The Hope Device

Preliminary Proposals

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1.1.1.2 Physical Challenge Description

Physical challenges and disabilities create complex, influential, dynamic, multidimensional barriers which reduce, limit and restrict the freedom of movement. Disability refers to a physical or mental weakness or illness which reduces an individual's capacity to handle or manage simple tasks in their living or work environment. People affected with physical challenges and disabilities experience major changes – physical, mental and psychological – which impact their quality of life by discouraging their abilities or capabilities to integrate and reintegrate into their societies. Findings presented by the World Health Organization (WHO) have claimed that approximately over 15% in the global population remain affected with some forms of disabilities and 2% to 4% among them experience extreme challenges in carrying out every day routine tasks (453-460). [6]

1.1.1.2**. Disability Factors and Causes**

Industry research on physical challenges and disabilities have identified several factors which primarily contribute their creations and developments as follows (68-71). [4]

- Communicable Diseases (poliomyelitis)
- Hereditary (muscle dystrophy)
- Nutritional Disorders (deficiencies of protein; minerals and vitamins)
- Injuries (traffic accident)
- Malignant Neoplasms
- Neuropsychiatric Conditions
- Cardiovascular Conditions &
- Diabetes Mellitus etc. (68-71). [4]

Medical industry professionals have confirmed that following leading health deterioration conditions, which prompt serious disabilities have been triggered by childhood malnutrition, polluted or contaminated drinking water, poor sanitary indoor and outdoor living environments and inadequate or utter lack of domestic hygiene (68-71): [4]

- Lower Respiratory Infections
- Diarrheal Diseases
- Perinatal Disorders
- Unipolar Major Depression
- Ischemic Heart Disease
- Cerebrovascular Disease
- Tuberculosis
- Measles &

Congenital Anomalies (68-71[4]

1.1.1.3 Assistive Technology (AT)

Men, women and children who are affected with physical challenges or disabilities require Assistive Technology (AT)'s support to function as normal persons in self-satisfying their needs, requirements, demands and expectations.

According to the definition presented by the Committee on Technical Assistance, "an assistive device represents a unique knowledge area which has facilitated effective incorporation of diverse characteristics that are mutually dependent such as products, materials, resources, performances, functionalities, applications, technologies, strategies and core utilities which facilitate, support and strengthen functionality of the physically challenged men, women and children, reduce or eliminate mobility barriers and physical disabilities in restoring people's autonomy, freedom, independence, social engagement and the quality of life (5570-5578). [7]

Assistive Technology (AT)'s innovative product development creativity process focus on delivering and maintaining its intrinsic characteristics related to users' emotions and experiences which facilitate and encourage faster rehabilitation. Device compatibility originates from AT's effectiveness, efficiency and satisfaction (5570-5578). [7]

1.1.1.4 User-Centered Design (UCD)

The strategic role of User-Centered Design (UCD) was first used in the technology factors related to human-computer interaction. UCD by expanding its reach in the ATs has provided state-of-the-art technology solutions which have transformed the lives of the physically challenged men, women and children in countries all over the world (5570-5578). [7]

AT's product features are required deliver and maintain increased user satisfaction related or linked with its safety, functionality, usability, happiness, and individualization for the purpose of ensuring perfect synergy between the aesthetic, symbolic, practical and semantic tasks, roles and activities (5575-5578). [7]

1.1.1.5 Significance of the Study

Millions of disabled men, women and children worldwide, who are physically challenged require sustained health care support, routine or regular medical checkup and home- based support. People with severe disabilities require in-patient care at public rehabilitation facilities. Government of many underdeveloped countries are unable to finance the high costs of public healthcare expenditures to support growing number of physically challenged people. Effective disability management policies, plans and programs require specialized medical, social, psychological, vocational, and other rehabilitative care, which are beyond the economic contributions of local healthcare centers (453-460. [6]

1.1.2 LITERATURE REVIEW

1.1.2.1 American Community Survey (ACS)

Findings presented by the ACS that gathered information and knowledge on the number of physically challenged people had indicated that approximately over 12.6% were suffering from one or other types of disabilities in 2015 which had severely restricted their abilities to carry out normal and routine functions from extensive survey The American Community Survey (ACS) estimates the overall rate of people with disabilities in the US population in 2015 was 12.6%. Physically challenged men, women & children are steadily increasing worldwide and the disabled people in the U.S.A., increased from 11.9% in 2010 to 12.6% in 2013, 2014 & 2015. Over 51.1% disabled in the U.S population were in working age group of 18-64 years and 21.2% of disabled U.S., civilians in working age lives in extreme poverty (2-41) [5].

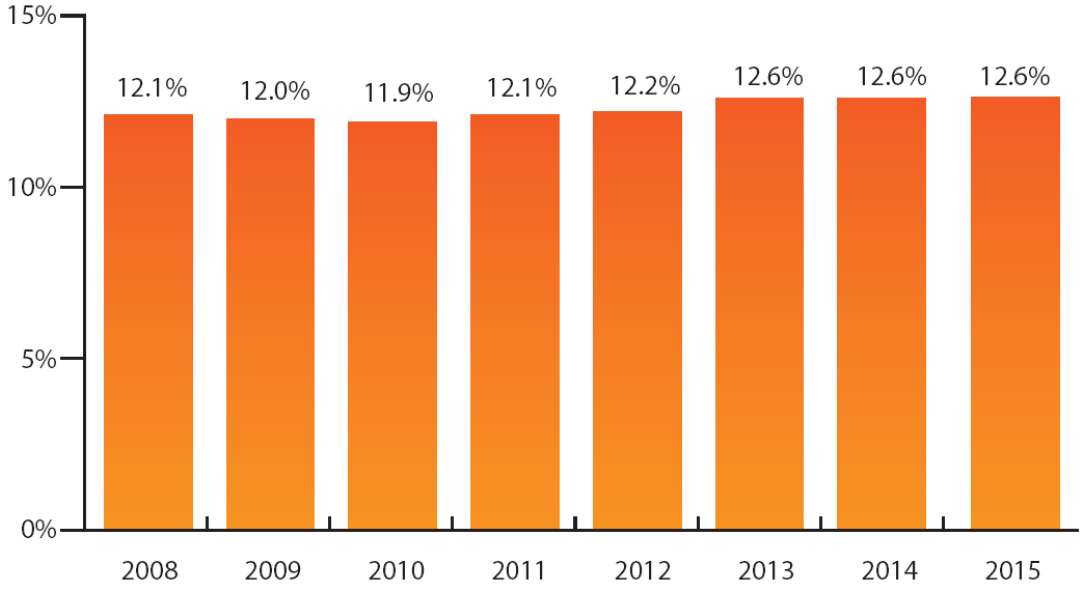


Figure - 1: U.S Disabilities in Percentage: 2008-2015

1.1.2.2 High and Low Disabilities Regions

Information gathered from researched studies in 2015 on U.S. states for reviewing and analyzing the rate or the percentage of disability measures against total population of particular states have established following key findings (6-41): [5]

Utah listed with 9.9% disabilities was rated as the lowest among the number of people affected with physical challenges.

West Virginia listed with 19.4% was acknowledged as the state reported with highest number of disabilities (6-41). [5]

Information listed in the below Figure, illustrates percentage of people to the United States' overall population who are living with various status of disability in different States in 2015 (6-41): [5]

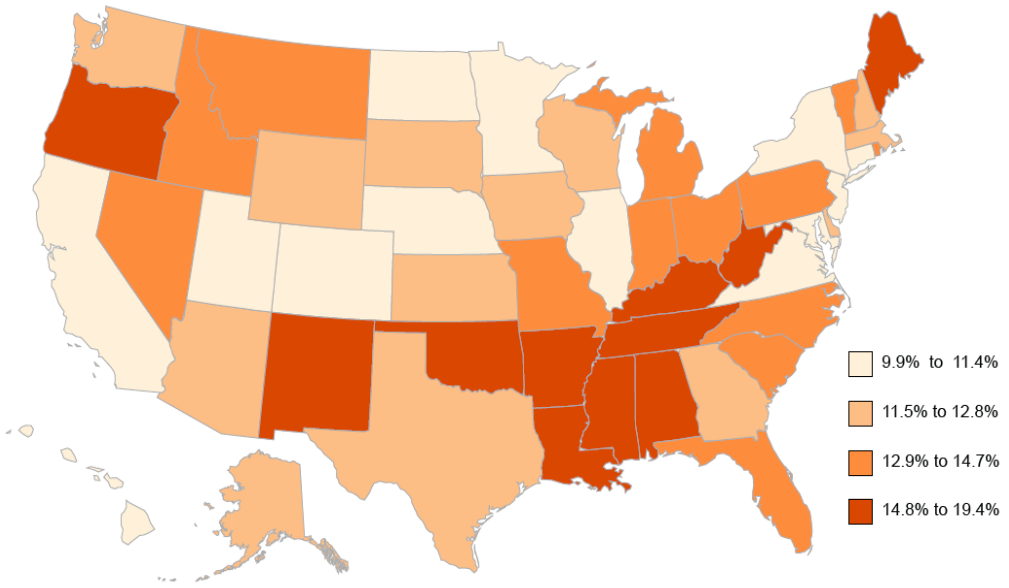


Figure - 2: Percentage of Disabled U.S. States to National Population

1.1.2.3 Disabled People Age Distribution

Information gathered from research studies on the disabled people's age distribution in the United States, have established the following key findings (7-41): [5]

- Children below 5 Years had registered less than 1% in the disability statistics
- People in the age group of 5-17 years had registered disabilities at 5.4%
- Adults in the 18-64 age group have reported 10.5% disability share
- Adult men and women who were +65 years have reportedly listed covered 35.4% in disabilities
- More than 51.1% in the age group of 18-64 years were reported with various types of disabilities
- Among the able-bodied men and women in the age group of 18-64 years. Approximately over 51.1% were reported as disabled
- 41.2% among the people in the age group ranging over 65 years were acknowledged as disabled 41.2%
- Teenagers and youths in 5-17 years age group were reported with 7.2% and 0.4% respectively (7-41). [5]

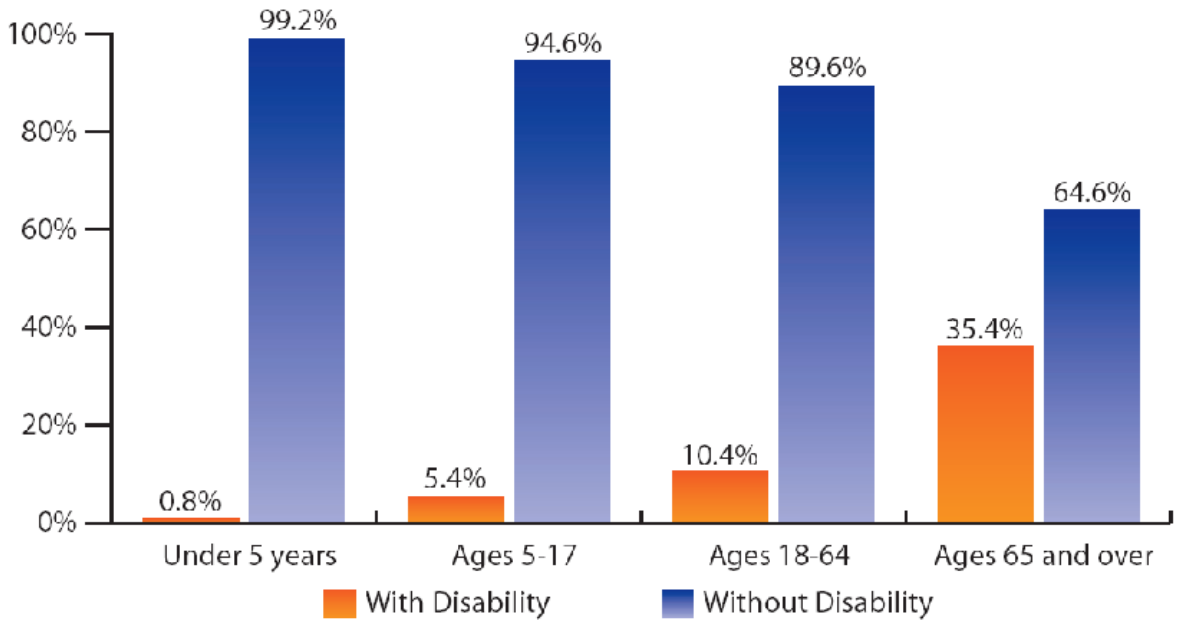


Figure - 3: Disabled People Age Distribution

1.2 Project Description

Making supporters for people who has foot paralysis or injured and they are not able to walk. The device will make them able to walk using their hands holding the two different supporters that holds their foot.

1.2.1 Project Sponsors

Following stakeholders who have teamed-up to complete current **Senior Design- I Project** on "***Assistive Device Project for Physically Challenged"*** have been acknowledged as the primary sponsors:

- Dr. Oman
- The Mechanical Engineering Department

1.1.3 Project Objectives

Following are some of key primary objectives of the project:

- To facilitate & support physically challenged people to rid their solitary lifestyles
- To attract & acknowledge them into mainstream society
- To make them forget their predicaments, sorrow, pain & grief
- To add more value contentment in their lives
- To provide opportunities for income growth
- To enhance happiness by improving their living standards

1.1.4 Project Goals

Primary goals of the project focus on providing required physical, emotional and psychological support to men, women and children who are affected with minor or major disabilities that have caused freedom of movement. Causes of disabilities may relate to the sustaining of injuries, age factors or decrease impacts such as paralysis.

The project seeks to eliminate dependence on wheelchairs by encouraging disabled people to engage in outdoor movements like normal persons to given them an enhanced opportunity to connect with members of their community.

Crutches device planned for innovative development under the Senior Design - I Project will facilitate and support people affected with disabilities caused by injuries or born with foot paralysis to stand on their feet strongly and firmly to take care of their personal needs, requirements and expectations in their living, work and social environments with greater acceptance, dignity, respect, and honor.

1.3 Original System (Underarm Crutches and Quad Cane)

Choosing original design need to be improve and develop are related to the customer needs, hat created by the team. The team decided to develop and improve the regular crutches and quad cane to make it more effective. One of the main reason to develop the crutches and quad cane is to help the person with disability walking easier. From those original designs below the team start to research and get many ideas to reach the customer needs.

Figure - 4: Underarm Crutches

Figure - 5: Quad Cane

2 REQUIREMENTS

Information presented here provides awareness and knowledge on the *Key Success Factors (KSFs)* that are important, required and necessary for accomplishing and maintaining successful innovative product development.

2.1 Customer Requirements (CRs)

Customer Requirements were reviewed, analyzed, evaluated and measured on the basis of knowledge gathered from the industry users' needs assessment that was gathered from literature review data. An ideal assistive device is required to fulfill following user needs, demands, requirements and expectations for achieving widespread acceptance, support and adoption:

1. User-Friendly

2. Affordability

3. Light-Weight

4. Low physical strain

5. Increased comfort and convenience

6. Low repairs & maintenance costs

7.Quality performance

8.Durability

9. Aesthetic design

10. Indoor & outdoor operation suitability

2.2 Engineering Requirements (ERs)

For the purpose of ensuring best safety, security, and mobility we had reviewed and analyzed product feature complexities and challenges covering the following crutch types that are most commonly used as they closely align with the Assistive Device that we are currently working on to develop:

1.Total cost $150.
2. Device weight cannot exceed 5kg
3. User must be able to left 5 kg
4.Appropriate price for spare parts ($40)
5.Maneuverability
6.Stability
7.Minimum changes in regular crutches
8.Safety
9.instant fitting and removal
10.Maintenance cost between ($50)

2.3 Testing Procedures (TPs)

Industry experts use innovative and advance testing procedures for reviewing, evaluating and measuring the safety, security, performance, weight, and durability of assistive devices. Considerable amount of time, efforts and money is spent on the Research and Development (R&D) processes of the prototypes which are prelude to the final product selections that are mass manufactured for worldwide marketing distribution. Among the diverse tests, experiments and analysis carried out on the assistive device prototypes, the spring constants for body weight measurement illustrated in the below Figure, is one of the most popular ones which had been used in worldwide industries. Production and safety engineers review and analyze feedbacks obtained on user tests' qualitative results, engineering specification tolerances, trend-lines and the target values. An upper and lower bound listed in the study parameter indicates diverse user requirements or preferences that is effectively determined by maximums and minimums. Person also remains very appropriate or suitable for assistive device users whose body weight ranges from 117 lbs to 198 lbs, which covers significantly a high number of both male and female users. However, we would take into consideration additional and various weight classes, while finalizing our crutch design (8-19) [3].

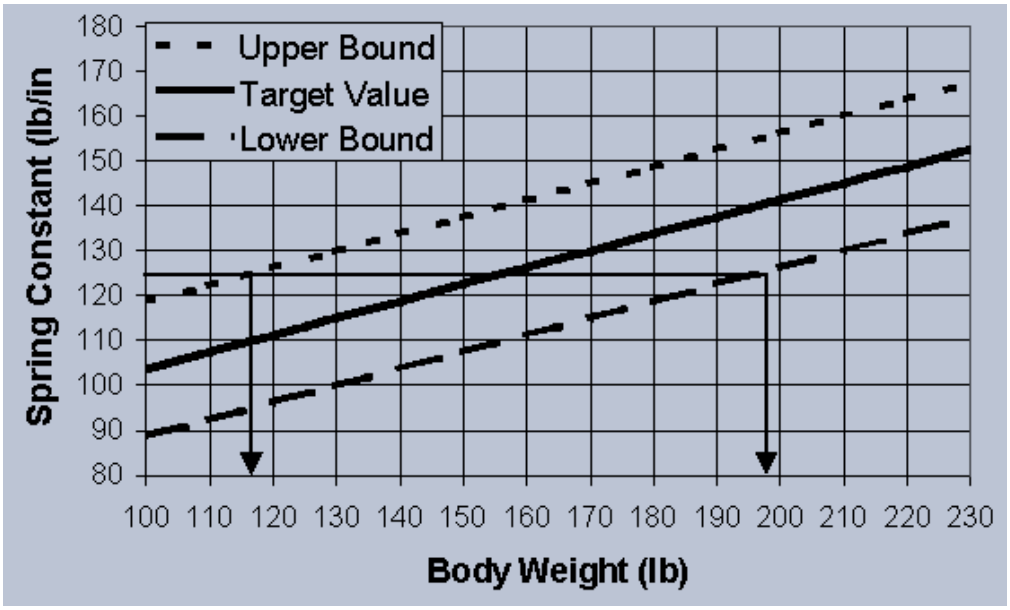


Figure - 6: Spring Constant Test Evaluations

2.4 House of Quality (HOQ)

Information presented in the HOQ illustrates the performance quality and competitiveness of the crutches that we had proposed for development under the Senior Design - I with other brands of that are currently marketed.

Table 1: House of Quality

House of Quality (HoQ)												
Customer Requirement	**Weight**	**Engineering Requirement**	**Total cost $150**	**Device weight cannot exceed 5 kg**	**User must be able to left 5 kg**	**Appropriate price for spare parts ($40)**	**Manuverability**	**Stability**	**Minimmum changes in regular crutches**	**Safety**	**instant fitting and removal**	**Maintenance cost between ($50)**
1. User-Friendly	3		9	9	9	6	9	6		9	9	6
2. Affordability	4			9	9	3	9		6			6
3. Light-Weight	5		6	9	9		9	9	6			
4. Low physical strain	4			9	6		9	9		9	9	
5. Increased comfort and convenience	5		3	6	9			9	6	9	9	
6. Low repairs & maintenance costs	5		6			9		6		9		9
7.Quality performance	4		9	9	9	9	9	9	9	9		
8.Durability	5		9	6		9	6	9	9	9		9
9. Aesthetic desiagn	3		9			3			6			3
10. Indoor & outdoor opreation suitability	4		9					9		9	9	
Absolute Technical Importance (ATI)			246	240	213	165	210	291	183	270	144	141
Relative Technical Importance (RTI)			3	4	5	8	6	1	7	2	9	10
Target ER values			$150	5	5	40						50
Unit			USD	kg	kg	USD						USD
Tolerances of Ers			±50	<5	<5	±10						±10

3 EXISTING DESIGNS

3.1 Design Research

Information and knowledge gained from existing designs and product features of the assistive devices that are marketed under various internal brands, in countries all over the world, will be effectively used for making our prototypes more suitable, perfect and satisfactory.

3.2 System Level

The Assistive Device which is under prototype development in our Senior Design–1 Project basically seeks to incorporate key prosthesis components, tools, liners, sockets, systems and applications contained in currently marketed devices. In our mechanical engineering product design and development, we have currently adopted following core concepts that are reflected in the top brands of ADs that are manufactured and marketed worldwide (5-98): [1]

- Best fit, grip and comfort
- Perfect alignment of modular parts, materials and components
- Reduced or minimum physical exertion in device use
- Enhanced energy transformation from the disabled through used devices
- Ease and speed of movement (5-98). [1]

3.2.1 Existing Design #1: Underarm Crutches

Crutches are a good for people who like using underarm crutches. This is because they are designed in order to compensate for the advantages of Forearm crutches. The disadvantage to using underarm crutches, and crutches in general is that they rely on the strength of the user to use them correctly and they can be difficult to use in rainy or snowy weather.

3.2.2 Existing Design #2: Exoskeleton

The Exoskeleton is a work in progress device that is being developed at North Carolina State/University of North Carolina-Chapel Hill Department of Biomedical Engineering. They believe that this will help people with paralysis, or trouble walking, overcome their disability. The current version of the device has resulted in an additional benefit of reducing the amount of energy required when using to device by seven percent. Another advantage is the light-weight aspect of the device, as it feels about the same as wearing a loafer on your foot. The biggest disadvantage to this device is that it is not fully tested, and the results are inconclusive for the time being.

3.2.3 Existing Design #3: Walker Crutches

The Walker Crutches, or two-wheeled walker offers the benefits of using wheels to make walking smoother as well as a seat for you to sit on when you are tired. This device makes it easier to go long distances when walking because of how much easier it is to use. Less strength is required for its use. This device has some drawbacks though. This device is difficult to use for some people who stand at full height, the wheels can spin out of control which can cause accidents, and the seat my not be comfortable.

3.3 Functional Decomposition

3.3.1 Black Box Model

The black box model shown below in figure (1) was created to imply the fundamental capability of disabled people who can walk normally by our proposed design. In this black box, bold black line is defined as the material in this model, thin line is used to state the energy for this model, and spotted line to identify the signal. The importance of this model is to show the functionalism of this device keeping in mind to reach the goal which is making disabled people who has paralysis to walk as normal people. We appropriated the fundamental elements of the hope device by making this model and can be comprehended when having the budget and data sources.

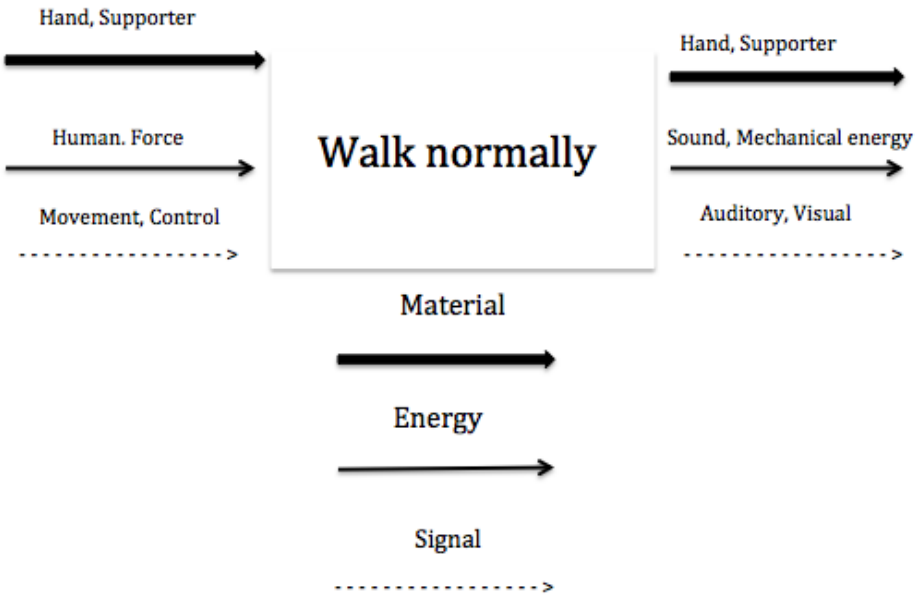


Figure – 7: Black Box Model

3.3.2 Functional Model/Work-Process Diagram/Hierarchical Task Analysis

The black box model presents the hypothesized functional model as it has the main function, material, energy and sound. The functional demonstrates the flows and main functions for the hope device. Hypothesized functional model indicates sub-functions, functions and flows that the hope device contains. The main function used in the black box model is walk normally, which can be designated as the final function for the hope device. This function related to customer needs in way or another. Functional model is important as the team learned how to divide product into functions and flows that are more accessible to the customer needs.

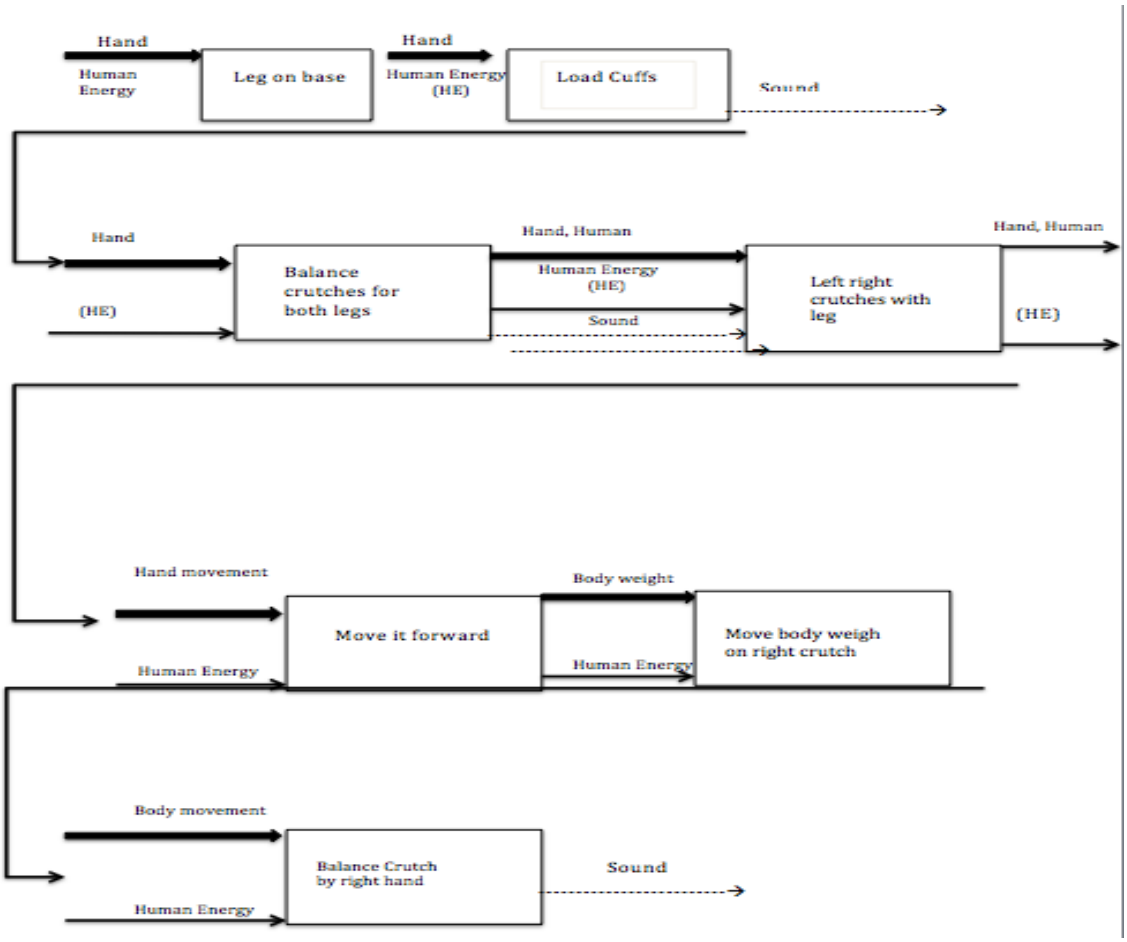


Figure – 8: Hypothesized Functional Model

3.4 Subsystem Level

3.4.1 Subsystem #1: Control

Controlling the design by the user is important. The user should have the most possible control to the design to be able to get more easy movement.

3.4.1.1 Existing Design #1: Underarm Crutches

Underarm crutches controlled by the user using his/her under arm to hold the crutches and control the movement by their hand

3.4.1.2 Existing Design #2: Exoskeleton

The Exoskeleton has sensor to feel the small movements and support them with electrical to mechanical energy.

3.4.1.3 Existing Design #3: Walker Crutches

Walker crutches controlled by the user's hand and body weight. The hand controls the directions and lifting the crutches, and the body weight control the stability.

3.4.2 Subsystem #2: Stability

Stability is one of the most important subsystems. The design has to be stable for the user to get more safety movements. Because if the design is not stable it will not be useful, and it might hurt them instead of helping them.

3.4.2.1 Existing Design #1: Underarm Crutches

Underarm crutches stability depends on the user's legs. The user takes a step using one step by the crutches and the other step by his leg, so the stability and movement depends by hands control the crutches and by legs

3.4.2.2 Existing Design #2: Exoskeleton

Exoskeleton is a device has electrical sensors and energy converts to mechanical movements. So, the stability depends on the device.

3.4.2.3 Existing Design #3: Walker Crutches

Walker Crutches is a manual design developed for old people to give more stability and less movements. The stability is too high because it has four legs.

3.4.3 Subsystem #3:

The holding means how the device will hold the user's body weight. Holding body weight depends on the strength of material.

3.4.3.1 Existing Design #1: Underarm Crutches

The weight held by the underarm pad vertically to the earth. So, the material is not too important, but it could not be weak.

3.4.3.2 Existing Design #2: Exoskeleton

Exoskeleton is an add-on device, it does not hold any weight.

3.4.3.3 Existing Design #3: Walker Crutches

Walker crutches does not hold a lot of weight as much as the regular crutches. The user uses his legs and walker crutches at the same time to take steps.

4 DESIGNS CONSIDERED

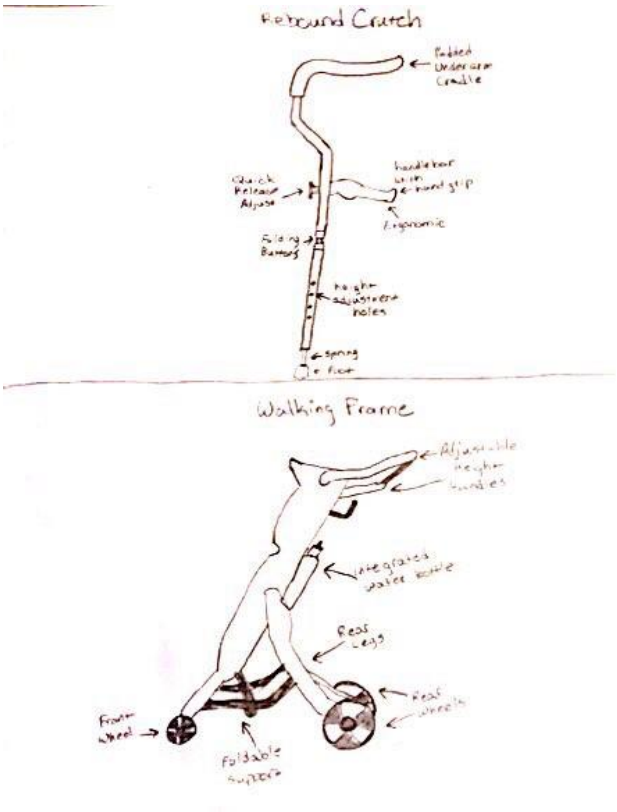


Figure – 9: walking frame and rebound crutch

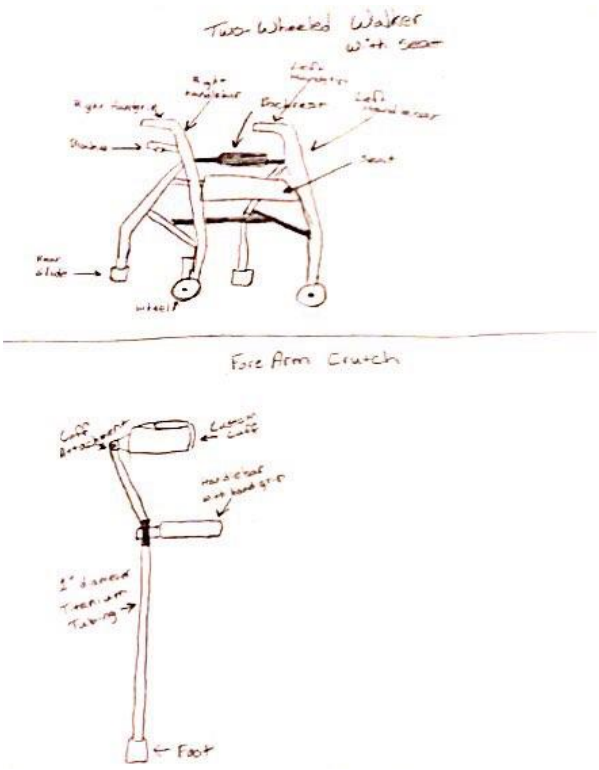


Figure – 10: The wheeled walker and force arm crutch

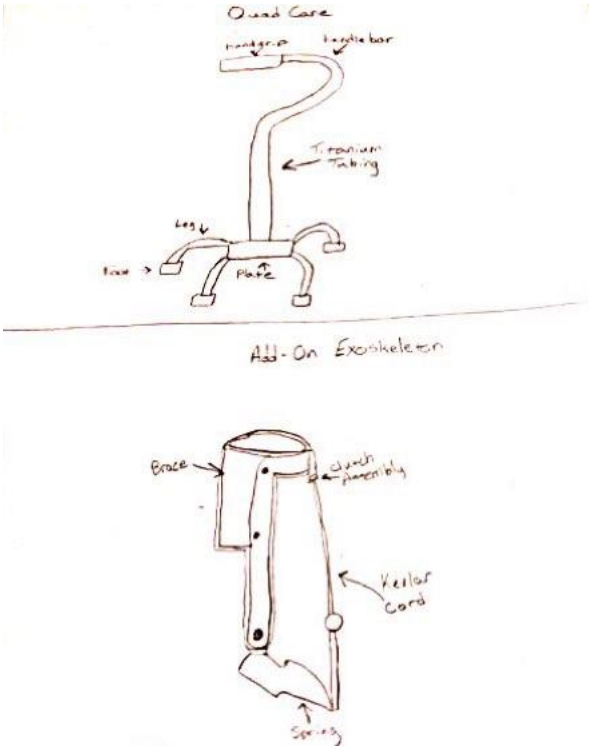


Figure – 11: Quad Cane and Add-on Exoskeleton

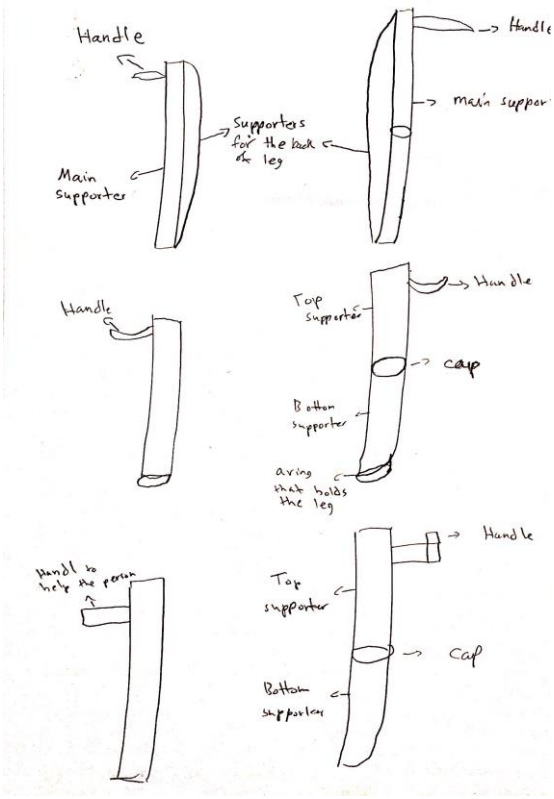


Figure – 12: Existing Designs

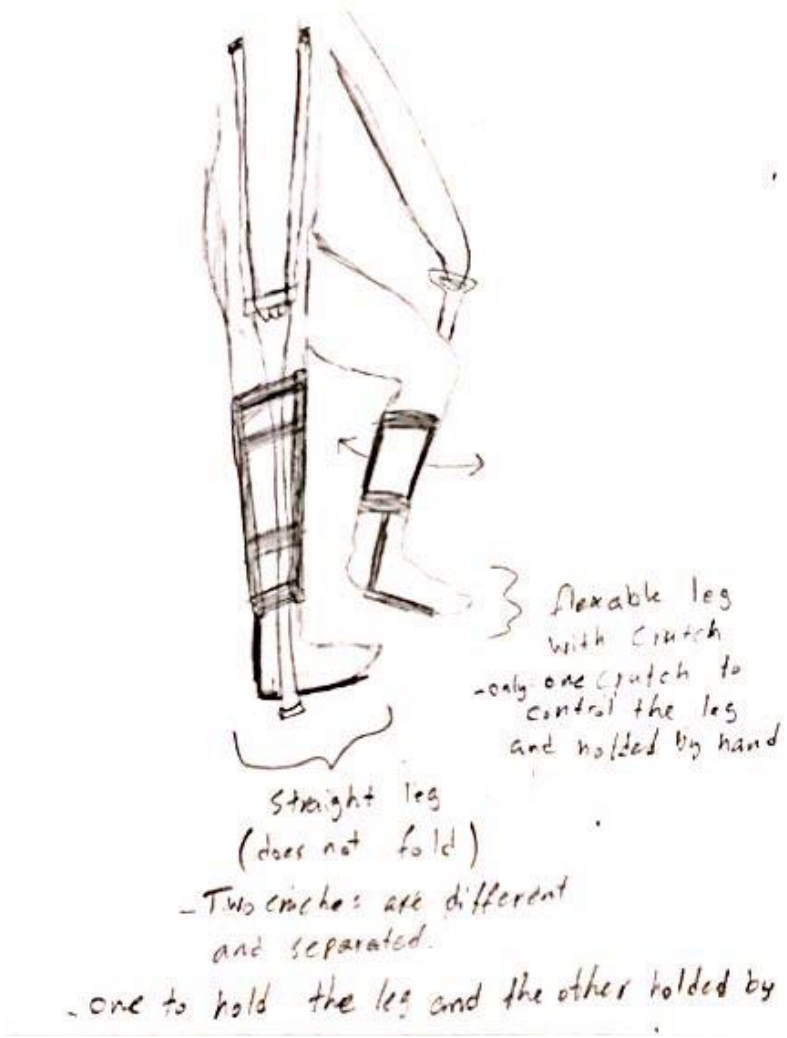


Figure - 13: Main design

4.1 Pugh Chart

The Pugh chart is the tool that analysis the designs below which are manual method, morph concept and bio inspired design. Pugh chart is important tool for designing project as it points the importance of sum the criteria for each design and analyzing each one. It also gives the team members the insight to analysis the application of the criteria for the three designs in this Pugh chart.

Table 2: Pugh Chart

Criteria	Manual Method				Morph concept				Bio Inspired Design			
concept	Ali	Abdulrahman	Mohammed	Sultan	Ali	Abdulrahman	Mohammed	Sultan	Ali	Abdulrahman	Mohammed	Sultan
Cost	+	-	-	-	-	+	-	-	-	-	-	-
Durable	-	-	S	-	S	-	-	-	-	S	-	-
Aesthetics design	-	+	-	+	-	-	+	+	+	-	+	+
afordable	+	+	+	+	+	+	+	+	+	+	+	+
safety	S	S	+	+	+	S	S	S	S	+	S	S
stable	S	+	-	S	-	S	+	+	+	-	+	+
Sum +	2	3	2	2	2	2	3	3	3	2	3	3
Sum -	2	2	3	3	3	2	2	2	2	3	2	2
Sum S	2	1	1	1	1	2	1	1	1	1	1	1

4.2 Decision Matrix

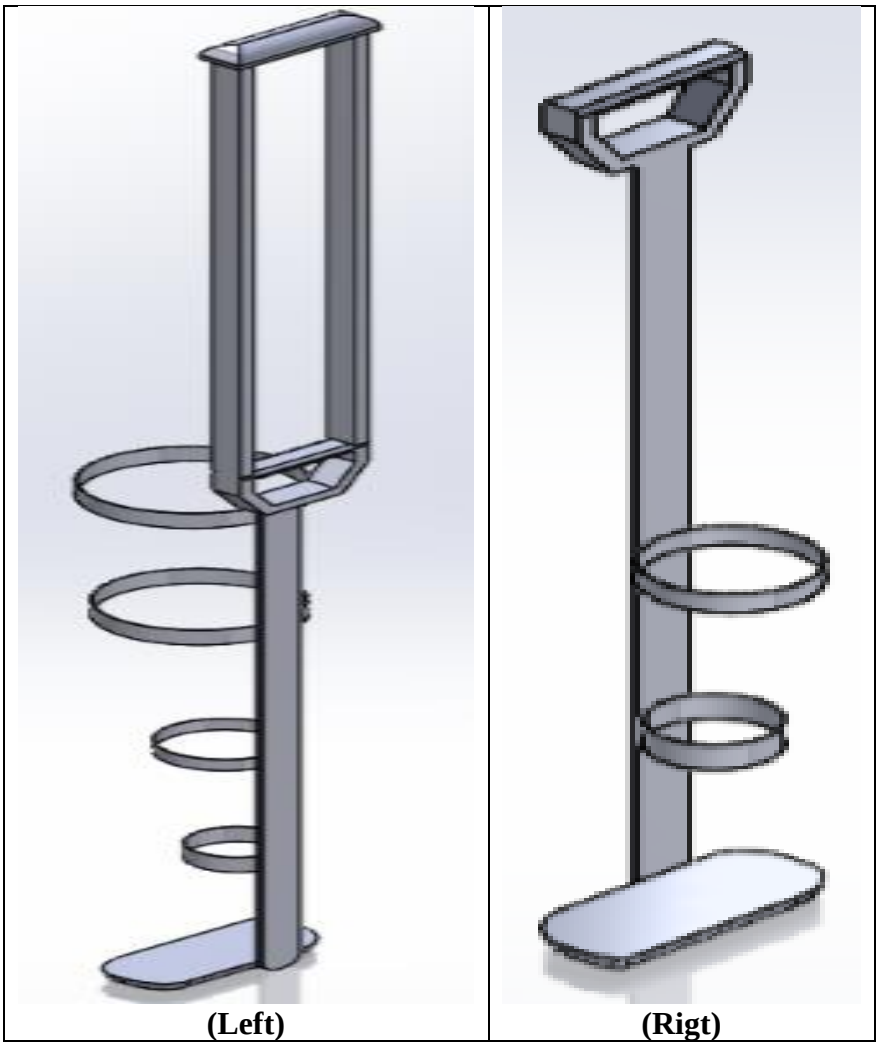
The decision matrix was done by assuming the four designs below which are Ali manual method, Abdulrahman bio inspired, Mohammad Morphological concept and Sultan manual method. The ranking estimated to be from 0 to 100. On the other hand, weigh estimated to be from 0 to 1. This decision matrix showing the evaluation for these designs below and A.M.M got the highest ranking which is 93.33 and M.M.C got the lowest ranking which is 90.83. Decision matrix helped the team to point the best design that we can propose and prevent proposing the other designs which saves the team time and work.

Table 3: Decision Matrix

		A.M.M	A.B.D	M.M.C	S.M.M
Criteration	weight				
Cost	0.13	90	85	95	90
Durable	0.17	95	100	80	80
Aesthetics design	0.17	80	100	95	95
afordable	0.18	100	95	90	100
safety	0.17	100	90	95	95
stable	0.18	95	85	90	90
Total	1	93.33333333	92.5	90.83333333	91.66667
Relative Rank	1_4	1	2	4	3

5 DESIGN SELECTED – First Semester

The group decided to make supporters for people who has foot paralysis or injured, and they are not able to walk. The device will make them able to walk using their hands holding the two different crutches (Attached to legs) that holds their foot. So, the person who is using it has to be strong to be able to lift his whole body weight by his hands.



(Left) **(Rigt)**

Figure - 14: Assistive Device under Senior Design Project – I Prototype Development

5.1 Rationale for Design Selection

Several Key Success Factors (KSFs), were taken into consideration in making the final selections of both the Left Crutch and the Right Crutch. Following are some of the most important technical features, which make these crutches most suitable, convenient and useful:

- Crutches work with users' physical strengths and powers, which has eliminated the need for attaching any mechanical devices' support.

- Lack of built-in mechanical instruments, tools and applications have enabled them to remain light-weight, which does not cause any stress or strain even when the device users remain on their support for prolonged duration.

- Foot-rest flat base helps users to reduce impacts of bearing total body weight under the supports of forearms and armpits.

- Simplicity of the design allows users to wear and remove the device dozens of times according to their needs, demands, and requirements without the least efforts, strains and stress.

- Crutches made with simple engineering technology applications provide safe and secured manual user support, which makes them quite inexpensive.

- Absence of mechanical devices or moving parts, make these crutches very durable while eliminating expensive repairs, maintenance and repurchase costs or expenditures.

5.2 Design Description

The Assistive Device under the prototype development contains a set of 2 Crutches, which could fit both the left and the right leg of the physically challenged person. The crutches have been designed with a flat base at the bottom for foot rest, which provides added comfort, support and convenience to the users in minimizing, reducing and eliminating physical exertions while walking around with the device.

5.1.1 Left Crutch

Disabled and the physically challenged persons who are using the Left Crutch are users who are required to take the major load of their physical weight from being transformed onto the device. To facilitate their needs, requirements and expectations, the Left Crutch has been designed with the following technical features:

- Hand Grip &
- Crutch Pad

By supporting body weight on the Crutch Pad and reducing additional load through strong Hand Grip, users are able to maintain their leg position without flexing it. Due to substantial distribution of body weight through both Hand Grip and Crutch Pad, device users are able to enjoy prolonged outdoor walking or moving around in the indoor environment such as climbing-up or down long staircases without any strain, discomfort, inconvenience and exhaustion. However, the Left Crutch device users are required to be in strong physical fitness with good amount of stamina and strength as they need to continuously maintain their body load under their arm pit and the hand that rests on the Crutch Pad. Foot-rest flat base provides ideal and critical support in reducing weight bearing problems and challenges.

5.1.2 Right Crutch

The design for the Right Crutch, had been significantly modified for the purpose of allowing the disabled and the physically challenged persons to flex their legs. Leg flexing is supported and facilitated by the following device features:

- Shin &
- Calf

The device users are provided with Hand Grip, which enables them to maintain their postures and memorability while moving around in the outdoor or the indoor environment. Hand Grip, provides added safety and security while also serving to assist device users in significantly reducing excess body loads onto the crutch.

References

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