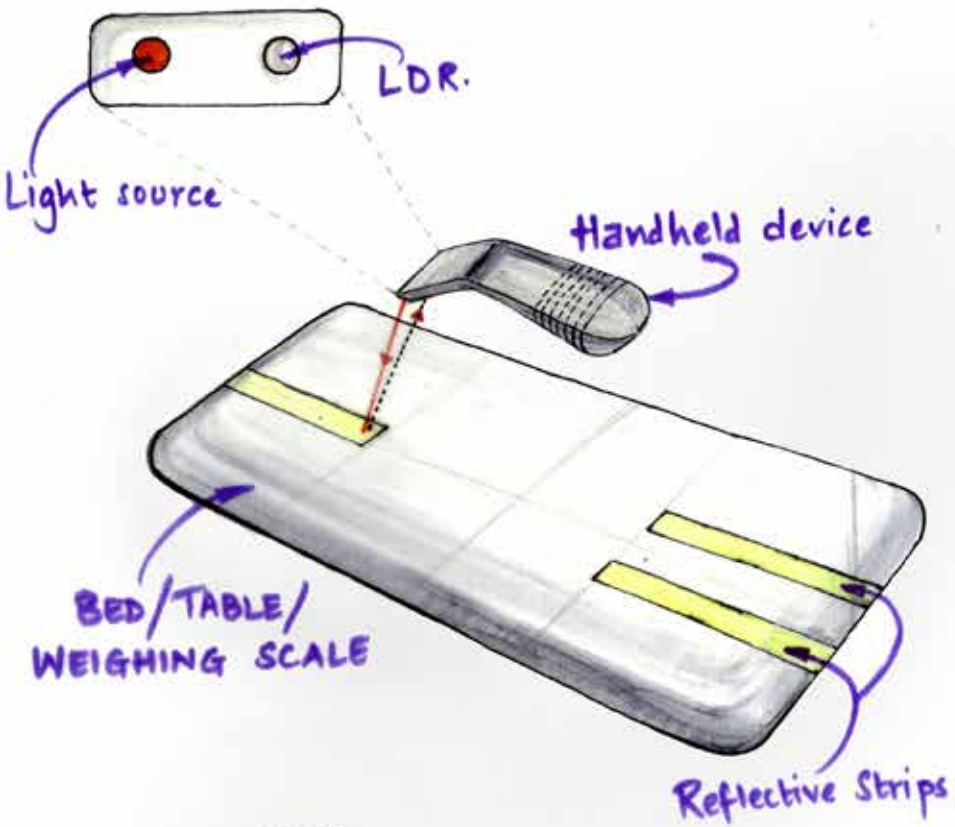
A spring loaded measuring tape is concealed in the casing behind the head support. The heel support is attached to the front end of the measuring tape. For measuring the infant, the tape is pulled out and the heel reference is used to measure the infant. Once the measurement is complete, the tape recoils and the attachment is compact again.

Pros:

- Simple mechanism is used in this device
- It is easy to use. No learning curve required
- Can be attached to any surface.
- The head and heel reference allows the reading to be accurate
- It is easily repairable

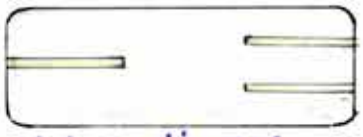
Cons:

- Does not cater to weight measurement or circumference measurements.
- Cannot be used on the floor since it requires to be clamped. In such a case, the product should be provided with another attachment to sit properly on the ground.

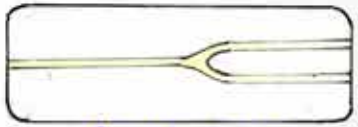


ROLL OF
REFLECTIVE STRIP

ORIENTATIONS OF
REFLECTIVE STRIP

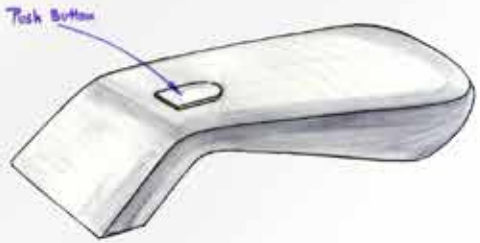


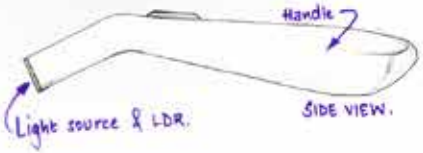
Not continuous

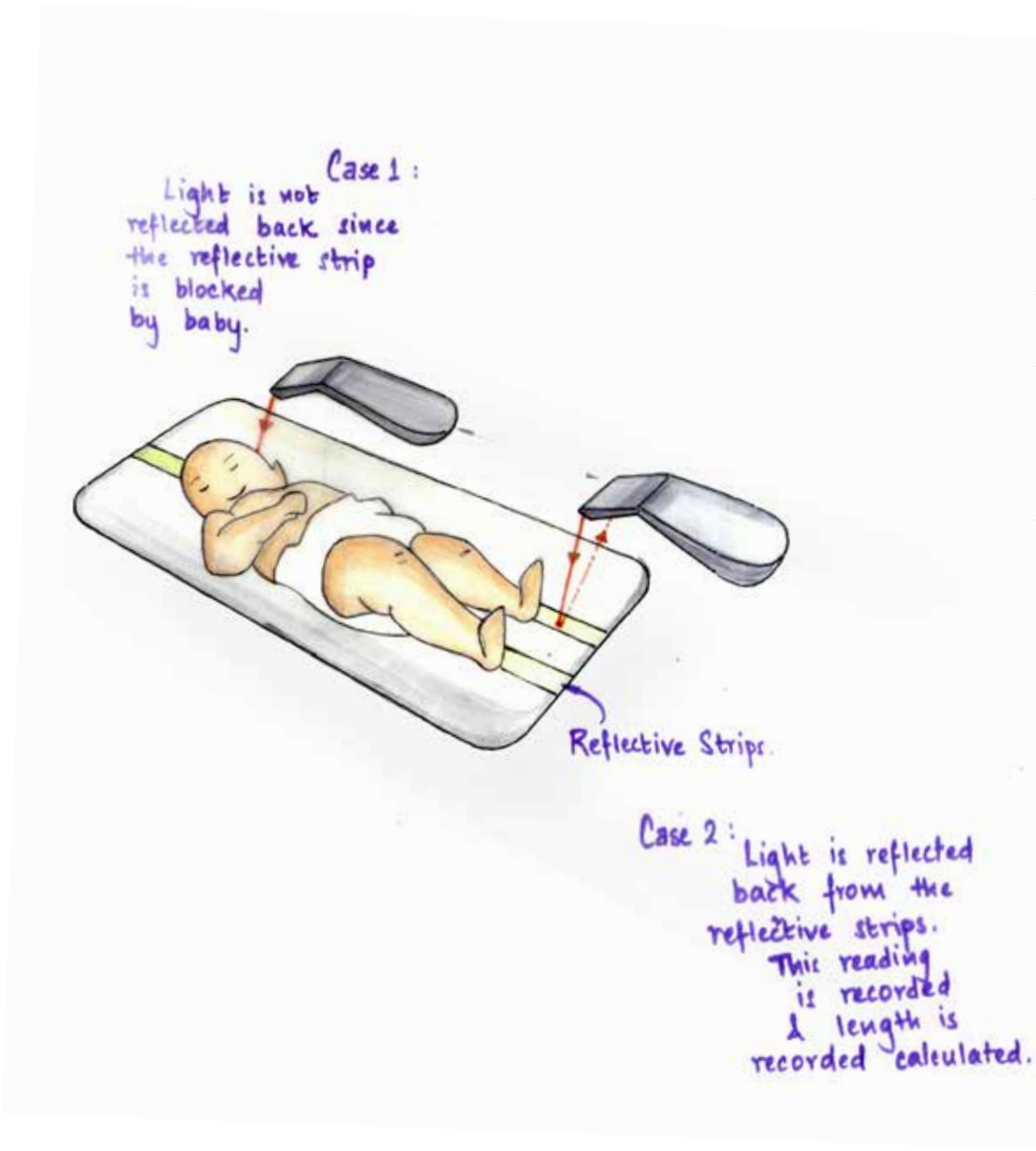


Continuous

BOTTOM VIEW







Concept Cluster 3: Scanning the infant

Scanning the infant safely, using various methods such as 3D scanning, sand scanning, livescribe, sensors etc. was explored. However, for the given application, most of these concepts turned out to be too complex or too expensive. Simpler scanning devices such as barcode scanners, CD scanners were considered. Ultimately light detecting resistors were used for scanning and recording the length.

Handheld device:

A handheld device consisting of batteries, a small light source and a Light Detecting Resistor (LDR) was used. This device would use simple circuitry to relay the light stimuli as start and end points of the infant's body, thereby converting it to a length reading. The light beam moves over the reflective strips and is reflected back to the LDR. When the light stops being reflected back, the infant's head begins. This is the first value that is fed to the microprocessor. Once the scanner goes past the infant's feet, the light starts getting reflected back to LDR. This point is the second value which is fed to the microprocessor. The programming of the processor allows the length to be calculated from these two values.

Reflective strips:

Reflective strips are used to reflect the light from the scanner back to the LDR. These strips can easily be pasted onto any surface on which the infant would be placed.

Pros:

- Inexpensive scanning method used.
- The components of the scanner can be procured easily.
- Accurate reading will be obtained.
- Simple to use
- The light beam being reflected acts as a guide to the hand moving in a straight line. Even if the hand deviates a little, the reading will not be affected.

Cons:

- Due to the use of a beam of light, it does not give the perception of safety. Most parents would seem apprehensive of their babies being scanned with a beam of light.
- Does not allow for circumference measurement.
- A separate weighing scale needs to be used for weight measurement as well.

Concept Evaluation Criteria

No. of measurements taken

The Growth Monitoring device is supposed to take the 6 measurements, viz. weight, length, head circumference, MUAC, chest circumference, abdomen circumference. Out of these, the first three are compulsory, and the next three are only for malnourished children.

No. of people involved in taking a measurement

Currently atleast two people are required to take most of the measurements. Often, three people are required to hold the child in position and take the reading correctly. One or two persons should be using the device, to ease the process and reduce effort required.

Ease of measurement

The growth monitoring process is important but often ignored since it does not have any immediate consequences. Moreover, taking measurements of an infant accurately can be quite cumbersome. Thus, it is necessary to make the whole process easier, simpler and faster.

Affordability

This product is for the segment that uses such devices in Health camps, Health centers, rural hospitals, remote places etc. and thus needs to be affordable.

Portability

The product is positioned to be used in temporary locations such as Health camps or used by doctors who visit homes and other places and set up equipment there. Thus, it is necessary for the product to be lightweight, easy to carry, easy to store, set up and dismantle.

Safety of the infant

Since this product would be used for infants right from birth to the age of 1.5-2 years, it needs to be safe for their delicate bodies, comfortable and hygienic

Perception of safety

Parents of new born babies are very apprehensive about what kind of equipment is used on their babies. Thus, it is important that the device has the perception of safety, such that it looks like it could do no harm to the infant.

Criteria	1	2	3	4	5
No. of measurements taken	Weight/Length	Weight, length	Weight, Length, 1 circumference	Weight, Length, some circumferences	Weight, Length, All circumferences
No. of people involved	3 persons	2 persons and very little help from third person	2 persons	One and very little help from another person	One person
Ease of measurement	More difficult than current process	As difficult as the current process	Easier than the current process	Easier, simpler than the current process	Easier, simpler, faster than the current process
Accuracy	1: Very expensive	Less expensive	Neither expensive nor affordable	Affordable	Very affordable
Portability	Lightweight	Lightweight, easy to carry	Lightweight, easy to carry, easy to store	Lightweight, easy to carry, easy to store, set up	Lightweight, Easy to carry, set up, dismantle
Safety of the infant	Very unsafe	Not entirely safe	Neither safe nor unsafe	Safe	Very safe
Perception of safety	Very unsafe looking product	Unsafe looking product	Safe looking product	Very safe looking product	Very very safe looking product

Table 6.1: Defining the evaluation criteria

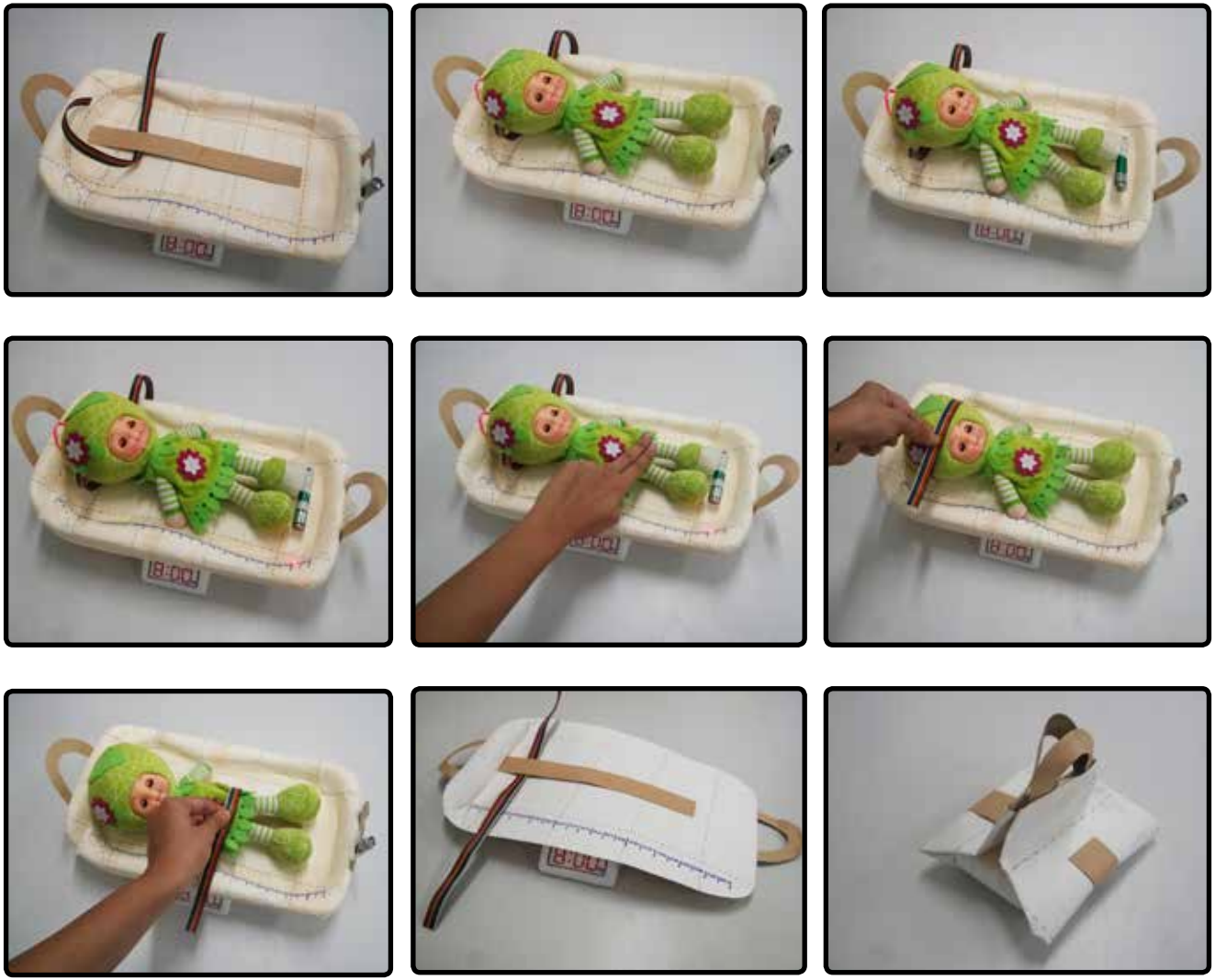
A scale of 1-5 has been used to score the concepts wrt each criteria. The points have been defined for each criteria.
Concept 1 and Concept 2 were further explored in terms of the activities associated with taking the various measurements.

Criteria	Concept 1	Concept 2	Concept 3
No. of measurements taken	5	3	3
No. of people involved	5	5	3
Ease of measurement	4	4	5
Accuracy	4	5	4
Portability	5	5	4
Safety of the infant	5	4	2
Perception of safety	5	4	2
SUM	**33**	**30**	**23**
Rank	**1**	**2**	**3**

Table 6.1: Evaluation of the three concepts

Activity Analysis using mockups: Concept 1

1. First the mattress is inflated by pressing the pump button.
2. The infant is placed on the contoured mattress against the head support. This makes sure that the start point of the infant's length measurement which is the top of the head is aligned with the scale on the mattress.
3. The small light unit is wrapped around one foot of the infant.
4. The light is switched on
5. With one hand, the person pushes down the knees of the child to make the legs straight so that the reading taken would be correct. The reading is then taken where the light beam falls on the scale.
6. The sliding tape is then used to measure the head circumference. It is wound around the head of the infant, and the reading is read from the tape.
7. The tape is then slid down and aligned to the reference lines on the mattress so that the to take chest and abdomen circumferences
8. After several uses, the mattress is deflated using the same pump button.
9. It is then folded up and the handles are used to carry it.



Activity Analysis using mockups: Concept 2

1. The attachment type device is taken out for use.
2. It is then clipped onto any surface such as a bed or a table.
3. The infant is placed on this surface with reference to the head support.
4. Pull the tape out which is attached to the heel support.
5. The heel support is placed under the foot to get the correct orientation and measurement.
6. After all the infants are measured, it is removed from the surface and stored away.

Results & Insights

Collapsible type:

1. Allows for measurement of an infant by one person.
2. It allows to measure all required measurements
3. Gives a head support for the infant. However, the soft material of the inflatable mattress might not give a fixed reference. In case the child is pushed upwards slightly, the support might yield and accommodate the infant's head.
4. Since the mattress is not completely rigid even when inflated, it will slightly buckle when the child is placed on it. Thus, the weight reading may not be correct.
5. The device is lightweight and portable and can be used in several scenarios.
6. The slider used is a plastic slider which may not allow proper movement once the weight of the infant is applied on it.
7. The inflatable mattress can be sold as a separate item as well. In such a situation, it is assumed that the buyer has some standard weighing scales and uses the mattress only for comfortably placing the child and taking length and circumference measurements.
8. The tape for circumference measurement needs to be moved equally from both sides so that it is not slanted.
9. The perforated tissue can have strips of tape for circumference measurements. These can be thrown away along with the tissue after taking the measurement. Thus keeping the use of the product hygienic.

Attachment type:

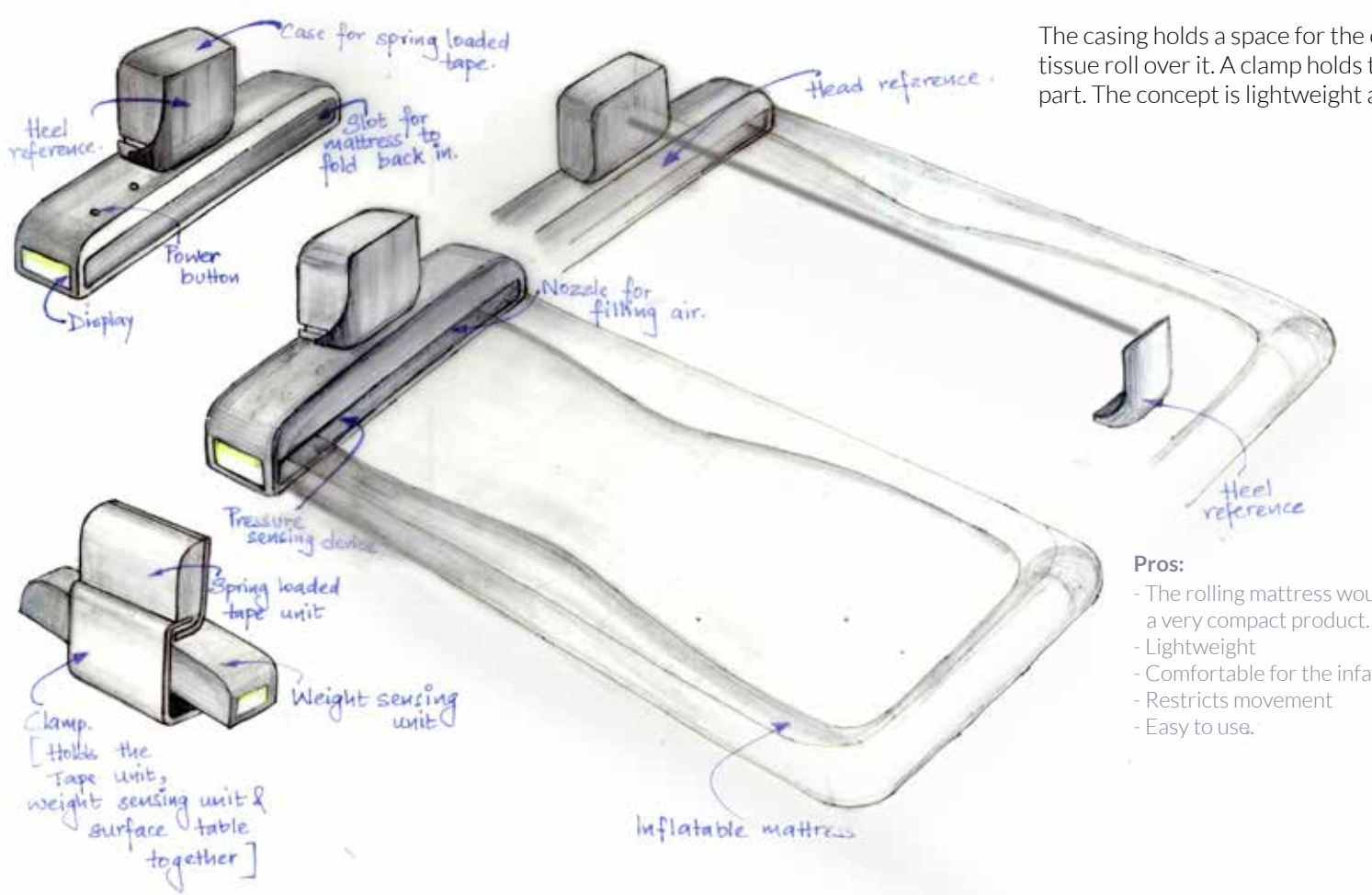
1. Allows for measurement of an infant by one person.
2. The Attachment type concept cannot be used to measure circumferences.
3. The device is lightweight and portable and can be used in several scenarios.
4. Here also, it is assumed that the buyer has some weighing scale and uses the attachment on any existing surface.
5. Provides head support which also acts as a head reference
6. The Attachment type device can be made low cost.

Based on the insights, the two concepts, integration of both concepts was started to get the best of both. Few more concepts were developed.

Pressure sensing mattress

In this concept, a regular weighing scale has been replaced by an inflatable mattress with pressure detecting sensors. A small pump is used to fill the mattress when needed to be used. The material used for the inflatable mattress is completely stretched out when it is inflated. Once the infant is placed on this mattress, there will be a change in air pressure inside the mattress. This will be picked up by the pressure detecting sensor. The change in pressure is calibrated as weight.

The casing holds a space for the collapsed mattress to be rolled into and a tissue roll over it. A clamp holds the length measuring attachment onto this part. The concept is lightweight and portable.

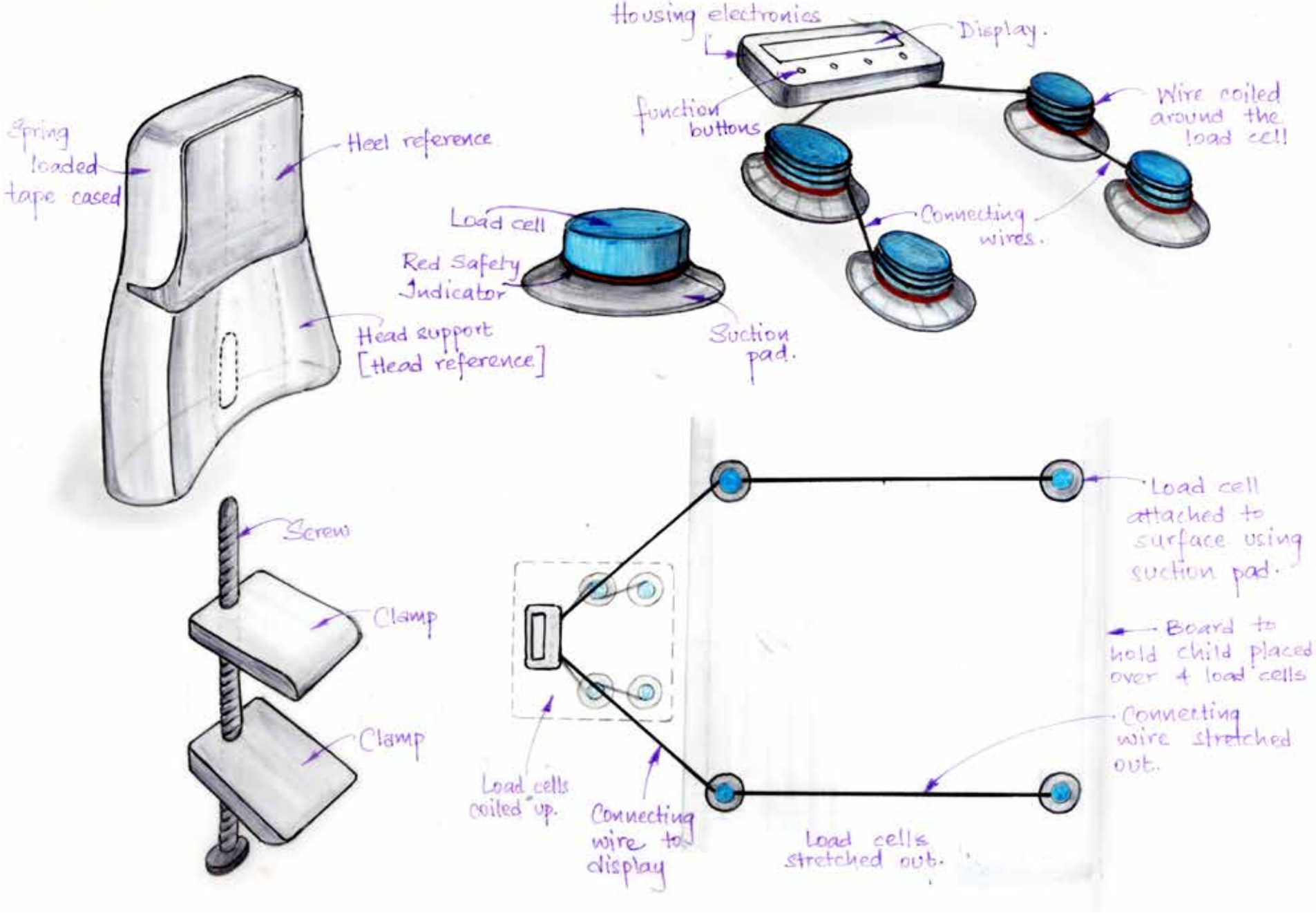


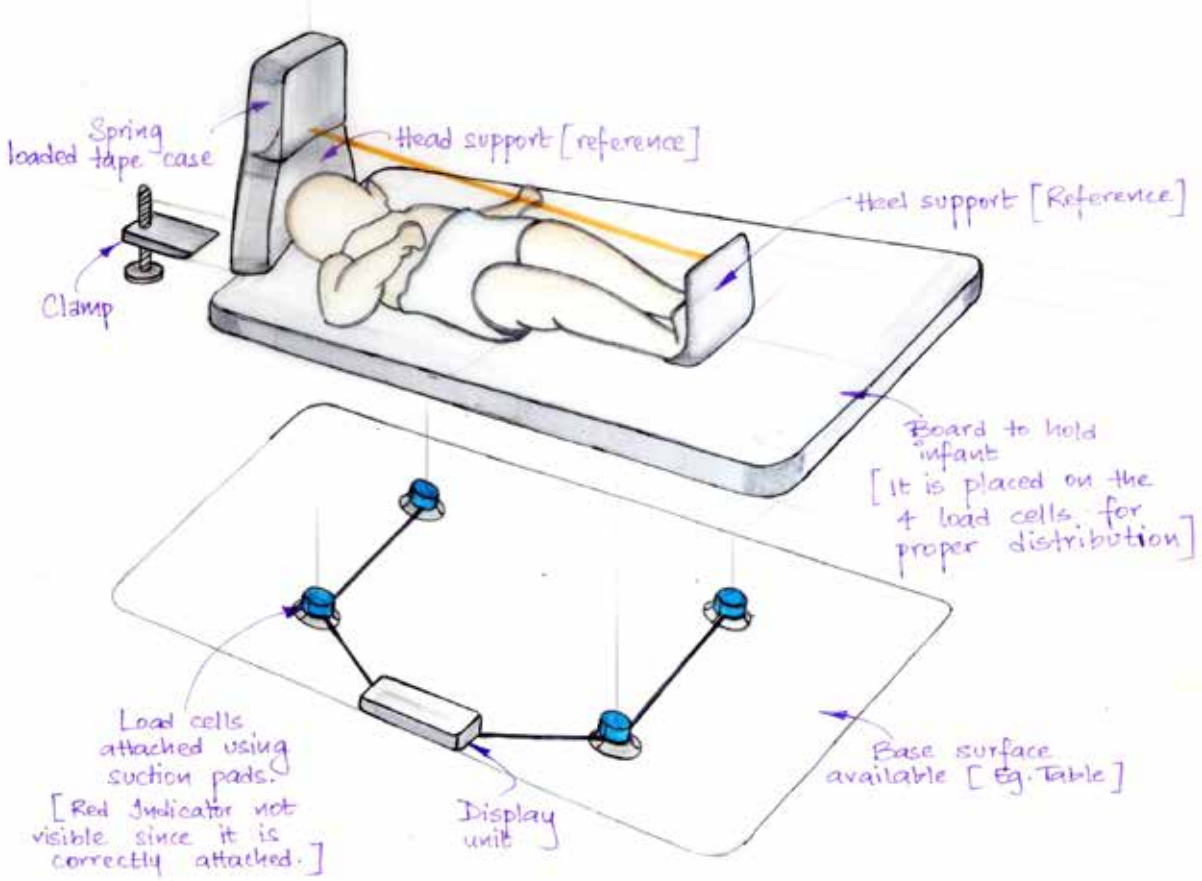
Pros:

- The rolling mattress would make a very compact product.
- Lightweight
- Comfortable for the infant
- Restricts movement
- Easy to use.

Cons:

- The material of the inflatable mattress has to be completely stretched out for the pressure sensing process to work.
- May become inaccurate over a period of time because of fatigue.


Housing electronics
Display.
function buttons
Wire coiled around the load cell
Connecting wires.
Load cell
Red Safety Indicator
Suction pad.
Spring loaded tape cased
Heel reference
Head support [Head reference]
Screw
Clamp
Clamp
Load cell attached to surface using suction pad.
Board to hold child placed over 4 load cells
Connecting wire stretched out.
Load cells coiled up.
Connecting wire to display
Load cells stretched out.



Dismantled Weighing scale

Instead of providing them with a weighing scale with a large surface to lay the infant in supine position, a small unit which could be set up as the weighing scale could be used. This would make the product much more portable by reducing the need for providing a large rigid surface for being weighed and measured.

The load cells of an electronic weighing scale were dismantled and the rigid member between them which held wires transmitting the values, was removed. Instead, these four load cells were connected with robust, insulated wires which were rolled up when not in use. The load cells were provided with suction pads which could be fixed on any flat surface. Once they were attached, and a surface was placed over it, the set up would act like a weighing scale.

Pros:

- The rolling mattress would make a very compact product.
- Lightweight
- Comfortable for the infant
- Restricts movement
- Easy to use.

Cons:

- The material of the inflatable mattress has to be completely stretched out for the pressure sensing process to work.
- May become inaccurate over a period of time because of fatigue.

Final Concept

The final concept was a combination of various features from the previous concepts.

The attachment type device from Concept 2 is used as a length measurement device which can be clamped onto any base.

The base would be appropriate to fit an infant upto the age of 2 years. Though children beyond the age of 1.5 years can be measured standing up, in case a child is unwell or crying , he may be measured in the supine position as well. The plank is provided so that it is the correct size and rigidity. It would also provide for circumference measurements.

An electronic weighing scale is given to measure the weight of the child.

By providing these parts, once set up, the product can take all the measurements required for growth monitoring of infants.

Tha length meausring attachment is made more compact and integrated in its form. It has a simple clip to hold onto the base. It is also lightweight. The heel reference can be pulled out to take measurements.

It was an important factor to have a rigid base which would allow for accurate measurement of weight and not buckle under the wieght of the infant. Thus, various ways to have a rigid base which was 2.5 feet by 1.5 feet were explored. The final shape that was fixed, made sure that the baby did not roll off the base. It also allowed the base to be folded to one third of its size thereby improving its portability.

The weighing scale is an electronic weighing scale. It would give a clear digital reading without any parallax. It would require a battery which would need to be changed after several uses since the power requirement is not much.

Form exploration of the attachment:

The form of the attachment for length measuring had to allow for the right shape of the head reference and heel reference, simple to use, attach, lightweight and portable.

Keeping that in mind, baby products such as baby monitors, apnea monitors etc. were studied. The clinical perception of such products was used in the attachment. Smooth, flowing ocntours were used.

At first, separate sections for the head support and the measuring tape was explored (Fig 7.1). However, this made the product look very big and bulky. Thus, they were integrated into a smaller unit. The heel reference had to be oriented correctly in the small unit for correct and simple usage.

The attachment was kept white, with a light blue rim for the heel reference. The colour defined the heel reference making it easier for the user to pull out the correct part.

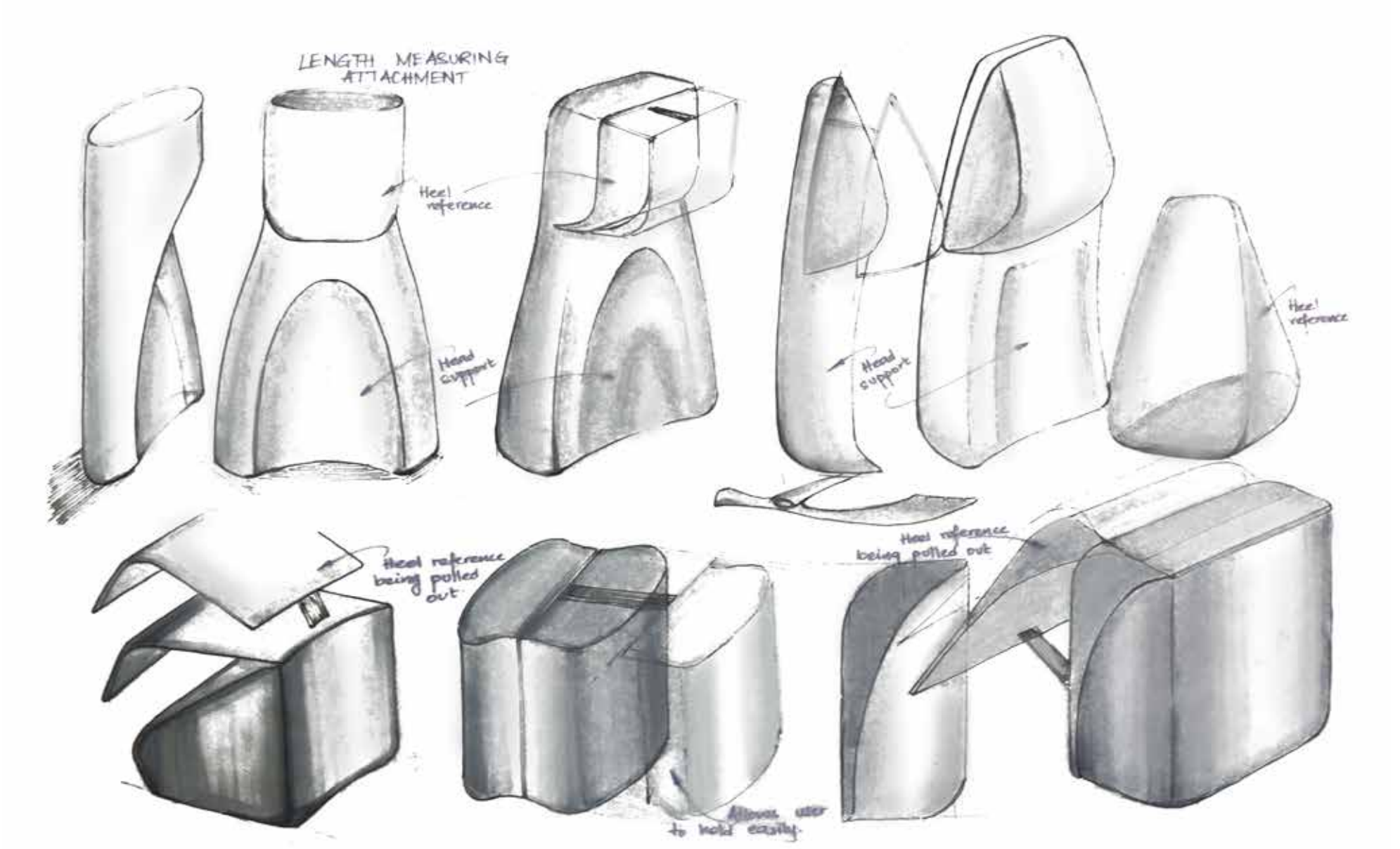


Fig 7.1: Attachment form exploration

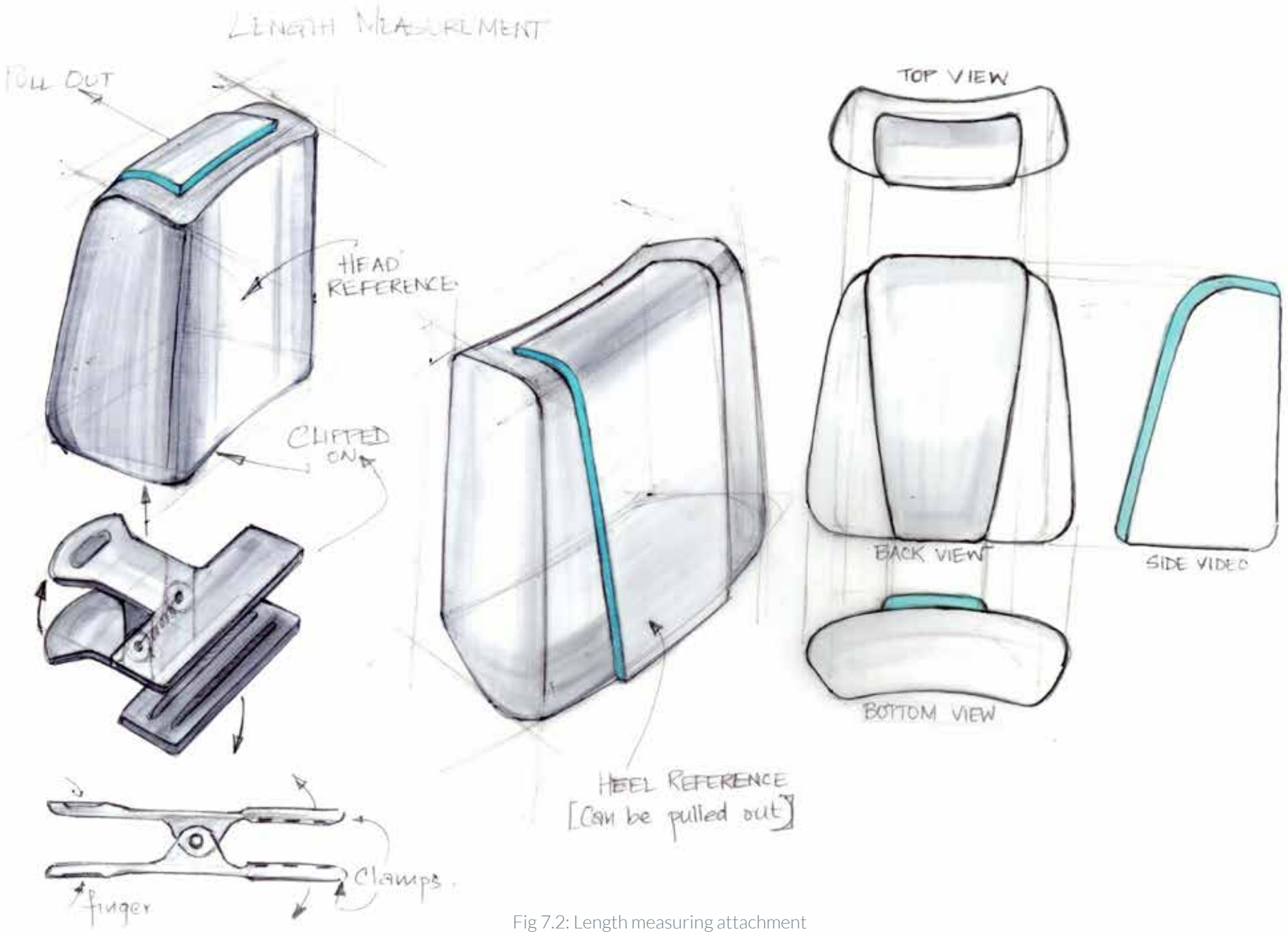
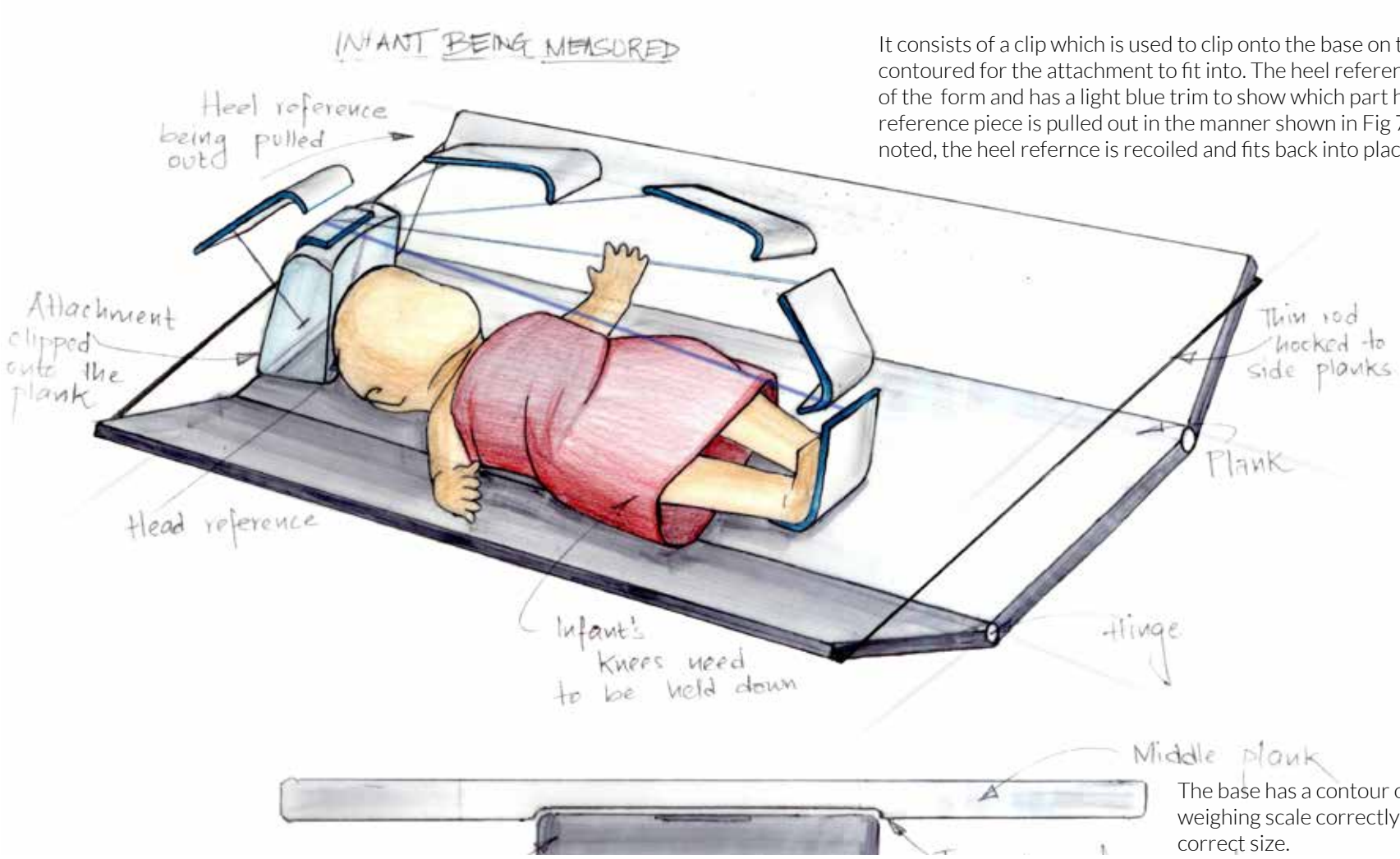


Fig 7.2: Length measuring attachment

Attachment for length measurement:

The length measuring device consists of a spring loaded tape for measuring the length. It has a head support which acta as a reference point for starting the measurement and a heel refernce which can be placed below the heel of the child and acts as the end point of the measurement.

It consists of a clip which is used to clip onto the base on the side which is slightly contoured for the attachment to fit into. The heel reference is slightly protruding out of the form and has a light blue trim to show which part has to be pulled out. The heel reference piece is pulled out in the manner shown in Fig 7.3. Once the reading has been noted, the heel refernce is recoiled and fits back into place.



The base has a contour on its lower side to fit in the weighing scale correctly so that it is centered and is the correct size.

Fig 7.3: Measuring length of an infant

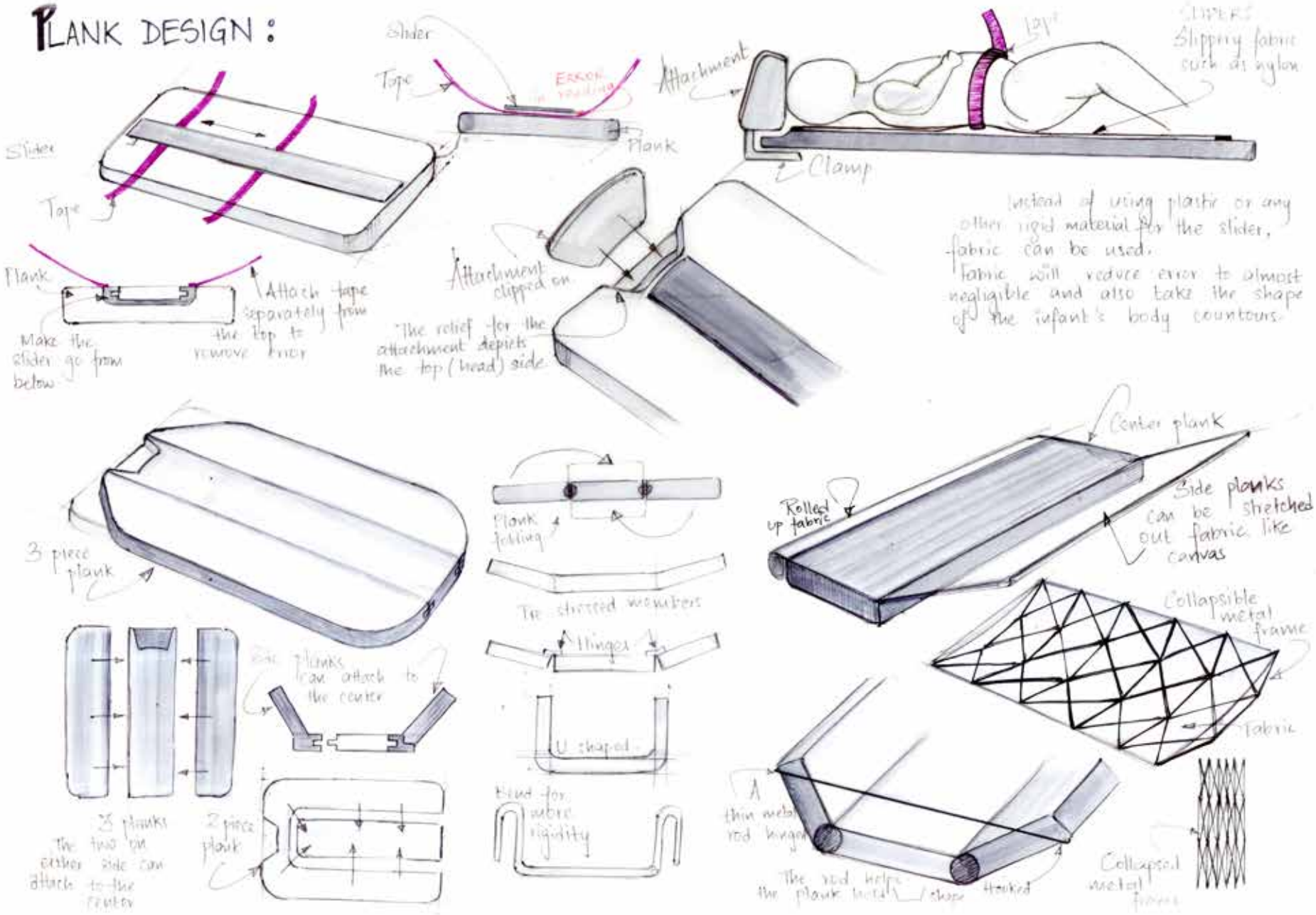


Fig 7.4: Base design exploration

Base Design:

Several ideas were explored fo the base as shown in Fig 7.4, such as stretched out fabric such as canvas on telescopic rods, mesh like frame which would collapse when not in use, a two piece base and a three piece base.

The slider was also changed so as to have minimal or zero error. Instead of using plastic to make the slider, nylon cloth was used. This would have a thickness in microns and allow the tape to slip through more easily. Also, it would curve around the contours of the infant's body more easily thereby making the reading accurate. The sliding tape would allow to take all the circumferences necessary.

The base needed to be rigid and foldable. It was possible to fold the base along the longitudinal axis so that it does not lose its rigidity. A three piece base was designed. One side could fold up, and the other side could fold downwards. The shape of the three pieces when they are unfolded would be trapezoidal. This would make sure that the baby does not roll off or move much.

The head side of the plank has an area contoured out for clipping on the length measuring device.

The bottom side of the plank has a small section contoured for the weighing scale to fit in. This is done to make sure that the plank is properly centered.

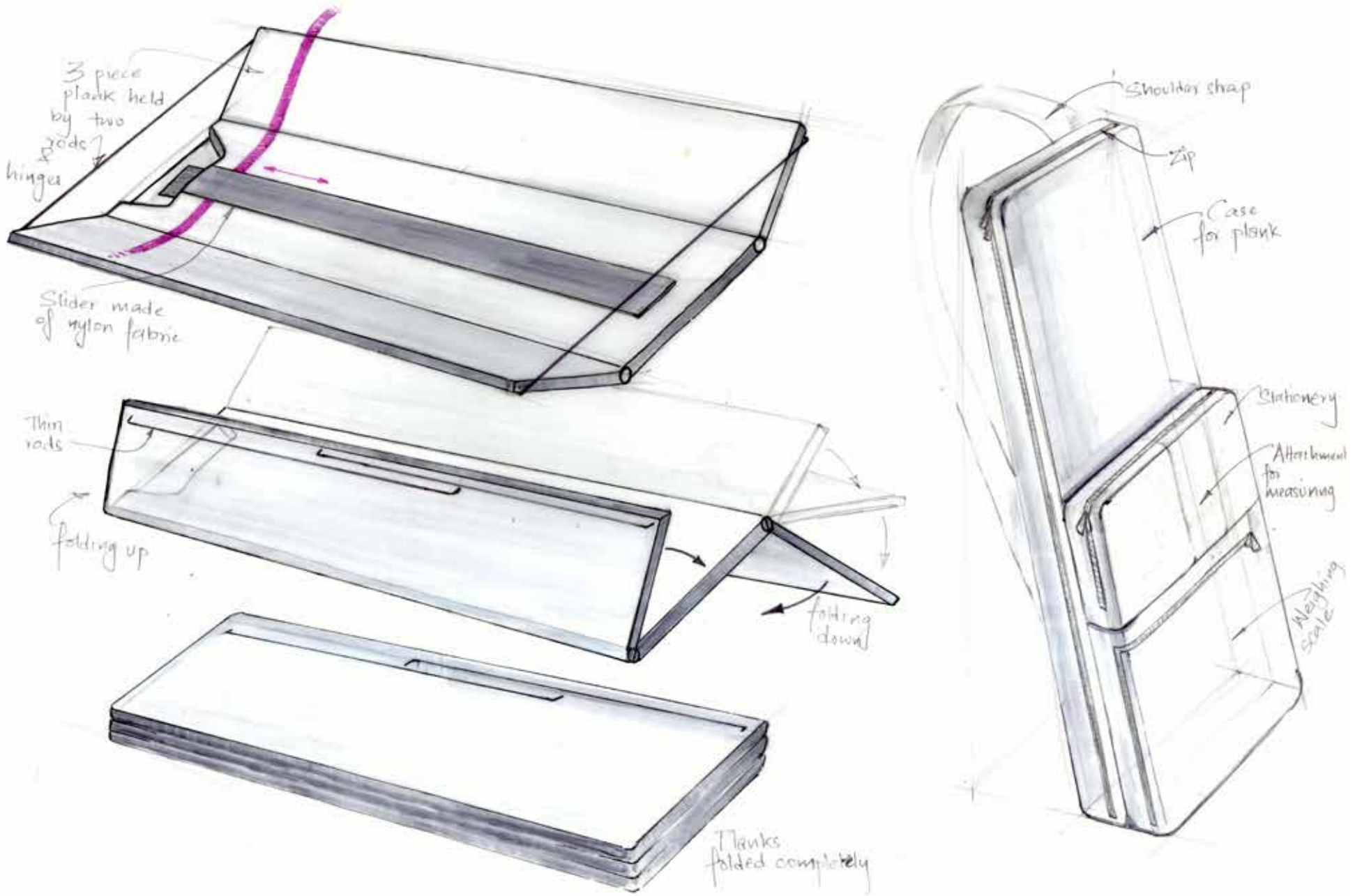


Fig 7.5: Plank Folding and Packaging

Folding the Base:

The three pieces of the base are hinged on the side such that they can fold over on either side as shown in Fig 7.5. They are held in place by two thin metal rods on either side. These hook the two pieces of the base together.

Packaging:

All the components of the device, viz. base, weighing scale and the length measuring attachment must be put together as one kit whichcan be purchased and used by the doctor/nurse. The kit must also have a cross spirit level so that the nurse can check if the plank is properly horizontal. This is important so that the weight reading is accurate.

A case similar to a guitar case can be used for packaging the product as shown in Fig 7.5. It will have a slot for the folded base, a smaller slot for the weighing scale and one for the attachment. It may also possess a small slot for extra items such as stationery.

If a clinic already owns a weighing scale, and does not wish to purchase the entire kit, they can purchase only the attachment. This attachment can be used on any existing base available in the clinic. However, in such a situation, the doctor must take care to adjust the weight reading to subtract the weight of the base.

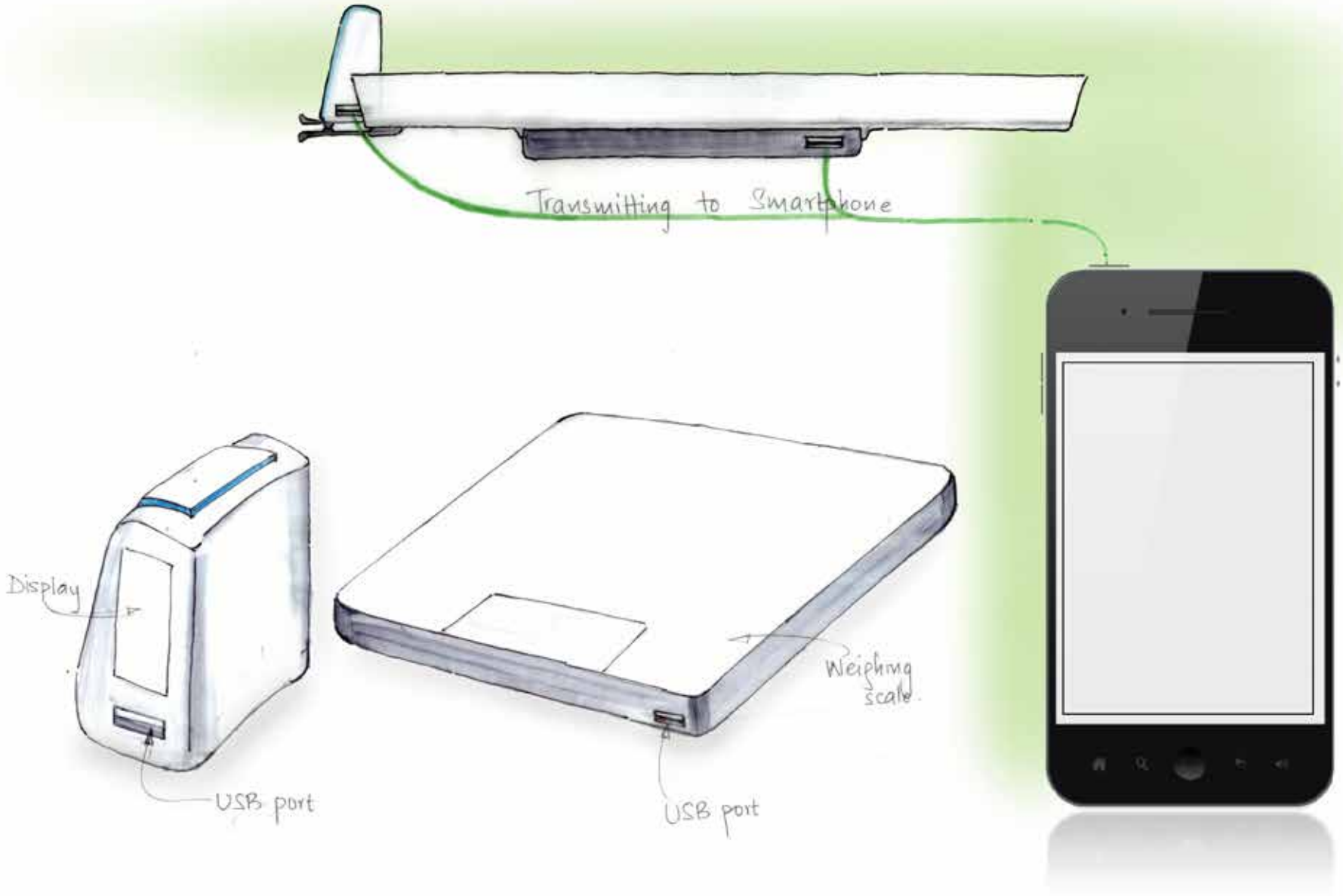


Fig 7.6: Data transmission to a smartphone

Data recording:

The government holds campaigns to get growth data of children and then plots them on a chart to standardize the data and provide a reference to compare data with. ICMR charts available get updated using this data. Instead of holding campaigns separately to record such data, it could be directly transmitted to a smartphone when the growth monitoring process takes place in rural hospitals etc.

The smartphone could have an application which allows the data to be recorded and updated to a centralized government database. The application could also give immediate results to the nurse or health worker informing them if the child's growth is normal or needs scrutiny. This would allow more immediate action and the parent could be informed if a consultation with the doctor is required.

The electronic weighing scale can have a USB port which transmits the data directly when connected to the smartphone as shown in Fig 7.6.

The length measuring attcahment can also have a digital display and small circuitry which would transmit the data using a data cable.

Product Detailing:

Keeping all the features in mind, it was noticed that the size of the product was still too big to be carried easily. A length of almost 3 feet made the product difficult to be carried by health workers in public transport. It was important to make the folding base smaller yet, and easily carried by the health workers.

A modified base was designed which folded laterally and not longitudinally as shown in Fig 7.7. It was kept rigid by the use of plates under a soft foam base. It folded between two rigid surfaces. This folding base required a rigid member under it so that it did not buckle when placed over a weighing scale.

The skeleton of the base and folding progression is shown in Fig 7.8. Gooseneck wires were used on the sides of the mat so that they would curve upwards and cradle the baby. The base was designed to remain rigid once opened with the help of extension rods below it. Depending on the length of the infant, the base could be opened up along with the extension rod.

For keeping the folding base rigid, two solutions were considered. The first was the use of extension rods as shown in Fig 7.9. Extension rods with less thickness and good strength could be used for keeping the base rigid and prevent buckling. The second solution was the use of a collapsible structure as shown in Fig 7.10, the cross members of which would increase strength and keep the base rigid.

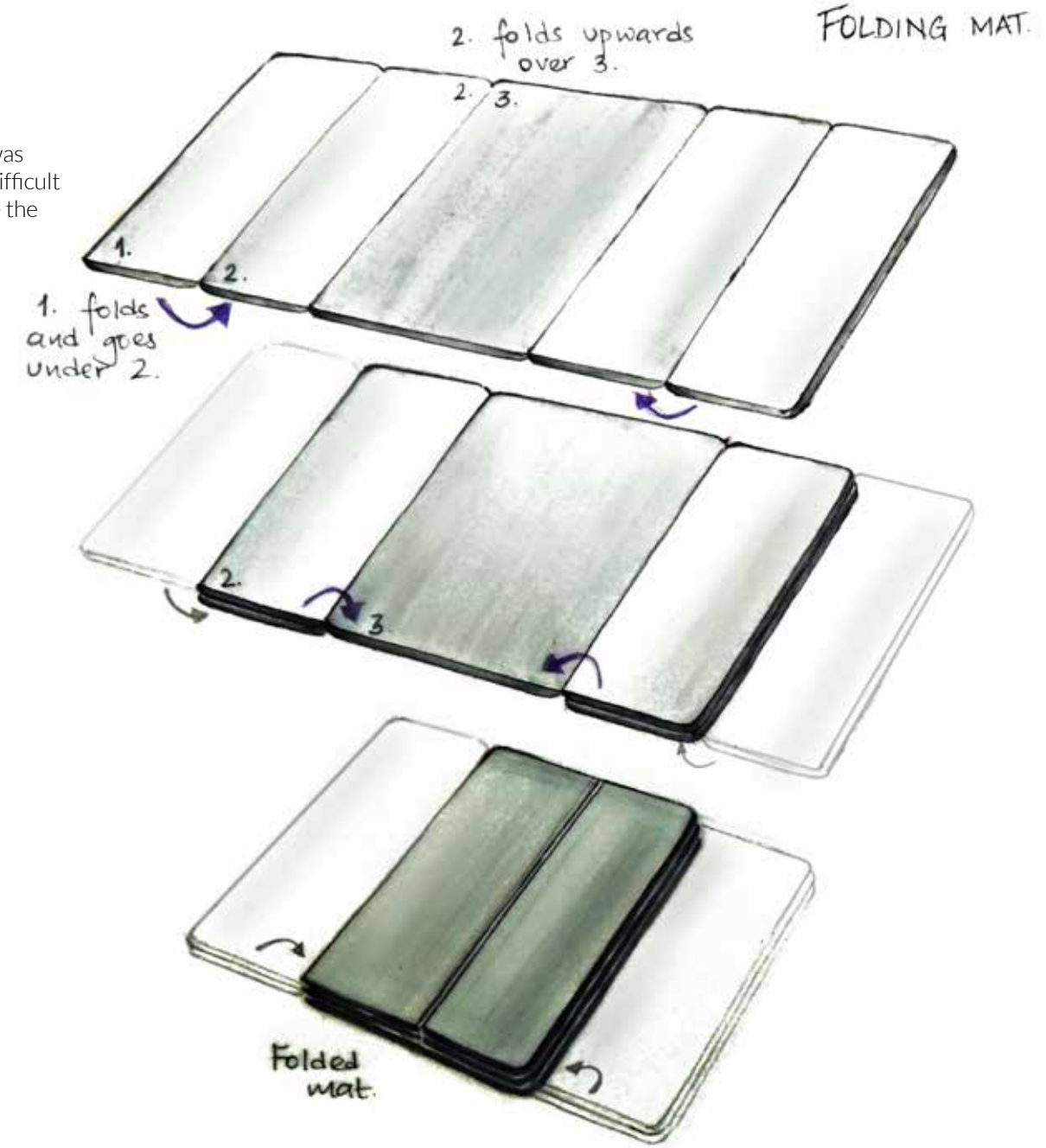


Fig 7.7: Folding Mat

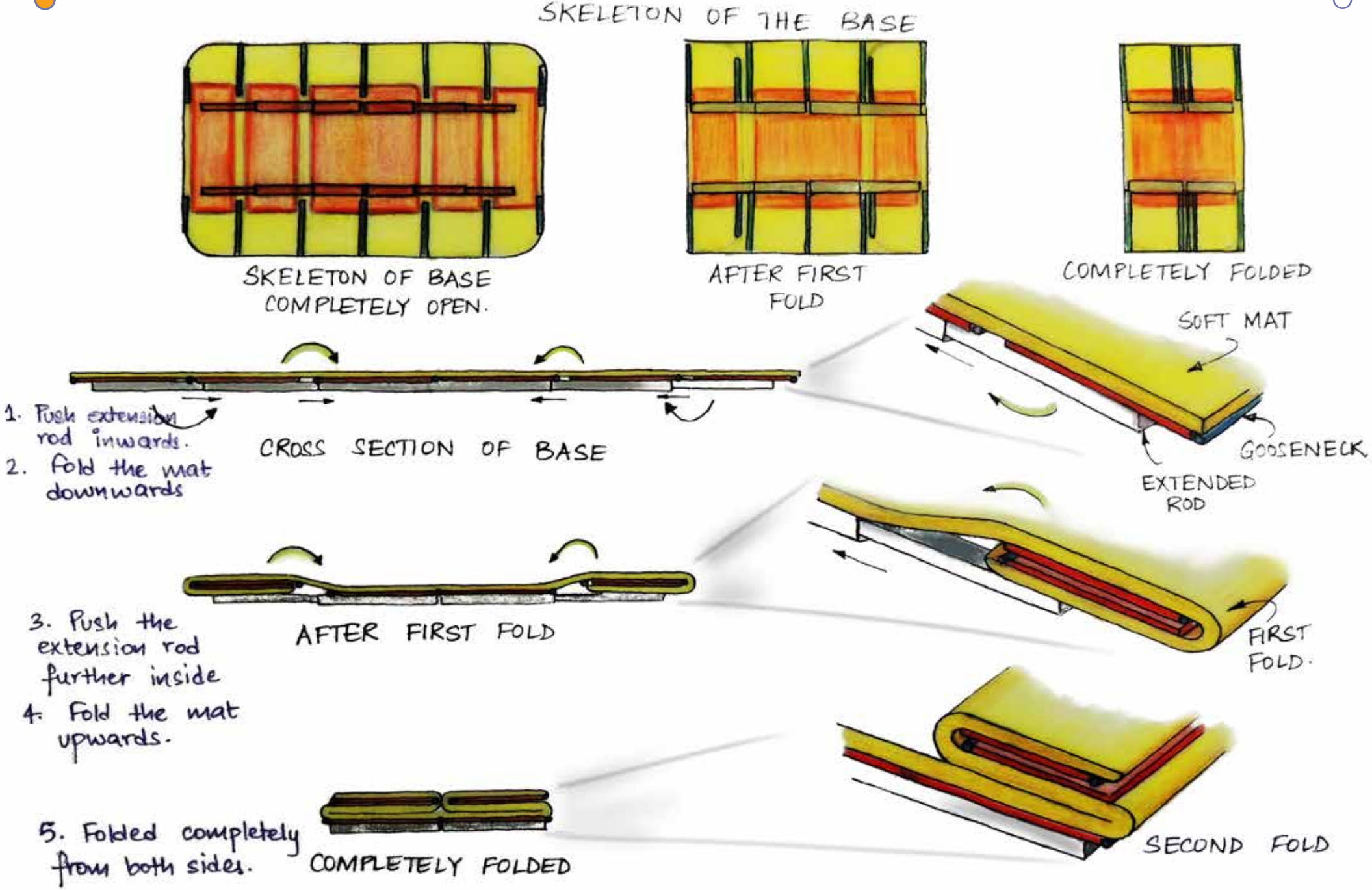


Fig 7.8: Progression of folding

Exploded view of the assembly:

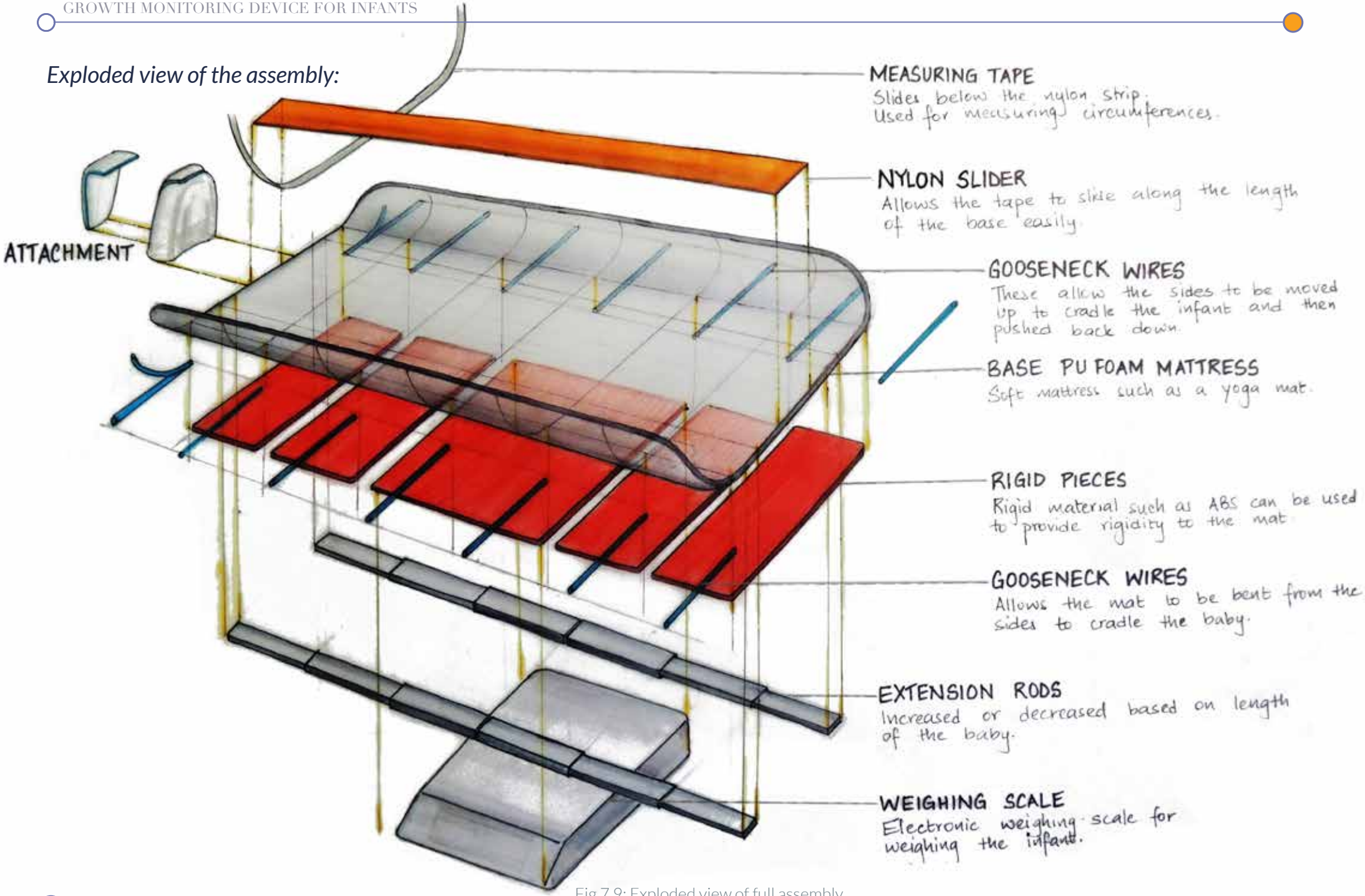


Fig 7.9: Exploded view of full assembly

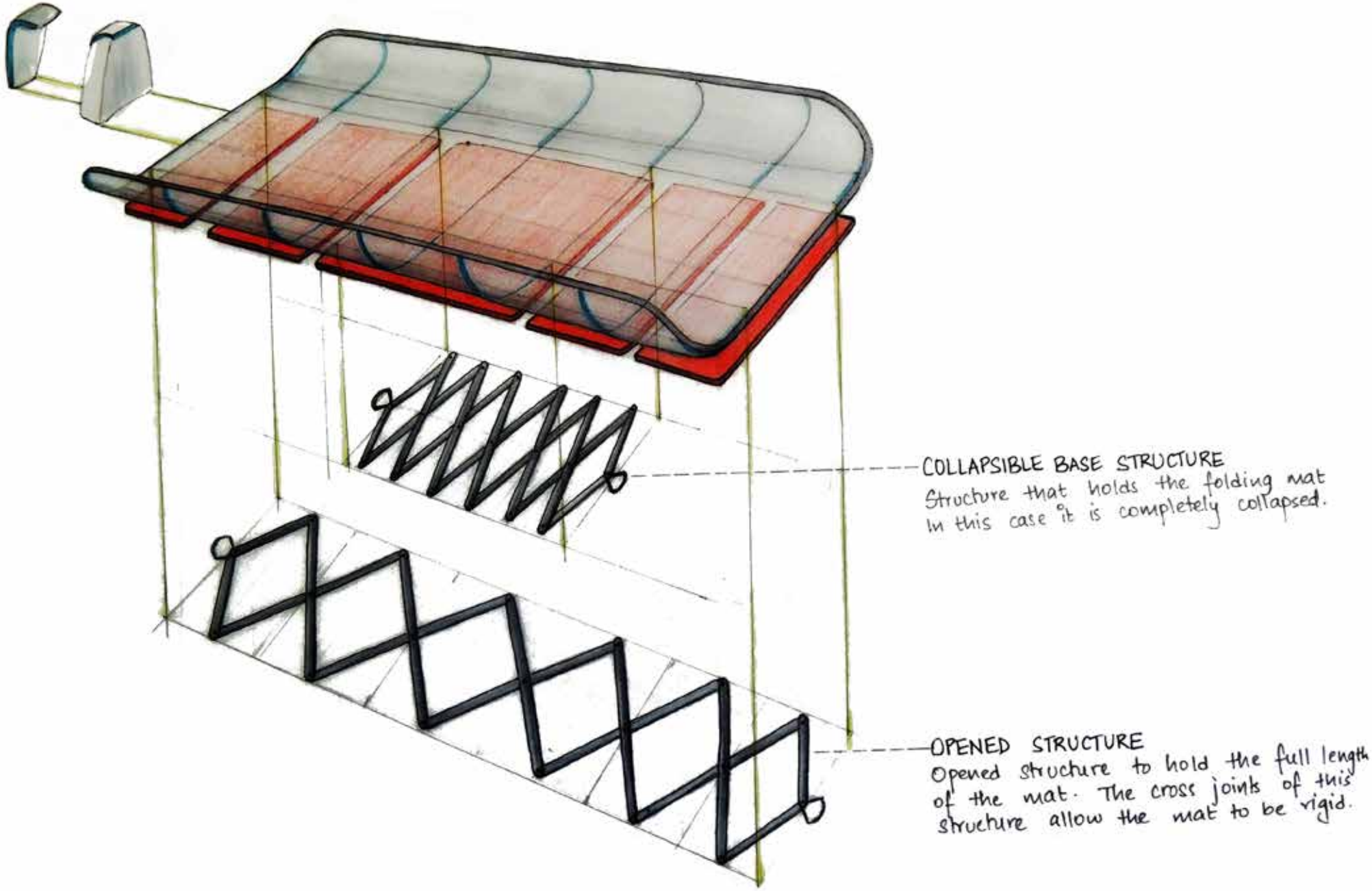


Fig 7.10: Collapsible structure

Final model 3D Renders

Fig 7.11 shows the design of the base. It shows the exploded view of the various parts of the base

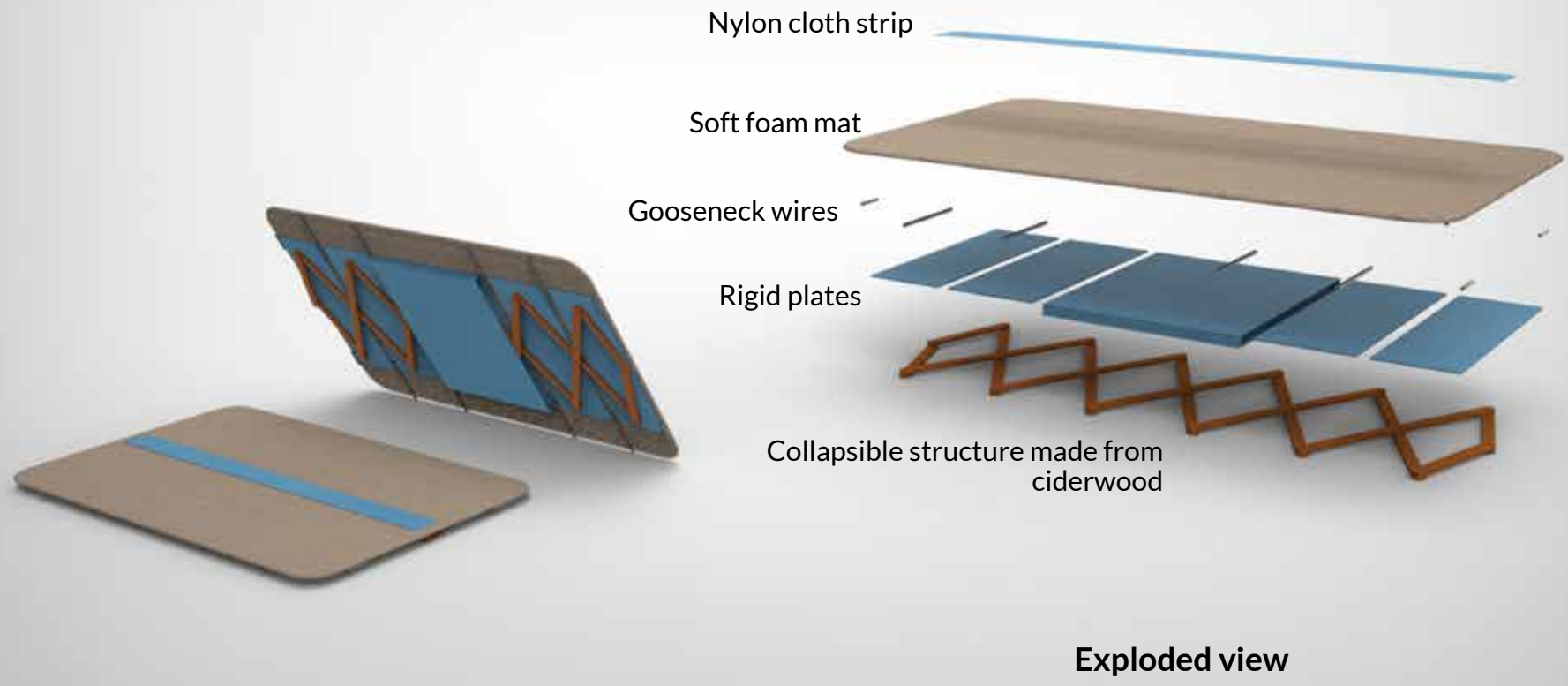


Fig 7.11: Base Design

Fig 7.12 shows the base when it is completely folded, and then the progression of how it opens.

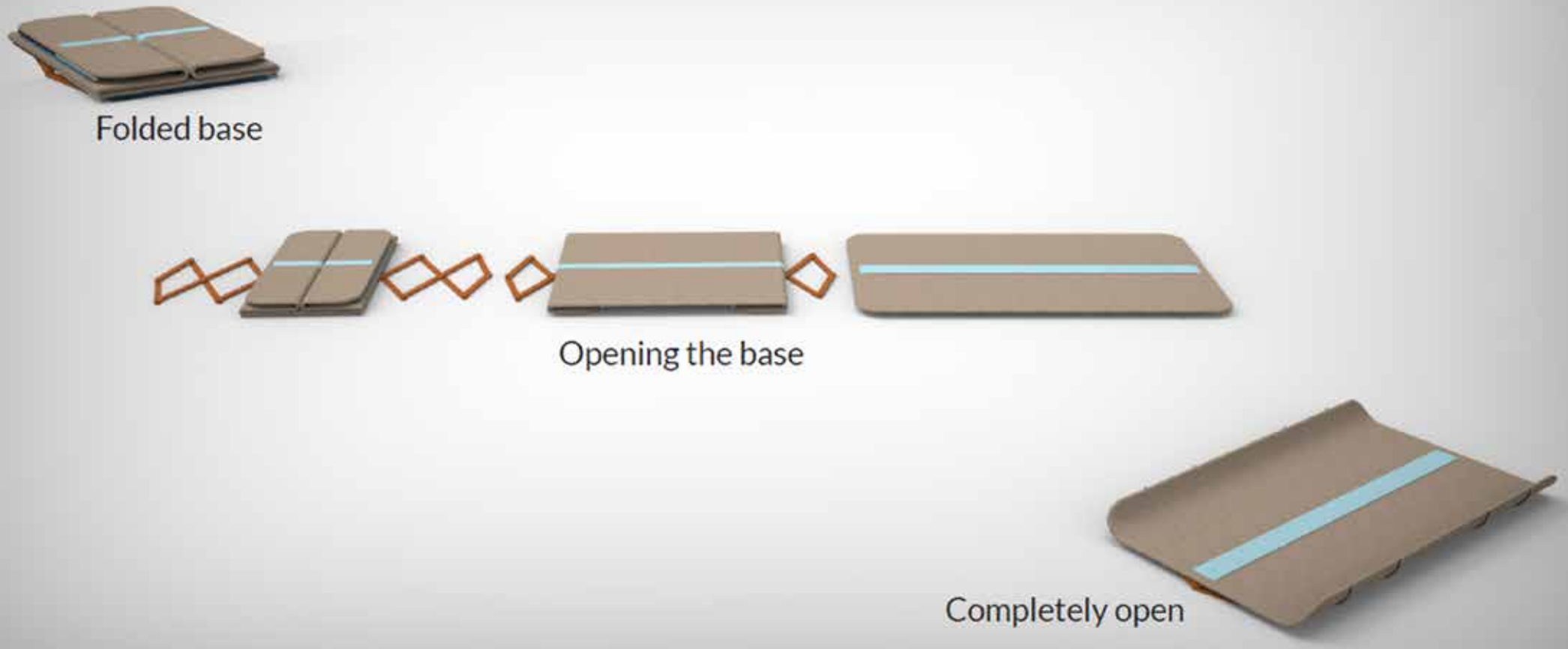


Fig 7.12: Opening the base

Fig 7.13 shows the use of the attachment in measuring the length of the infant.

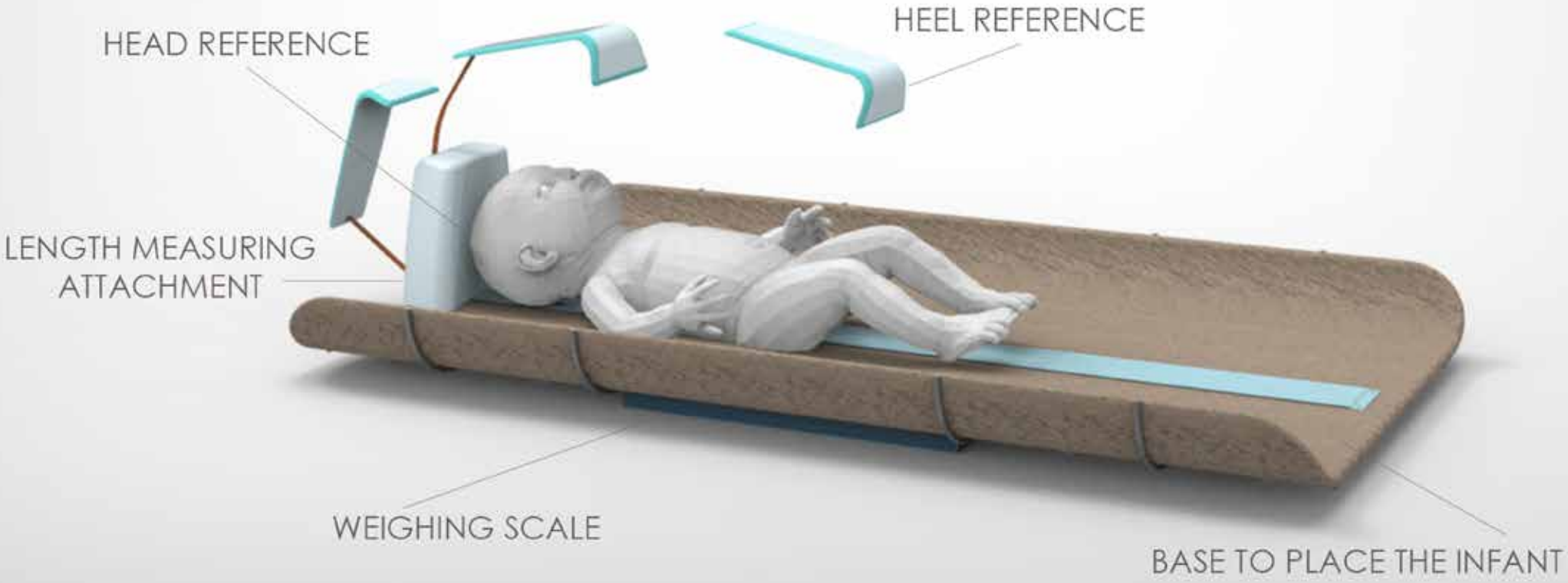


Fig 7.13: Length measuring attachment

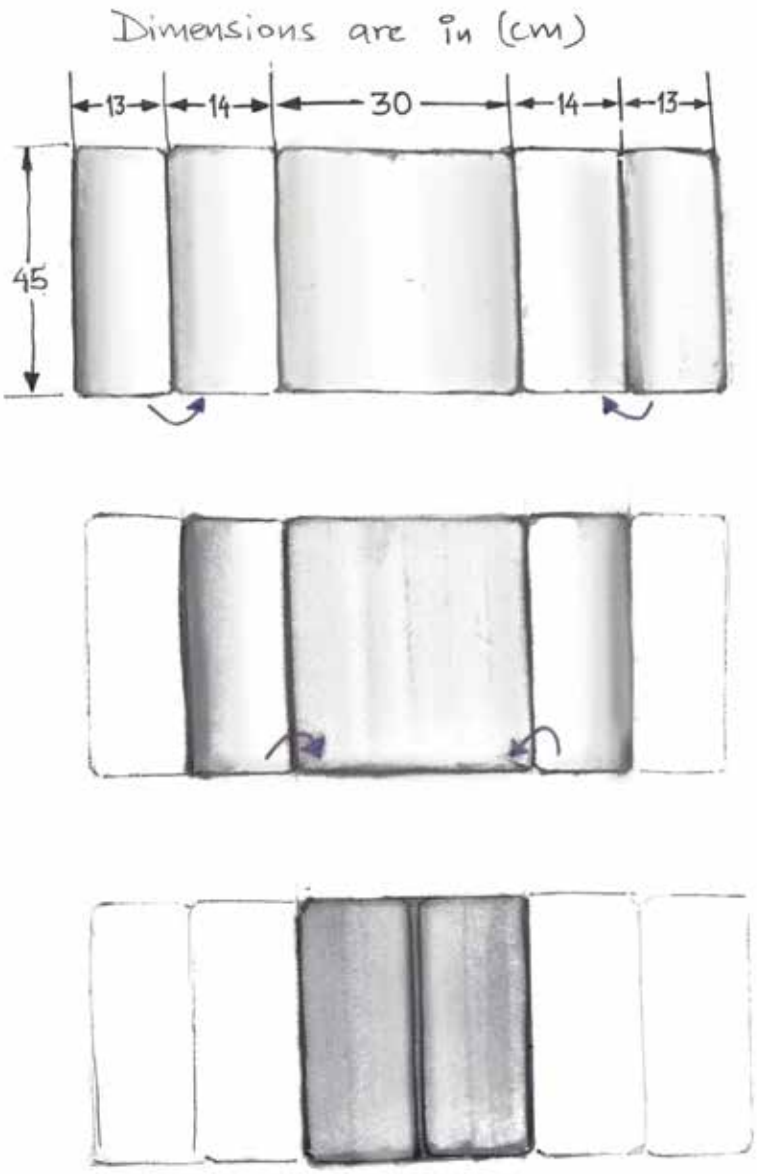


Fig 7.14: Dimensions of the base

Anthropometry

The dimensional details of the product were based on anthropometric data provided by ICMR.

Length and weight of infants upto the age of 1.5 was taken from these charts
The maximum length: 80.5 cm
The maximum weight: 10.6 Kg

Several existing folding mats and changing mats for infants were studied and the width of the base was derived from that.

Dimensions of the base: 85 x 45 cm as shown in Fig 7.14.

The height of the attachment was kept 16 cm in accordance with the head size and body of the infant.

Final Prototype

The final prototype was made by vacuum forming the attachment as shown in Fig 7.16. Th ebase was made by cutting a foam mat and then fitting it with thick pieces of styrene for the rigid base with gaps in between which allowed for folding the mat. Gooseneck wires were also stitched onto the sides of the mat. It was then covered with waterproof cloth suitable for an infant.

The final prototype was tested using a doll as shown in Fig 7.15. The entire setup time was checked for a first time user with no experience and a user who had some practice.

Set up time for new user: 4-5 mins
Set up time for experienced user: Under 1 minute

Total weight of the base structure and attachment: Less than 2 Kg

Fig 7.15: Final prototype

Fig 7.16: Prototyping

References

Khadilkar, V.V, 2007. IAP Growth Monitoring Guidelines for Children from Birth to 18 Years. Indian Pediatrics, [Online]. Volume 44, 1,2. Available at: http://www.indianpediatrics.net/mar2007/mar-187-197.htm [Accessed 17 April 2015].

Hall DMB. Health for all children. Report of the third joint working party on child health surveillance. 3rd Edition. Oxford: Oxford University Press, 1996. [Accessed 17 April 2015]

Medline Plus. 2014. Endocrine Diseases. [ONLINE] Available at: http://www.nlm.nih.gov/medlineplus/endocrinediseases.html. [Accessed 17 April 15].

Stanhope R, Wilks Z, Hamill G (1994) Failure to grow: lack of food or lack of love?. Prof Care Mother Child 4 (8): 234-7. [Accessed 17 April 2015]

British Columbia. 2013. Healthy Children and Women. [ONLINE] Available at: http://www2.gov.bc.ca/gov/topic.page?id=D6C60F70F8434E0A8991717BB7268245. [Accessed 17 April 15]