University of Southern Queensland

Faculty of Engineering and Surveying

LIFTING MECHANISM OF WHEELCHAIR

A dissertation submitted by

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towards the degree of

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LIFTING MECHANISM FOR WHEELCHAIR

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Bachelor of Engineering (Mechanical)

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Dr. Harry Siu-Lung Ku
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1. INTRODUCTION

A wheelchair is a device used for mobility by people for whom walking is difficult or impossible. It may due to ageing, illness or disability.

2. BACKGROUND

Elderly or disable people whom are physical disabled have problems getting in bed from the wheelchair or from the bed onto the wheelchair. They might be subject to great pain during movement from wheelchair to bed or vice versa.

The caregiver also subject a great risk to having back problems if they have to lift the disable people several times a day.

3. Objective

The main aim of this project are :
a. To make it easier for caregivers to transfer the disabled people from wheel chair to bed or vice versa.

b. To reduce the potential risk of back problems of caregivers due to daily carrying of disabled people.

c. To minimize the injuries or pains created on disabled people during the transfer from wheelchair to bed or vice versa.

4. Design Methodology

A conventional wheelchair will be used as a available resources for improve version. Further reliability test is needed for safety and validation purpose.

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I would like to thanks my supervisor Dr. Harry Ku and Dr. Wenyi Yan for their guidance and support throughout the duration of my project.

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ENG4111 & ENG4112 *Research Project*

Limitations of Use

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Certification

I certify that the ideas, designs and experimental work, results, analysis and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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25 Oct 2005
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Date

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Teo Chin Teng

University of Southern Queensland

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NOMENCLATURE

A	area (general)
At	stress area of the screw
dm	minor diameter of the screw
d	nominal diameter of the screw
E	modulus of elasticity
f	frequency
fn	natural frequency
g	gravity
k	safety factor
L	length
Le	equivalent length
M	bending moment
M_{max}	maximum bending moment
p	pitch of screw thread
P	applied load
P_{cr}	critical load
w	average human weight

Greek Letter

δ deflection

δ_{max} deflection

σ bending stress

σ_{max} maximum bending stress

υ Poisson's ratio

v linear velocity

ω angular velocity

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1.0 Introduction

A wheelchair is a device used for the mobility of people who walks with difficulty or is impossible to walk, due to aging, illness or disability. However, wheelchair is always view as a symbol of illness and loss of ability. After traumatic event such as spinal cord or brain injury, people will be resist purchasing a wheelchair on the early stage. Because they insist they will walk again. They refused to be wheelchair bounded, as it is a symbol of disability. This belief is totally not true. The wheelchair is a tool. It makes life possible for those who might need it. Even for the people with life threatening illness, the “right” wheelchair facilitate their ability to be out of sick bed, continuing their life, partaking of human experience. In other words, a wheelchair is a chair with wheels that is used to move a person who is unable to walk. The wheelchair may come in different shapes and sizes to enhance the comfort and convenience for users.

There are various reasons causing people being unable to walk by him or herself. The disability may due to age, accident or sick. People may need a wheelchair for a short time or even for the rest of their life. People of different age will need different types of wheelchair to meet their specific needs. It can help the users to continue doing activities and enjoy doing their own things. The initial purpose of the wheelchair is aimed to give more freedom for these people to do simple things on their own, such as carrying items from one place to another. A wheelchair can help disabled people perform more activities if they have trouble in walking. With the aid of a wheelchair, disabled children can go to school and enjoy outdoor activities themselves. Disabled adults may need the wheelchair for increasing his / her mobility and working areas. Disabled senior citizens may need it for increasing their quality of life by not staying at home for the whole day. Overall, a wheelchair helps to increase the mobility of disabled people.

Wheelchair may also help those disabled people to save their strength and energy; or even to reduce their pain if they are injured. However, the user of a wheelchair should choose an appropriate model and the accessories tailored to provide the best support for their activities and health concerns.

The person might choose to use a wheelchair, if:

a. He/she has an illness or injury that does not allow to him / her to walk.
b. He/she is too weak to walk long distances.
c. He/she is on the recovery from a surgery.

In the market, there are various types of wheelchairs. Generally, they can be classified as manual and electric wheelchair. A manual wheelchair is a good choice for users who have reasonable upper body strength; they can move the wheelchair by themselves. People with upper body impairments prefer electric wheelchairs. For people whose problem is simply limited ability to walk or stand for long period of time, motorized scooters are preferred. However, the design for electric wheelchair is much more complicated and battery powered one. A disabled person can simply move around by controlling the joystick. It is advisable to seek doctor’s comment about your ability, before the choosing the right wheelchair.

1.1 Manual Wheelchair

A manual wheelchair is more economic as compared with an electric wheelchair. Manual wheelchairs are available online for between US$200 to US$4,000, depending on the model and features selected.

They are two main types of manual wheelchairs: standard wheelchair and transport wheelchair.

1) Standard wheelchairs are those that can be pushed or moved by moving the wheels. The wheelchair consists of two small wheels and two large wheels. The two small wheels are in front and are approximately 8 inches (200 mm) in diameter; two large wheels are at the rear of the seat and are usually 22 -24 inches (550 – 600 mm) in diameter.

2) Transport wheelchair cannot be propelled by the users, but by a companion or caregiver. Instead of large rear wheels, all four wheels are small and their diameters are 8 inches (200mm).

There are also some additional accessories that can be added to manual wheelchair to enhance their performance. Wheelchairs come in many sizes and can be highly customized with several options including the width and depth of seating size, seat to floor height, footrests or leg rest and others. Armrests and footrests on wheelchair can be removed. Moving the footrest and armrest will enable the caregiver to carry the disabled person to and from the wheelchair easily. The wheelchairs are also fitted with heel loops for extra comfort and safety. They are also padded for additional comfort and the height is adjustable to suit the disabled person. Parking brakes are also fixed on the rear wheels to provide complete reassurance.

Normally, conventional manual wheelchairs have foldable frame, with an X-shaped brace at the centre that allows the frame to be folded sideways. The foldable structure enables easy storage.

Newer versions of the folding wheelchair are lighter than previous steel models. A disadvantage to folding wheelchair frames is that they are not as durable as previous models. The joints of the foldable wheelchair suffer a lot of wear and tear due to closing and opening of the wheelchair. It is also troublesome to keep moving joints in proper alignment, making the folding frame less efficient.

Rigid frame wheelchairs have welded joints and a seat back that folds for transport. Most users are able to load their rigid wheelchair into a car without assistance, because it is made of lightweight aluminium and usually weighs about five to ten kilograms without wheels.

The footrests on rigid wheelchairs are attached to its frame, acting like a platform that runs across the front. Some rigid models are available with a wheelchair-latching bar attached to two flip-up wheelchair footrests. Rigid frame wheelchairs are for users concerned with efficiency and lightness.

1.2 Electric Wheelchair

Electric wheelchairs make use of either gears or belts. Powered wheelchairs with belt drives are very quiet, but they require more maintenance. Modern gear drives are fairly quiet with low maintenance, but they tend to wear out more quickly then belt drives, and get noisier in the process.

Low-end electric powered wheelchairs have light frames that are suitable for indoor use, but their wheelchair frames crack, front forks bend easily; wheelchair motors will also be out of order when they are used excessively; they are more suitable for light duty. The latest high-priced electric wheelchairs are more powerful and reliable, with frames designed to handle more weight. Its weight capacity can be up to 200kg. Some newer electric models even have spring suspension, which allows a smooth ride over uneven ground.

Electric wheelchairs currently cost between US$1,600 ~ US$7,500. They are available in three basic models: rear-wheel drive, front-wheel drive, and mid-wheel drive.

1. Rear-wheel drive wheelchairs are the traditional and most popular style. They are generally faster than the front-wheel models but provide poor turning capabilities when compared with front-wheel and mid-wheel models.

2. Front-wheel drive wheelchairs have become more common because they provide tighter turning functions. Most front-wheel drive wheelchairs have a slightly lower top speed than rear-wheel models because they tend to turn too readily at relatively high speeds.

3. Mid-wheel drive wheelchairs provide the tightest turning of all, but have a tendency to be unsteady at stopping and starting. Mid-wheel drives have caster wheels in the rear and an extra

set of anti-tip wheels in front, which may limit their use on uneven surfaces.

Electric powered wheelchair is suitable for the users who have insufficient endurance or face the difficultly to propel a manual wheelchair independently. It can save or conserve energy for long distance wheeling to school or work. It is a very powerful travelling tool for disabled people.

1.3 Used Wheelchair

Due to financial concern, a lot of disabled people will tend to make use of used wheelchairs. There is no way to ensure whether a used wheelchair will fit a new user's needs. The new user's weight, width, physical limitations and capabilities will all affect the durability of a used wheelchair.

Wheelchairs require a recommendation from a doctor, therapist, mobility equipment provider and potential user to ensure that an appropriate piece of equipment is matched to the user. Since wheelchairs are individually tailored medical devices, they are generally not meant for resale.

However, it is understandable with the mounting costs of health care and the cuts to government funding, that mobility users might need to seek for the cheaper alternatives, like used wheelchairs or scooters.

Many 'Used Wheelchair for Sale' advertisements are put up on the bulletin boards, websites and newsletters at local rehabilitation hospitals and independent living centres. State rehabilitation departments or local disability organizations are more reliable as there are professional personnel to give advice. Advertisements that appear in the classified pages of newspapers, on eBay or used wheelchairs that appear in pawnshops are not valuable resources as there is no professional standard governing these sales.

It is very important to remember that second-hand wheelchairs do not have transferable warranties. This means that even if the warranty was still valid under the previous owner, it is not valid if the wheelchair switches owner.

1.4 Walking Aid

Many people use wheelchairs, but they are not totally confined to them. A lot of people are still able to walk with the help of a walking aid. A walking aid is ideal for getting out of the wheelchair for a little exercise and freedom. They are also useful if the user needs to go somewhere that is not wheelchair accessible.

There are various types of walking aids, such as walkers, canes and crutches, available that will allow these people to walk freely. The user can purchase single point canes, quad point canes, crutches, forearm crutches, walkers, rolling walkers, and rollators. These walking aids are all relatively lightweight and portable.

The type of walking aid that is chosen usually depends on the user's physical limits and stamina. The user must also learn how to safely use their walking aid, as improper use will result in injuries. It is probably a good idea for the user to consult his doctor before deciding on which walking aid is most suitable for him / her.

Walking aids are also ideal for people who are temporarily injured or immobilized and are often used during the rehabilitation process and physiotherapy. Most walking aids are adjustable to suit one's height, but one needs to make sure that one's aid or aids are the proper size for one. They are also usually built to handle a certain weight capacity, so make sure the walking aids one is using are built to handle one's body size and weight. One needs to be comfortable with one's walking aids. It is advisable not buy anything that one is not satisfied with.

2.0 Background

Many people choose using wheelchairs to improve their lives. A variety of medical conditions may exist that require the use of wheelchairs. Some of the conditions include:

a. Paralysis

b. Old age

c. Weight

d. Degenerating muscle diseases

e. Broken or weak bones (bone diseases)

f. Accident

Old age can be considered the main contribute to sales of wheelchair as it has become one of most readily available commercial product in the market, particular in the developed countries like Japan, Spain and Singapore (for the next 10 years). The total population of Singapore was 4.17 millions in 2002 and was up slightly to 4.18 millions in 2003. (Data collected from Singapore Department of Statistics, www.singstat.gov.sg) The population of Singapore who was more than 65 years old was 7.5% in 2002 and was up to 8.0% in

2004. On the other hand, the population with less than 15 years old was 21.2% in 2002 and dropped to 20.1% in 2004. The trend of newborn baby is down, due to various reasons.

At indicator shows that the birth rate was 11.4 per 1,000 population in 2002 and dropped to 10.1 in 2004. Due to improvement in medical standard, the death rate was down from 4.4 per 1,000 persons in 2002 to 4.3 per 1,000 persons in 2004.

Based on the above statistical data, the population in Singapore will increase at a very slow rate. Singapore's resident population is growing older. Fifteen to 20 years later, Singapore will be facing double-digit increases in the number of residents who are more than 65 years old. The high proportion of senior citizens will increase the demand for caregivers or old folks homes in the market. The caregivers and healthcare centre demand are expected to increase dramatically in future.

Many Singaporeans are single and young couples also have planned not to have babies. The Singapore government is trying to battle the reverse of its falling birth rates. Prime Minister Lee Hsien Loong unveiled the Parenthood Package, which includes longer maternity leaves, in August 2004. The number of citizen births has increased by 3 per cent from May to July 2005 as compared to the same period previous year. The Registry of Births and Deaths said that in the first half of 2005, 18020 babies have been born, 237 more than the same period last year. Below are the basic supports for the families who need the health care services at Singapore:

Long term care: The elderly can be admitted to nursing home, if they need daily nursing care and nobody looks after them at home. Generally, Singaporeans are expected to work until 65 years old, unless they have health problem. Singaporean government officially recognizes 65 years old as retirement age. Most of these elderly are left at home with no one to take care of them. Elderly who stay in nursing homes might be semi-ambulant, wheelchair bound or bed bound.

Short term care: Respite care is also available at some nursing home to provide short-term care. Respite care can last for a few hours to a few weeks.

Rehabilitation Centre: In the centre, doctors will be able to access to the patient's need for rehabilitation such as physiotherapy and occupational therapy to elderly who suffer from stoke, fractures, lower limb amputations and other impair functional abilities. The rehabilitation centre mainly cater for patients suffering from stroke, Parkinson's disease, post fractures, post amputation, reduced functional status following hospitalisation or inactivity and any other medical conditions.

Below is an on site case study:

<u>Case Study</u>

I visited an old folk home located in the Jalan Sialang, Tangkak, one small town located in West Malaysia. (Figure 2.1 shows Old Folk Home located at the Tangkak, one small town in West Malaysia.) There are no nurses or volunteers to help in looking after these old people on the daily basis. The disabled senior citizens are seen to have been watching television programmes throughout the whole day as they pass their times in the home. They are also required to prepare their own food. There are no special programmes or activities assigned to increase their physical activities or lifestyle.

Figure 2.1: Old Folk Home located at the Tangkak, one small town in West Malaysia.

There are up to 14 senior citizens staying in this run-down yet peaceful old folk home. Occasionally, there will be some gifts offered to them by local people.

Madam Rajumic who is 81 years old this year (Figure 2.2), commented that the wheelchair is not user friendly. Eight years ago, she had an accident that lost her the bottom part of her right arm. She starts her life again with the help of a false leg. Now, she manages to cook herself in the kitchen.

Figure2.2: Picture on the left shows Madam Rajumic with her false leg. Picture on the right shows that she manages to walk and cook with the aid of her false leg.

Figure 2.3 is Mr. Pakli, who is 98 years old. He spends most of his days laying down in bed. He refuses to get out of bed due to the pain on his underarms caused by lifting and transferring to the wheelchair. He had been disabled for 9 years when he had an accident. During the first 3 years of his disability, he was still able to sit on a wheelchair by the help of his caregiver Ms Kamala, who is the only relative staying in this small town. Ms Kamala also suffered from back pain problem at the initial stage of lifting of her uncle to and from a wheelchair to bed several times a day.

Figure 2.3: Mr Pakli is bed bounded as he complained arm pain during lifting from the bed to wheelchair.

After surveying on nursing homes and old folk homes, these are some feedbacks from the disabled people. Most wheelchair users mention that the wheelchair needs to be improved. Existing wheelchair expects the lifting of the disabled by the caregiver from the people's underarms.

The disabled person felt pain on their underarms when lifted. Improper lifting by caregiver sometimes causes bruises. The caregiver may also subject to big risk in back problem if they have to lift the disabled several times a day. Many caregivers complained that they have a hard time for lifting the patient particularly if his/her weight is more than 100kg. It may need two or more caregivers to perform this basic daily routine. Recently, these is increasing number of lawsuits about professional healthcare providers due to improper transfer of the disabled from wheelchair to bed at developed countries like United States.

Elderly or disabled people who have problems from getting in bed from wheelchair or vice-versa are subjected to great pain during movement from conventional wheelchair to bed, because they need manual lifting. It is very inconvenient for them and their family as most of latter need to work. Therefore in this project improvement in the mechanism of wheelchair would be made to benefit the users and caregivers.

3.0 Literature Review

Wheelchair was developed from simple chair that attached with wheels to scooter. Below is history and development of wheelchair (Sawatsky, 2002):

- 6th century - this is the earliest found image of a wheelchair. It is incised in stone on a Chinese sarcophagus.
- 16th century - King Philip II of Spain used an elaborate rolling chair with movable arm and leg rests.
- 1700 - King Louis XIV used a 'roulette' for moving about while recovering from an operation.
- 18th century - the first wheelchair that resembles today's design. It had two large front wooden wheels and one caster in rear.
- 19th and 20th centuries - following the American Civil war and World War I, the first wheelchairs were built with wooden frames, wicker seats, adjustable arm rests, footrests, and large wheels.
- 1894 - a U.S. patent was filed for a wheelchair with a fixed frame, adjustable surfaces, firm wicker seats, and large rear wheels for self-propulsion.

- 1932 - Herbert Everest (an injured mining engineer) and Harold Jennings (a mechanical engineer) collaborated to design the first folding frame wheelchair. They went on to form the company that is today known as Everest & Jennings or E&J.
- 1937 - a patent was filed for the x-folding frame wheelchair. Sam Duke also marketed a folding wheelchair at same time.
- 1950s - Everest & Jennings developed the first powered wheelchair. They followed the development of transistor-controlled motors and adapted it to their interest by adding a motor to their manual wheelchair design.
- 1952 - the beginning of wheelchair sports occurred with the first games held at the Stoke Mandeville Rehabilitation Center in England.
- 1964 - the first Paralympics games were held in Tokyo, Japan.
- 1975 - Bob Hall competed in Boston Marathon.
- 1970/80 - revolution in lighter weight manual chairs driven by the need and desires of wheelchair athletes.
- 1980s - microprocessor-controlled powered wheelchairs were developed, which allowed customization of controls to meet the needs of more user needs.
- 1980-90s - the revolution in powered wheelchair design, control, styles, range or travel distance, suspension, maneuverability, and seating and other user options.

From the population data as highlighted on to Chapter Two, the numbers of elderly and disabled people is increasing dramatically in recent years. In order to achieve world class standard of health care, Minister of Health of Singapore (2004) (Data collected from Singapore Department of Statistics, www.singstat.gov.sg) has set following mission statement:

a. To promote good health and reduce illness.

b. To ensure that Singaporean have access to good and affordable healthcare that is appropriate to their need.

c. To pursue medical excellence.

The residents who have multiple disabilities are unable to care for themselves independently. Many of them are abandoned. Normally, elderly and disabled people will be sent to government health care centres. Besides a daily routine that aim to improve the basic living skills of the residents, various programmes and therapy are also run to enhance the residents' mental and physical well being. The government tries their best to take care the welfare of people in terms of fundamental education and basic facilities for the disabled people, including the promotion of wheelchair sports.

Wheelchair sports will help increase strength, flexibility, and muscle-tone, aid mobility and self-esteem, help control weight and aid digestion. (www.wsusa.org) The wheelchair sports start developed since 1952, from the Stoke Mandeville Rehabilitation Center in England. Now, there are more than 70 countries involves in the Internal Stoke Mandeville Wheelchair Sports

Federation. The other sports for disabled people, Paralympics are the event that parallels to Olympics. It is ultimate sports for disabled people. It takes place every 4 years and is held in the same country and in the same years as Olympics. It often uses the same venue as Olympics game. The first Paralympics was held on the Rome in 1960, which attracted about 400 competitors from 23 countries. Since then, the Games have grown dramatically. In the Sydney 2000 Paralympics, 3843 athletes from 123 countries gathered together to compete in 18 sports.

Disabled people who are bounded with wheelchairs with the upper-body strength shall be going for exercise. Wheelchair sports will also help alleviate the shoulder; neck and back strain that wheelchair user's often experience. Before beginning any wheelchair exercise regime it is important to consult a doctor to determine which wheelchair sports are suitable. A certified personal trainer is very helpful to teach and help transfer the disabled people from gym machines.

Followings are some tips to perform wheelchair sports safely and effectively:

a. Warm up 5 to 10 minutes with stretches.

b. Use proper posture.

c. Start with a lighter warm-up weight - then increase gradually between sets.

d. Breathe - exhale as you lift, inhale as you lower weights.

e. Drink plenty of water.

f. Eat a light meal or snack at least 1 hour before exercising.

g. If you feel faint - stop or take a break.

The Singapore Disability Sports Council (SDSC) is the national sports body for the disabled in Singapore. It is a voluntary organisation that registered under the Commissioner of Charities.

The SDSC aims to:

a. Provide training to the disabled people in various wheelchair sports.
b. Enhance the lifestyles of the disabled people and integrate them into the community through recreational sports and activities.
c. Increasing public awareness and promoting a widespread support for the sporting and recreational needs of the disabled community in Singapore.

SDSC believes in the rehabilitative value of the sports. Its programmes and activities underscore its guiding principle that "Disability must never Disqualify". SDSC depends on the kind and generous contributions of corporate sponsors and members of the public to advance its cause.

Another association, The Riding for the Disabled Association of Singapore (RDA), provides free therapeutic horse riding lessons to children and adults with disabilities from all over Singapore. It aims to teach people with disabilities to ride to the best of their ability. RDA can benefit virtually all disabilities, both physical and intellectual, in children and adults. As well as providing recreation and sport, disabled riders can gain self-confidence, improved blood circulation, respiration, balance, coordination and mobility.

For someone who cannot walk, see, communicate, etc, riding a horse allows them to experience a new sense of freedom and independence.

Beside the sports, public building shall be modified or design that assessable for wheelchair. The Commonwealth Disability Discrimination Act (1992) state that disabled people should enter and use any public building, facilities and services in an equitable manner as normal people. Building should dismantle physical barriers or set up adaptations such as wheelchair ramp. This Act comes into effect on March 1993. Buildings that are built before the Act must remedy the situation through an alteration and modification. This not only reduces the burden of caregiver, but also improves the mobility of disabled people.

The existing hardware function of wheelchair and its accessories needs improvements. These items might include:

- Mounting system for communication devices.
- Protective pads for arms, elbows, and legs, and cushions from back.
- Voice activated wheelchair control.

Different grade of disability will require different wheelchair for different functions. So, the user shall make the right choose on wheelchair. But in the market, there are less chooses to fulfil the various demands of end users. From the case study, Madam Rajumic only depends on the false leg to increase her mobility. However, the existing wheelchair cannot provide its service for Mr.

Pakli. He required a wheelchair that provides less or no handling from bed to wheelchair or vice versa. In other words, both the conventional manual wheelchair and electric wheelchair is not suitable to him. My research project will be mainly concentrating on the modified the existing manual wheelchair. So, the final design wheelchair shall be provided less handling process subject to disabled people. Manual wheelchair was selected due to its frame required less components, if compared to electric wheelchair. It is cheaper and affordable for the disabled people from developing countries. The designed wheelchair shall be provided flexibility and mobility for sick people like Mr Pakli. At least, it can improve their lifestyle after disability.

4.0 Objectives

The objective of this research project is mainly to maximize the performance of the existing wheelchair. The designed wheelchair shall be reduce or minimize the handling process during transfer of the disabled from wheelchair to bed.

The principal aims of this research are to:

1. aid caregiver to transfer the disabled from wheelchair to bed or vice versa.
2. reduce the potential of back problem due to carrying the disabled several times a day.
3. minimize the injury or pain created on disabled during transfer from wheelchair to bed or vice versa.
4. minimize the dependency on caregiver for household activity, as mobility of disabled is increased.
5. maximize the quality of life of the disabled particularly for outdoor activities.
6. design a wheelchair at a competitive cost with proper material selection.

In the past, the feedbacks of consumers and end users are usually ignored. These consumers are not given many choices nor are they asked to contribute to the decision making process. But now, consumers' responses have become highly critical to the design process of providing assertive technology and rehabilitation services.

The following steps were taken to address the above objectives:

1. develop an interview or survey to access the requirements of disabled.
2. gather ideas to improve the wheelchair prescription process. Use the feedback as main input for this design.
3. review current practice based on the information and data.
4. develop an enhancement model.

5.0 DESIGN

Designers shall be 'making things better for people' (Seymour, 2002). The design activity shall be mainly focused on human behaviour, human factors and quality of life. The designer can improve the functions of a certain product or make the product more users friendly. There may be no absolute definitions of design that will please everyone, but it can attempt to create or supply the needs for the end users (Ertas, 1993).

A designer always turns a concept into something that's desirable, viable, and value added to people's lives. Designers have to ask themselves questions such as: is the product they are creating really wanted? How is it different from everything else on the market? Does it fulfil a need? Will it cost too much to manufacture? Is it safe?

When designing for people with disabilities, consideration of his/her relationship to the product or environment is of utmost importance. The design problem must be well defined. Design criteria must be established before proceeding to the ideation stage. Methods in this stage include interviews and questionnaires with users of wheelchair and caregivers concerning their experiences and attitudes. Here, the feedback from Mr. Pakli and his caregiver Ms. Kamala will be cited as main motive for this research project.

The real problems of existing wheelchair are:

a. Pain on the underarms felt when the disabled is lifted from wheelchair to bed.

b. Care person usually suffers from back problems due to lifting of disabled person several times a day.

A conventional manual wheelchair will be used as reference to update the current design. Observation of existing conditions is critical to provide a thorough understanding of the problem. The wheelchair design includes consideration of diverse uses and geographical conditions. The wheelchairs should be designed for indoor use or outdoor use, long distance travel or rural use. A wheelchair that can provide the greatest degree of movement for a disabled person to and from a stationary place will be considered best.

Before beginning a major design project, it is important to have work plan for design methodology (See figure 5.1: Work Plan for Prescriptive Design Methodology). The advantage of a design methodology comes in its organization of design principles.

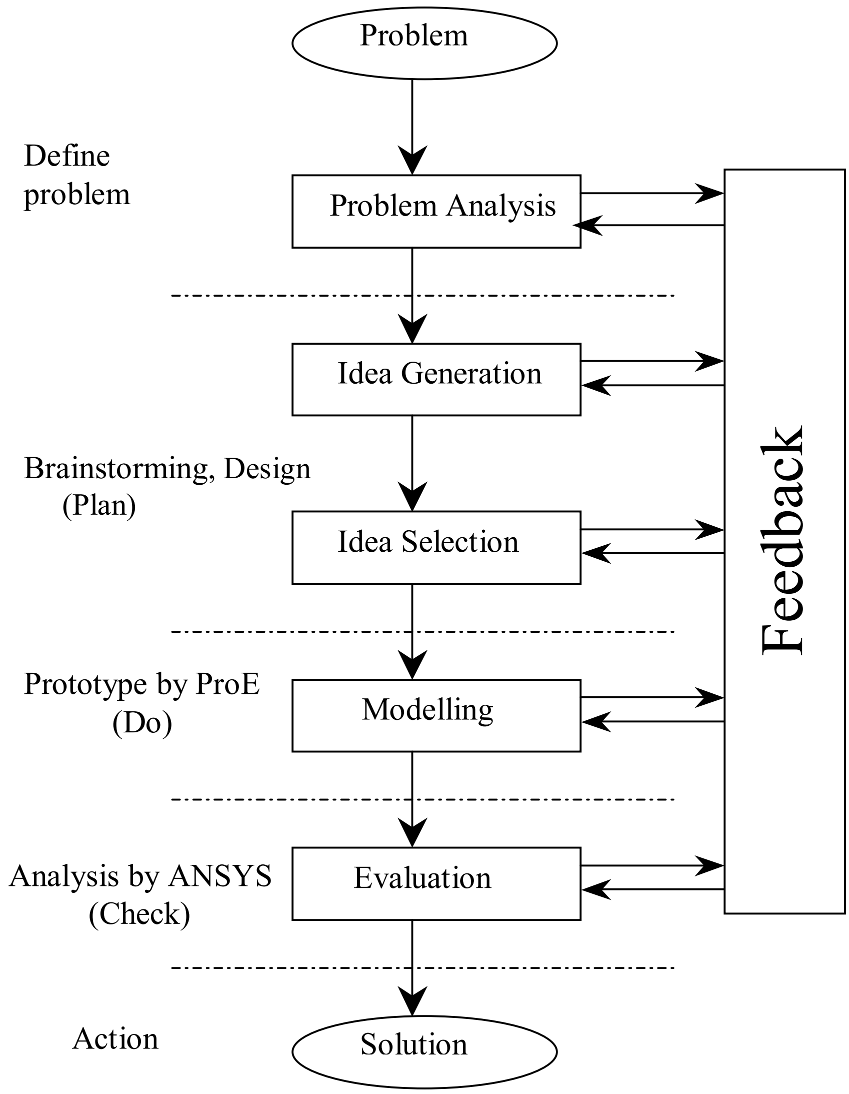


Figure 5.1: Work plan for Prescriptive Design Methodology

A design layout on the wheelchair criteria, constraints, available resources, and ideals is done and then applying the methodology to guide the design process. If the methodology is followed in proper order, a resulting design should fit all of the criteria and be the optimal solution to the described problem.

Today, the one of the most common design methodologies used in modern manufacturing is the prescriptive design process. A multi-step linear process of problem formulation, idea generation, and prototype production characterizes this methodology. It presumes that the most significant relevant information and resulting solutions can be done before production, and it relies on highly research in every single stages of a centralized design process. The prescriptive process minimizes the risk before large amounts of capital is invested in the production of costly prototypes. Generally, the process itself requires the expenditure of significant amounts of capital.

For prescriptive design, the time and money spent on problem formulation and ideation prior to prototype construction may reduce the number of prototypes necessary to produce a successful design.

For this project, there are two main areas to be defined in order to improve the expected end function of the wheelchair. a more user-centred design approach has been developed.

The two areas that are subjected to more improvements are:

a. Vertical lift of the disabled person to a suitable height.

b. Horizontal transfer of the disabled person to and from wheelchair.

It is necessary to treat these two areas as value added to the original conventional manual wheelchair. Users of wheelchair can just install the particular spare part to meet their specific needs.

Design Phase:

a. Design input: the fundamental ideas were evaluated. The concepts shall adhere to the objective and design requirements. The designed wheelchair shall be capable to lift up and transfer the disabled up to 100kg.

b. Design methodology: using the prescriptive design approach

i. Calculate the capacity of each components of wheelchair.

ii. Verify with supplier whether specifications of components meet expected requirements.

c. Design modelling: modelling the component in Pro E (refer to Chapter 9.0).

d. Design evaluation: evaluate the performance of wheelchair by ANSIS. Use MATLAB to calculate the second moment of area, displacement and maximum bending stress.

Design evaluation shall include the failure analysis and prevention, as they are important functions to all engineering disciplines. In any case, one must determine the cause of failure to prevent future occurrence, and/or to improve the performance of the device, component or structure.

Evaluated items:

a. Design validation - to perform. Validate the wheelchair as per specific requirement

b. Component reliability test – to perform. Use ANSYS for stress-strain analysis
c. Structural analysis - analysis the main components, like "C" and "U" beam on Chapter 8.0.

Note: This is totally a different descriptive design methodology. The descriptive process is characterized by the early production of a prototype. The design is refined through repeated prototype and evaluation cycles. The designer learns about the problem through the generation and evaluation of sequential prototypes.

5.1 Design Modelling

This part of the research project is the conceptual stage where techniques such as problem analysis and brainstorming are used. It is essential and crucial that in this stage, solutions are found and not only seeing the problem in its fundamental elements.

Design visualization is a powerful tool for representing an idea. This design project is done in 3D modeling. It includes the individual component drawings and in assembled drawings.

By looking inside the 3D space through renderings and animations, potential problems can be spotted and corrected much more easily than in two-dimensional drawings.

From the Pro E, the following drawings shall be provided:

a. Part detail drawings

b. Components specifications – materials, process, colour, textures

c. Assembly drawings

d. Assembly instructions

5.2 Design Evaluation

The safety aspect of the wheelchair needs to be considered for. Safety issue will be discussed in chapter 6; this will be related it to the hazard assessment of the design.

The designed wheelchair is only considered reliable when it shows good consistency of its expected performance. In short, the wheelchair must perform with good repeatability. Fatigue must be considered in the early phase of design.

A test of validation on the wheelchair stability is to be done. Validation is very crucial. Validity is more important than reliability, because if the wheelchair does not accurately perform what it is supposed to, there is no reason to use it even if it performs consistently or reliably.

Note:

There should be feedback from the user on the designed wheelchair. However, due to time and cost constraint, testing of protocol and feedback from the user are not performed.

5.2.1 Reliability

Nowadays, end users always talk about reliable products. Reliability can be referred to as "repeatability" or "consistency" of performance. Reliability always means trustworthy. It gives confidence to users that it can show a good performance. For example, a 'X' model car can speed up to 200km/hr within 10 sec. It shows the repeatable capability without any problem. Then, one can say that the 'X' model is reliable.

Reliability is a ratio or fraction (Ertas, 1993). In a layman term, one might define Reliability, R as True Value / Actual Value.

For technical terms, one might define it as :

Reliability, R = Variance of True Value / Variance of Actual Value

$$= \frac{\text{var}(T)}{\text{var}(T) + \text{var}(e)}$$

If the item is perfectly reliable, there is no error or mis performance,. so var (e) = 0,

$$\text{Reliability, R} = \frac{\text{var}(T)}{\text{var}(T) + 0} = \frac{\text{var}(T)}{\text{var}(T)} = 1$$

So, the reliability, R = 1. Now, if one has a perfectly unreliable product. there is no true scope or true value. The actual value is entirely error. Var (T) = 0, and Variance of actual value = var (e).

$$\text{Reliability, R} = \frac{0}{0 + \text{var}(e)} = 0.$$

Form here, one knows that reliability will always range between 0 to 1. The value indicates the proportional of variablility in measured attribute to true scope. A reliablity of 0.8 means the variability is about 80% true and 20% error.

5.2.2 Reliabiltiy and Validaty

One might view reliability and validity as separate issue and not related to each other.(www.socialresearchmethods.net/kb/rel&val.htm). Figure 5.2 shows the relationship between reliability and validity.

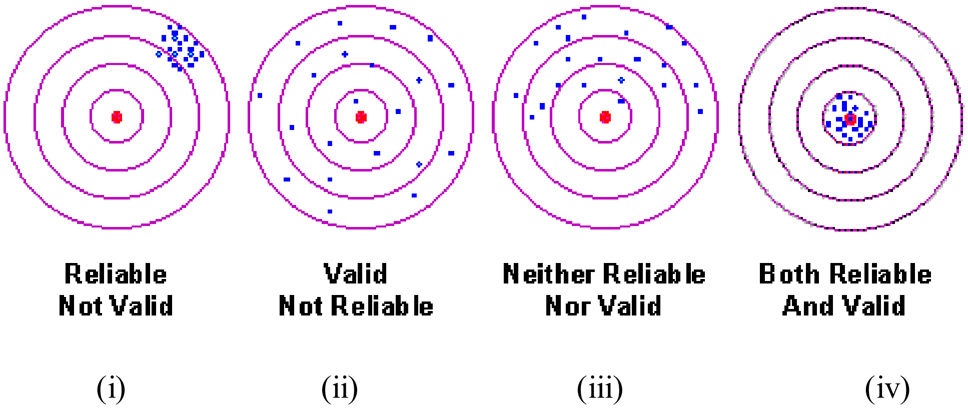


Figure 5.2: Relationship between reliability and validity

From figure 5.2 it is found that (i) Reliable and Not Valid: the performance meets the target consistently; however, it misses the center of target. It consistently shows the same characteristic but not valid (because of off center of target value); (ii) Valid and Not Reliable: the performance is randomly spread across the target. It seldom meest the center of target and shows consistency; (iii) Neither Reliable nor Valid: the performance is not consistent because the performance spreads over at other portion of target and it misses the centre of targe; (iv) Reliable and Valid: the performance shows consistency and meets the center of the target.

The designed wheelchair shall perform consitently on the expected function. It shall show good reliablility and validity.

5.3 Design Concept

The seat of conventional manual wheelchair will be changed from stationary to movable. Figure 5.3 shows the concept of design on modified manual wheelchair. Portions to be modified from conventional manual wheel chair are described below:

A. Vertical Lifting: adjust seat of wheelchair to the same height as bed.

B. Horizontal Transfer: transfer the disabled from wheelchair to bed or vice versa.

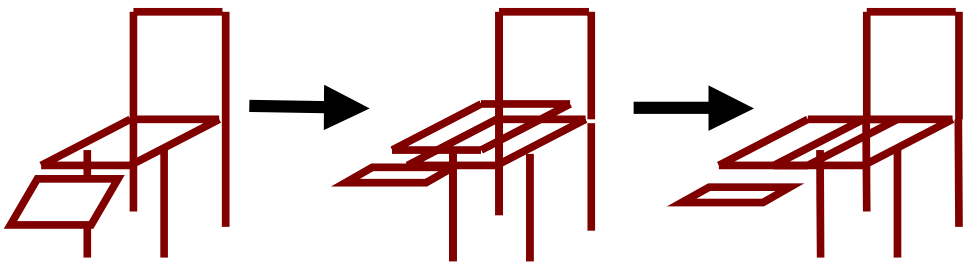


Figure 5.3: the concept of design on modified manual wheelchair.

5.3.1 Design Concept for Vertical Lifting

There are various commercial components that can be used for vertical lifting; the most common components are :

a. Hydraulic or pnematic jack and

b. Scissor lift

Power screw is selected as the lifting component for this project due to its simplicity. There is no problem of storage or leakage like hydraulic jack. It is easy for caregiver to operate.

5.3.2 Design Concept for Horizontal Transfer

Figure 5.4 shows the direction of "X" and "Y" on a wheelchair, which can be designed to transfer the seat in the described "X" and "Y" directions.

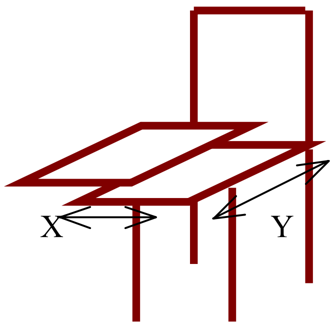


Figure 5.4: the direction of "X" and "Y" on a wheelchair.

a. Seat Transfer in " Y " axis

Figure 5.5 shows the seat transfer in the "Y" direction. This means longer distance has to be transferred, 2/3 of "Y" distance is longer than "X" distance. However, it is quite unstable to transfer disabled people in such distance. Disabled people need to turn 90 degrees, in order to lay down in the bed. It is quite inconvenient to the disabled and caregiver.

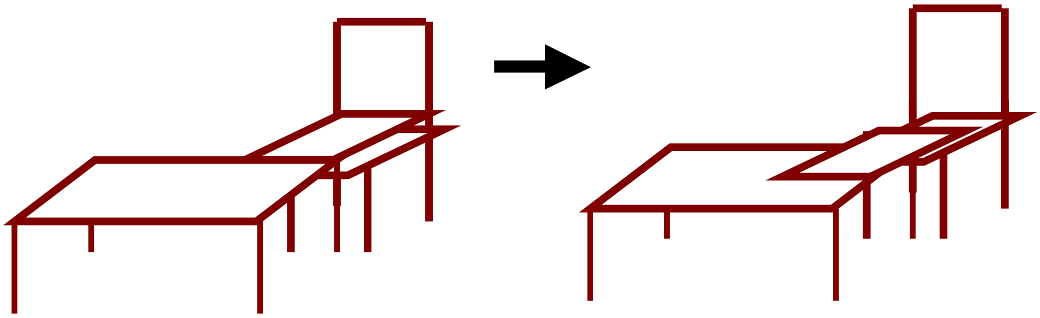


Figure 5.5: the seat transfer in the "Y" direction.

b. Seat Transfer in X axis

Figure 5.6 shows the seat transfer in the "X" direction.The 2/3 distance of X is transferable. The design is much easier and comfortable for the disabled to lay down the bed.

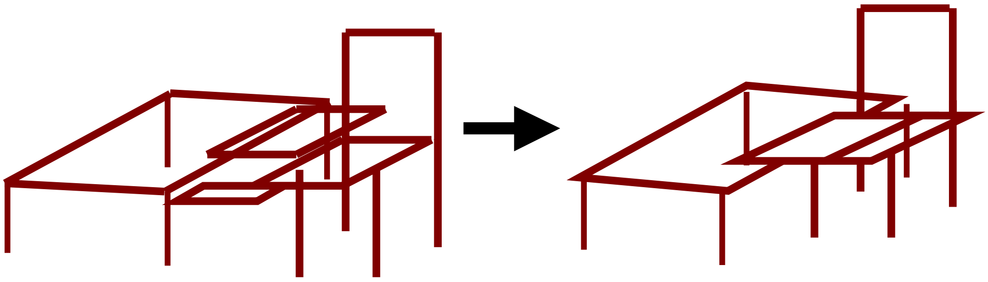
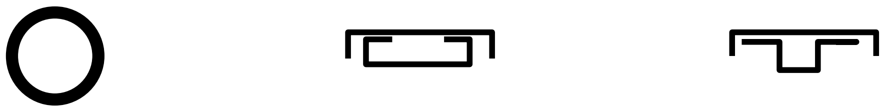


Figure 5.6: the seat transfer in the "X" direction.

In the design for horizontal transfer components, three options have listed down for horizontal transfer component. Figure 5.7 shows the views of the respective options.

Option A : steel rollers can be selected for transfer of the seat but they are very slippy. Caregiver has to be very careful to transfer the disabled from wheelchair seat to bed. The centre of gravity becomes higher, that causes relative unstable when turning the wheelchair.

Option B and C : the origin of this idea comes from the movable seats in the car. This method is simpler and lighter when compared to steel rollers. Option "C' is a better design as compared to the option "B". It uses less material when compared to Option "B".



a. Steel roller **b. Two "C" beams** **c. One "C" and one "U" beam**

Figure 5.7:the views of respective options.

The design refers to existing wheelchair dimensions and their characteristisc. Figure 5.8 and 5.9 show the conventional manual wheelchair and electric wheelchair respectively. Tables 5.1 and 5.2 provide the parameteric informations for both manual and electric wheelchair respectively.

Figure 5.8:conventional manual wheelchair

Figure 5.9:electric wheelchair

Type of Chair:	Standard
Weight Capacity:	120 kg
Weight of Chair (Without Footrests):	20kg
Seat Width:	457mm
Seat Depth:	406mm
Seat to Floor:	Adjustable from 450mm to 501mm
Seat to Top of Back:	419mm
Overall Width:	635mm
Overall Height:	914mm
Overall Depth Including Footrests:	51
Overall Depth (Chair Only, No Footrests):	42"
Folded Width:	10.5"
Armrests Fixed or Detachable:	Fixed
Foot or Legrest fixed or detached:	Swing Away, Detachable
Upholstery Type:	Nylon
Front Wheel Size:	203mm x 44mm
Rear Wheel Size:	609mm
Back Type:	Fixed

Table 5.1: the parameteric information for manual wheelchair

Weight Capacity	226kg
Over-All Length	990kg
Over-All Width	685mm
Seat Width	609mm
Seat Depth	558mm
Maximum Speed	8 km/hr
Range of Travel	Up to 40km Per Charge
Caster Wheels	(Front) 203mm X 50mm
Drive Wheels	(Rear) 304mm
Turning Radius	800mm
Largest Batteries Available	2 - 12 Volt - 75AH Group 24
Battery Weight	20kg Each
Ground Clearance	88mm
Breaks Down Into	4 Pieces
Heaviest Piece	61 kg
Total Weight With Batteries	127kg

Table 5.2: the parameteric information for electric wheelchair.

5.4 Ergonomics

Ergonomics is about ensuring a good fit between people, the things they do, the objects they use and the environments in which they work, travel and play. Human factors (or human factors engineering) are an alternative term for ergonomics. Ergonomics needs to be considered in the design of any product, system or environment. Failure to do so may lead to designs which do not fit the physical, psychological or sociological needs of the users, leading to ineffective, inefficient or unsafe designs, which are unlikely to be commercially successful.

The human sciences of psychology, anatomy and physiology provide information about the abilities and limitations of people, and the wide differences that exist between individuals. People vary in many ways: body size and shape, strength, mobility, sensory acuity, cognition, experience, training, culture, emotions, etc. Ergonomics are trained in analytical techniques, which will consider user characteristics and individual differences to the full extent in the design process.

Good designers shall consider the people who will use the products, systems and environments they design, but they also have many other factors to consider. Often, it was due to commercial or percentile of population mean that ergonomics principles are compromised or not given adequate priority. Figures 5.10(a) to 5.10(d) are the body dimensions to different percentile for men and women. (Dreyfuss, 1967).

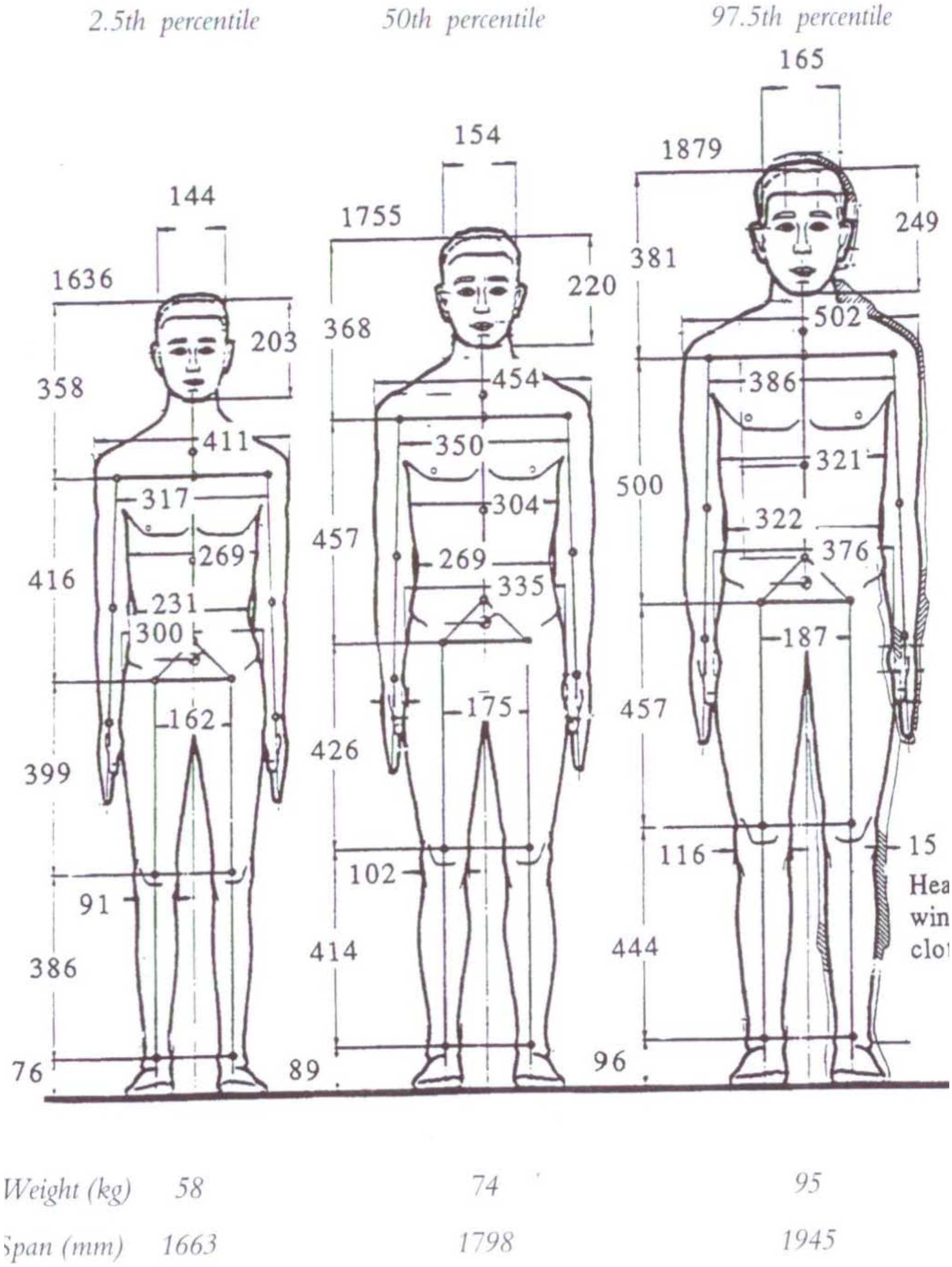


Figure 5.10(a): the body dimension for men respect to different percentile at the front view.

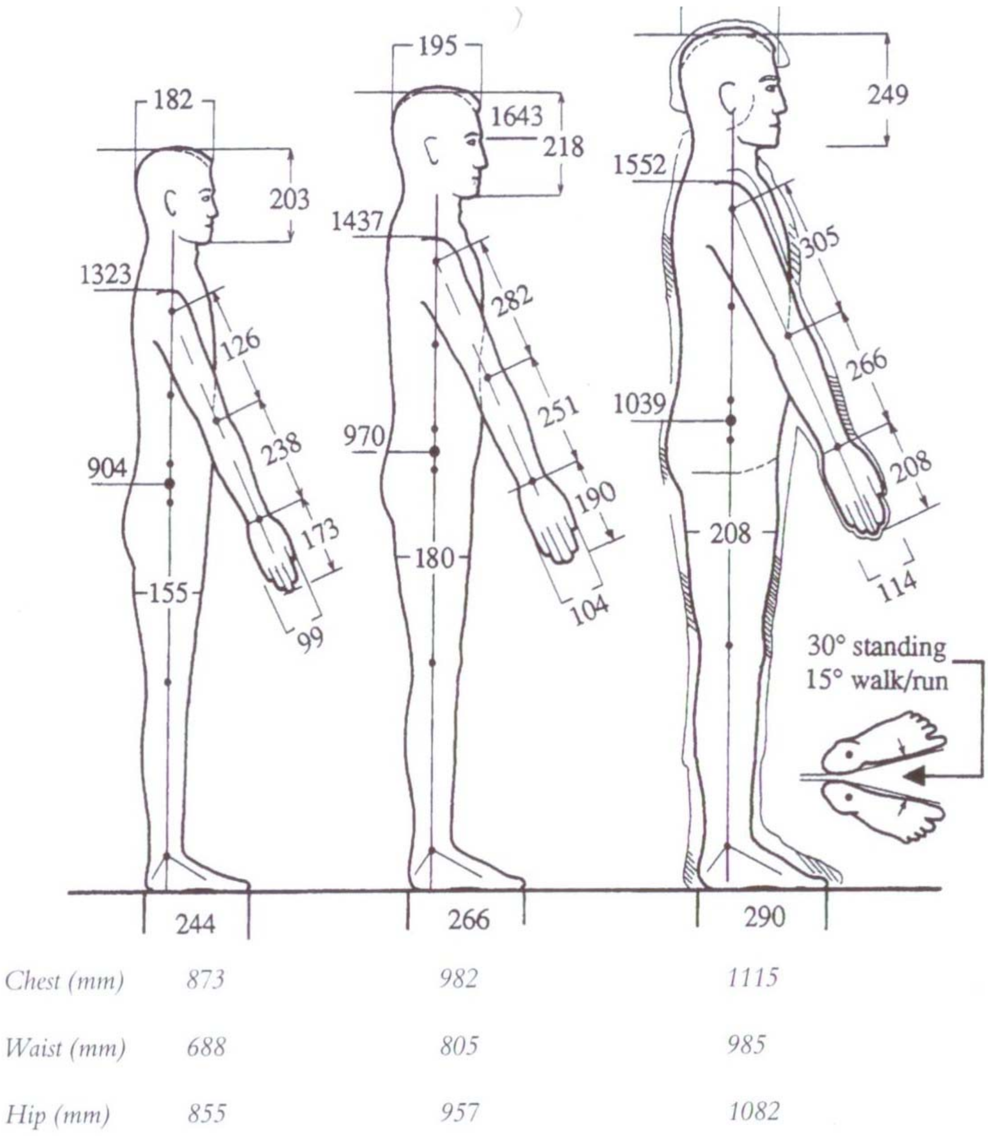


Figure 5.10(b): the body dimension for men respect to different percentile from the side view

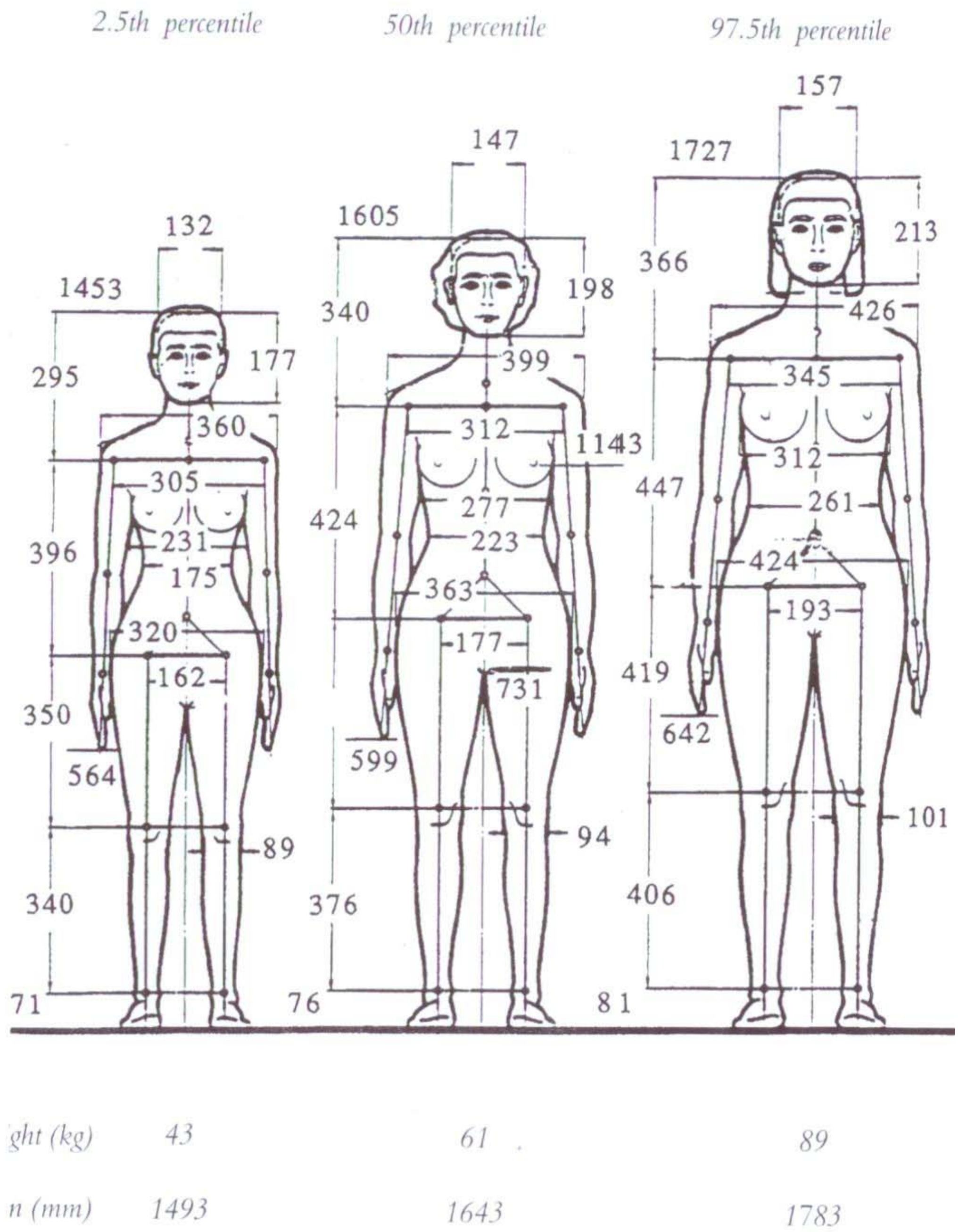
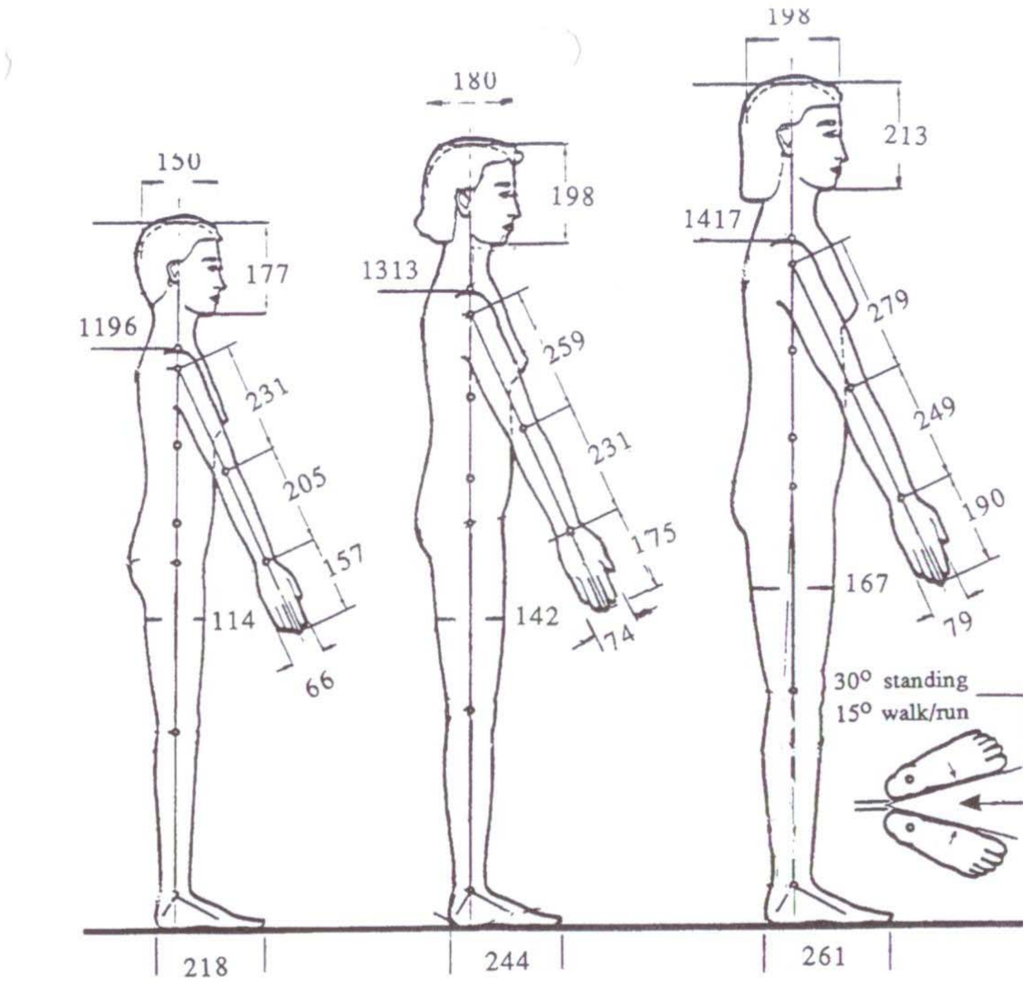


Figure 5.10(c): the body dimension for women respect to different percentile from the front view



Bust (mm)	*762*	*904*	*1143*
Waist (mm)		*741*	
Hip (mm)	*838*	*985*	*1108*

Figure 5.10(d): the body dimension for women respect to different percentile from the side view.

From the above information, it is found that wheelchair shall have weight a capacity of 100kg. The seat width of the wheelchair shall be greater than 424mm. Both of conventional manual wheelchair and electric wheel chair shall meet these requirements.

6.0 RISK ASSESSMENT

Risk analysis is to be assessed at the initial stage of design. Risk(R) is composed of two components - probability (P) and severity(S). (Zurich Insurance Group, 1987). It can be defined as:

$$R = P \times S$$

Probability deals with how likely it is that the occurrence will happen. Severity measures how significance is the occurrence. This significance can be measured in injuries or deaths, impacts on the environment or financial loss.

Hazard analysis is a very versatile method that can be used on a product, a system or a process. Here, it is used as a tool to assess the risk during design phase for the new features of wheelchair. The steps are:

Step 1. Define the scope. The time and information factors shall be considered in defining the scope.

Step 2. Think about the potential hazards at all area by brainstorming.

Step 3. List the entire hazard, the trigger or cause, the effect as well as relative severity and probability. Below are the terms used in the hazard catalogue:

Hazard: The hazard or potential threat is listed in general terms.

Trigger / Cause: Any particular hazard can have several potential causes; these are usually best handled by listing each separately. Also there may be multiple causes that must occur in order to generate the hazard.

Effect: The possible consequence or result of the event.

Hazard Cause Level: This is the relative probability of an occurrence of a potential cause on a scale of the following five levels:

A. Frequent - Often experienced, likely to occur frequently, 10+ times/year.

B. Moderate - occurring several times, 1-10 times/year.

C. Remote - may occur or be experienced, 1 time/year.

D. Unlikely - unlikely to occur or be experienced, 1 time/5 years.

E. Impossible - practically impossible, 1 time/20 years.

Note: The ranking of possibility is based on the estimation, instead of actual data collection.

Hazard Effect Category: The relative severity of the occurrence is divided into the following four categories:

I. Catastrophic - death(s), loss of company image/extensive publicity, detrimental financial loss, major environmental impact, system loss.

II. Critical-severe injury(s), severe impact on company image, large financial loss, significant environmental impact, partial system loss

III. Marginal - injury(ies), transient loss of image, indirect financial loss, environmental impact, system damage

IV. Negligible - minor injury(ies), minor image or financial loss, slight environmental impact, minor system damage

It is important that levels are clearly defined, documented and understood as well as definitions remaining the same for all effects in a particular hazard analysis.

Step 4. A chart is prepared where the hazard effect catalogue is plotted on the x-axis and the hazard-cause level is plotted on the y-axis. These are plotted in such a way that the intersection of the x-y axes is the point of lowest probability and lowest severity. Dangerous and high probability risk will be found towards the top right-hand corner. Prior to plotting the hazards, a protection level is agreed upon and plotted. This is a very important step as it defines the level of acceptable risks. The grey areas as show on the Figure 6.1 are judged as unacceptable and require additional actions to reduce the risks.

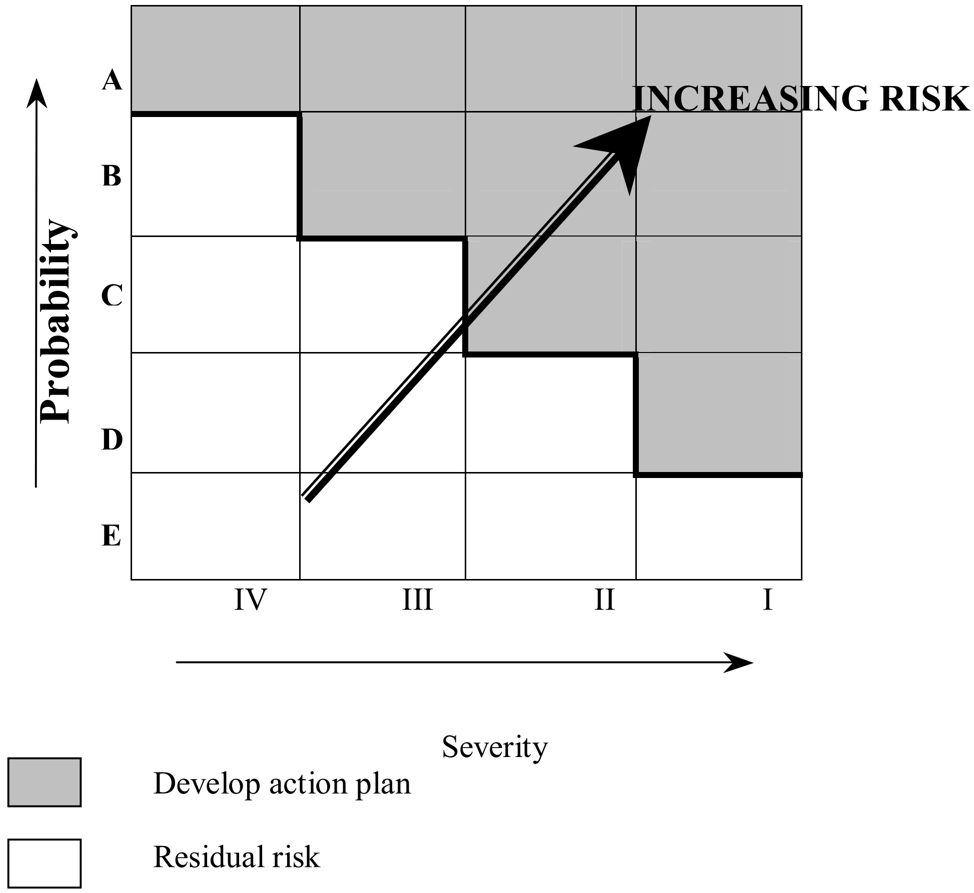


Figure 6.1: The hazard analysis with Probability vs. Severity.

Step 5. Once the protection level has been plotted, the hazards are graphed on the risk profile. The points located above the protection level lines (as shown on grey areas) are considered for risk reduction.

Step 6. Provide a safety precaution if it is needed.

6.1 Hazard analysis for the Horizontal Transfer

Below are the six basic steps to assess the risk on the horizontal component (option A, B and C) of the designed wheelchair.

Step 1: scope definition

Overview the potential risks in all possible areas of transfer the seat from the wheelchair to bed or vice versa. The horizontal operating scope of options A, B and C, as described in chapter 5 will be analysed at here.

Step 2: brainstorming

After a review of the three options, the possible hazards and causes were analysed. Main area to identify potential hazards is the operating method, rather than on the material selection.

Step 3: hazard catalogue

Please read Table 6.1

Step 4: protection level

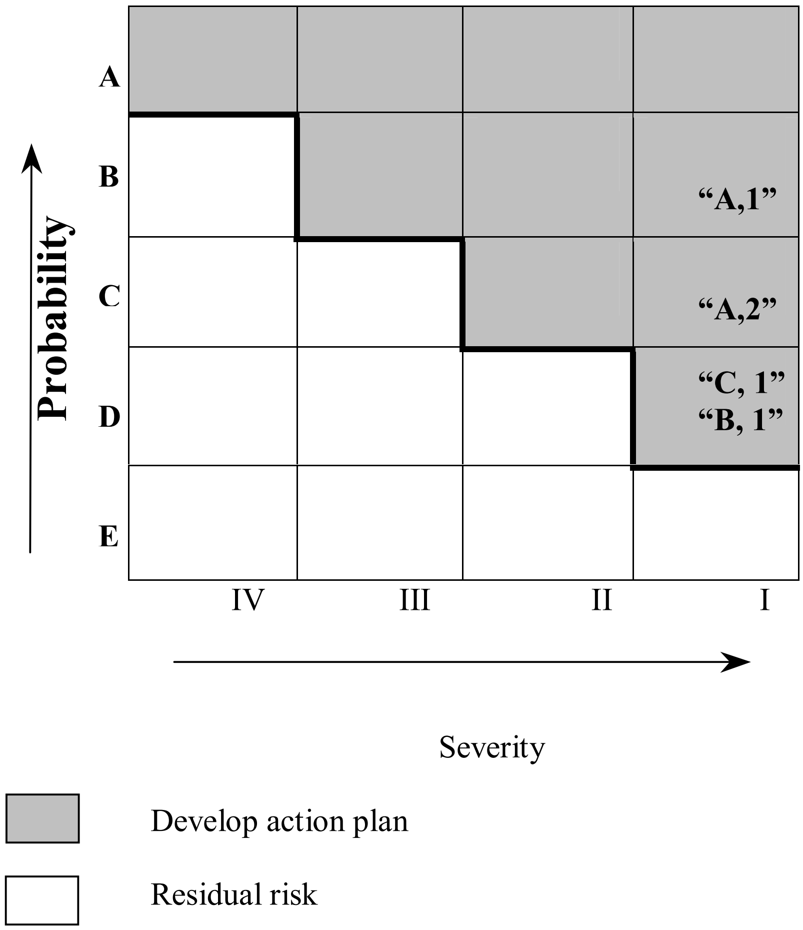
Figure 6.2 shows the hazard analysis of options A, B and C with respect to probability against severity. All three options are located at the grey areas as shows on the figure 6.2.

ZHA Hazard Catalogue					
Option	Hazard (what / where)	Trigger (how / why)	Effect (how big/ bad / much)	S	P
A	1. Disabled person may fall down from seat during the horizontal transfer, as the roller may slip out from its trap. 2. Seat of wheelchair may become unstable or move away from bed, during transfer disabled people to bed.	By unintended forces. Because the roller is easy to move.	The disabled may fall down. The disabled may fall down.	I I	C B
B	1.Seat of wheelchair may be sliding or move away from bed, during transfer disabled people to bed	The 'U' beam might slide over the 'C' by unintended force.	The disabled may fall down.	I	D
C	Same As Option B	Same As Option B	Same As Option B	I	D

Table 6.1 shows the ZHA Hazard Catalogue for the Horizontal Components.

Step 5: risk profile

Option A is judged as unacceptable and requires additional actions to reduce risks, if this option is selected. Here, option C would be recommended as horizontal transfer component in the design, as it saves the material if compared to option B.



S = Severity

P = Probability

Figure 6.2 shows the hazard analysis for Option A, B and C with respect to Probability vs. Severity.

Step 6: risk reduction

Table 6.2 shows the protective sheet being prepared for the option C. It is also applicable for option B, as the structural designs of both are almost same.

<table>
<tr><td>No</td><td>Task</td><td colspan="2">Hazard
Current Rating:</td></tr>
<tr><td rowspan="3"></td><td rowspan="3">Define the Task

Once the disabled people are transfer by caregivers from seat to bed or vice versa, the seat might be shifted on same time by unintended force.</td><td rowspan="3">Describe all hazards and their effects for each task

Once the disabled people to be transfer, the seat might be movable. People due to improper handling by caregiver.

Note: Additional hazards may be caused by interaction with other work</td><td>Severity:
Disabled people might fall down from wheelchair.</td></tr>
<tr><td>Exposure:
Frequent</td></tr>
<tr><td>Risk Level
High / Medium / Low:
High</td></tr>
<tr><td>No.</td><td colspan="2">Protective Measure</td><td>Target Rating</td></tr>
<tr><td rowspan="3"></td><td colspan="2" rowspan="3">Fully describe all controls applicable for each hazard

Eliminate the hazard:
1. Two pieces of canvas with Velcro at the ends for holding the frame of wheelchair and bed, before sliding the seat.

2. A safety handle lock is design, in order to lock the “C” and “U” from sliding between each other by unintended force. The caregiver shall applied lock the “U” and “C” beams, before transfer the disabled to bed.

Use warning and alerting techniques: Write the “letter’’ that attached on new wheel chair. To let caregiver notice about the grips and handle lock with care. From time to time, caregiver shall be inspected the lock regularly whether till function effectively. If not, it shall be send for repair or service.

Use administrative controls: The caregiver shall be proper train. They shall be understood the risk might subject to disabled people due to their careless. He or she shall pay full attention to transfer their patient to bed once the lock been released.

Use personal protective equipment: Not needed. However, the users are encourage to used others personal protection equipment for double protection.</td><td>Severity
Identify severity with controls.
In place</td></tr>
<tr><td>Exposure:
Identify exposure with controls In place
200% (Double protection to user of wheelchair).</td></tr>
<tr><td>Risk Level
High / Medium / Low:
Identify risk level with controls In place
Low (Note: This shall be sent for reliability test and validated as per maximum load condition. Because the user is handicap, their safety is ultimate responsibility of manufacturer.)</td></tr>
</table>

Table 6.2: the protective measure sheet for option C.

6.2 Hazard analysis for the Vertical Lifting

Below are the six basic steps to assess the risk on the scissor lift of the designed wheelchair.

Step 1: scope definition

Overview the potential risks in all possible area of lifting up the seat to designated height by scissor lift.

Step 2: brainstorming

The component of scissor may fail due to fatigue, so the capacity of the scissor lift shall be more than 100kg; a safety factor shall also be applied. The speed of turning of power screw shall be considered before achieving its natural frequencies.

Step 3: hazard catalogue

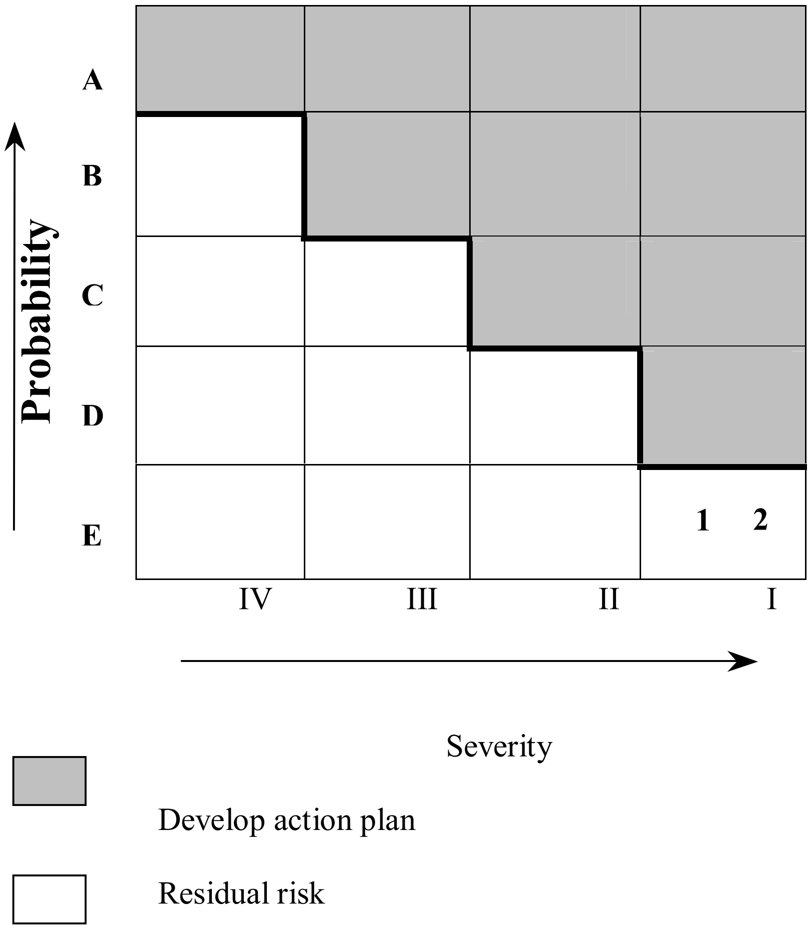
Table 6.3 shows the Zurich Hazard Catalogue

ZHA Hazard Catalog					
Option	Hazard (what / where)	Trigger (how / Why)	Effect (how big/ bad / much)	S	P
A	1.Disabled person may fall down from seat if the components of scissor lift fail.	Fatigue.	The disabled may fall down.	I	E
	2.The power screw become unstable, if the turning speed applied same as its natural	If the natural frequency of power screw is achieve.	The seat adjust might be unstable, disabled may fall down.	I	E

Table 6.3 shows the ZHA Hazard Catalogue for the Vertical Lifting Components.

Step 4: protection level

Figure 6.3 shows the hazard analysis of scissor lift with respect to probability against severity. The hazard analyses of scissor lift are located below the grey areas as show on the figure 6.3. No action required reducing the hazard.



S = Severity P = Probability

Figure 6.3: The hazard analysis with probability vs. severity.

Step 5: risk profile

Hazards 1 and 2 are judged as acceptable. No additional actions required reducing the risk. Hazard 2 is not applicable, as the power screw is turned manually instead of automation.

Step 6: risk reduction

Not Required.

7.0 Vertical Lifting Mechanism

They are many devices available on the market to provide the lifting mechanism. Hydraulic and pneumatic jacks are the most common one. However, scissor life has become a more preferred design, as it is simple. Figure 7.1 shows the operating function of scissor lift. Scissor lift has been chosen as a main component for lifting the seat of wheelchair to predefined height.

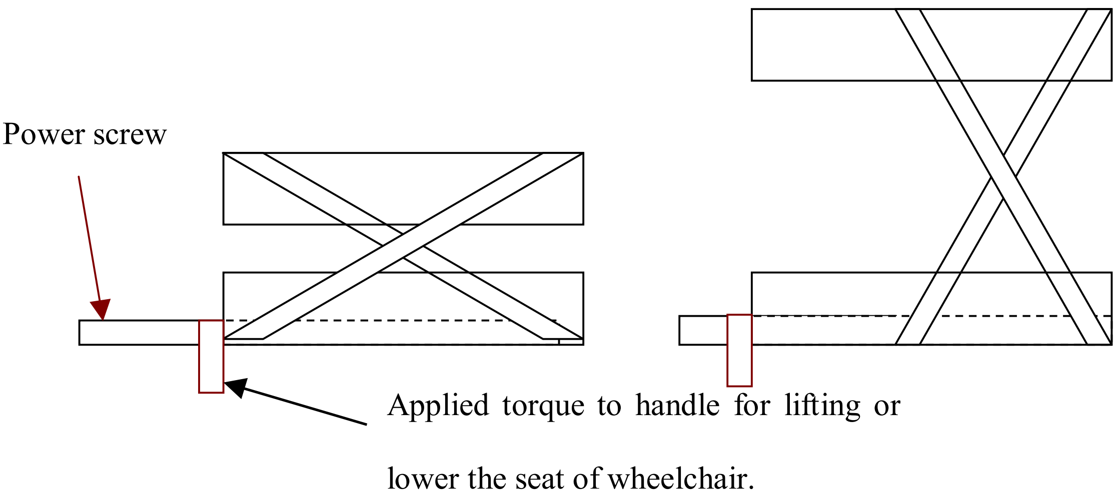


Figure 7.1: the operating function of scissor lift.

The main spare part of scissor lift includes the scissor like arm and power screw. Power screw covers a wide variety of screw series include Acme, Stub Acme, Trapezoidal and Buttress (Juvinall, 2000). They are ideal for replacing hydraulic and pneumatic drive systems because they do not require compressors, pumps, piping, filters, tanks, valves or any support items. The advantage is that the power screw will not leak, so there will be no problems with seals that are so common to hydraulic and pneumatic jacks. Lastly, the system operating the power screw is very simple, reliable and easy to utilize.

7.1 Power Screw

Power screw can provide a compact means for transmitting motion and power. They are simple and inexpensive for use in different applications. Screw always converts the torque to thrust as shown in Figure 7.2.

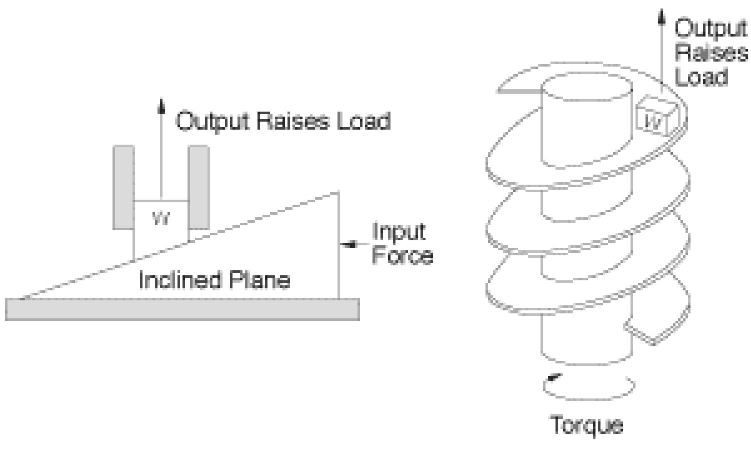


Fig 7.2: Concept of power screw

The efficiency of power screw and nut depends on the coefficient of friction between the screw and nut materials, the lead angle and the pressure angle of screw thread. The lead angle is the main contributor of force to the power screw. It follows by coefficient of friction and the pressure angle has the minimum effect. Efficiencies of power screws may vary with load. The sharp crests were subjected to easy or vulnerable damage. Besides this, sharp roots cause severe stress concentration. It is not advisable to select fine thread unless it is for light duty. Figure 7.3 shows the detail dimensions of power screw.

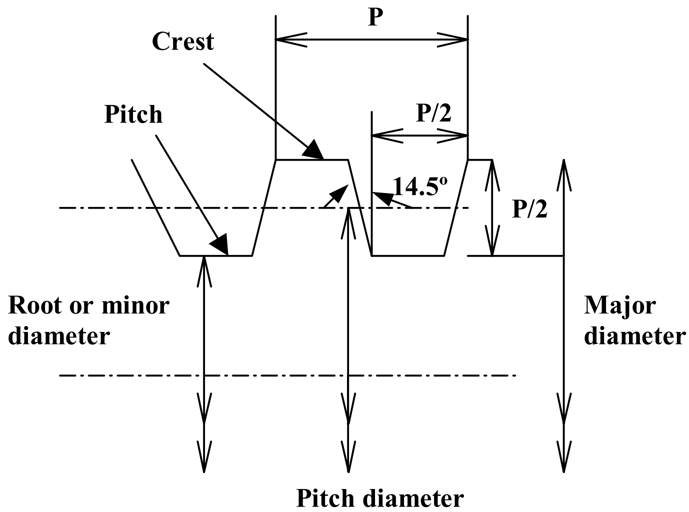


Figure 7.3: The detail dimensions of a power screw

When the load is increased, the pressure increases and the coefficient of friction can drop. This is especially true for the Acme screw series (single start screws). They can sustain loads without the use of holding brakes. In vibrating environment, some locking means may be needed. But Acme screws rarely require brakes because they are self locking.

(Juvinall, 2000. From Table 10.2 Basic Dimensions of ISO Metric Screw Threads, page 398.) Detail dimension of power screw with coarse thread as shows on Table 7.1(Juvinall, 2000).

Nominal Diameter d (mm)	Coarse Threads		
	Pitch p (mm)	Minor Diameter d_r (mm)	Stress Area A_t (mm^2)
3	**0.5**	**2.39**	**5.03**
3.5	**0.6**	**2.76**	**6.78**
4	**0.7**	**3.14**	**8.78**
5	**0.8**	**4.02**	**14.2**
6	**1**	**4.77**	**20.1**
7	**1**	**5.77**	**28.9**
8	**1.25**	**6.47**	**36.6**
10	**1.5**	**8.16**	**58.0**
12	**1.75**	**9.85**	**84.3**
14	**2**	**11.6**	**115**
16	**2**	**13.6**	**157**
18	**2.5**	**14.9**	**192**
20	**2.5**	**16.9**	**245**
22	**2.5**	**18.9**	**303**
24	**3**	**20.3**	**353**
27	**3**	**23.3**	**459**
30	**3.5**	**25.7**	**561**
33	**3.5**	**28.7**	**694**
36	**4**	**31.1**	**817**
39	**4**	**34.1**	**975**

Table 7.1 **Basic Dimension of ISO Metric Screw Thread**

Following is dimension of the selected power screw with coarse:

1. Nominal Diameter, d (mm) : 24
2. Pitch, p (mm) : 3
3. Minor Diameter, dr (mm) : 20.3
4. Stress Area, At (mm^2) : 353

Collar diameter (Juvinall, 2000, Figure 10.5, page 401.) for power screw for my design is 38mm.

7.2 Load

The application of power screw in a wheelchair may be subjected to tension and compression loading. (www.roton.com, 1980). Figures 7.4 and 7.5 show the power screw subjected to tension and compression loading.

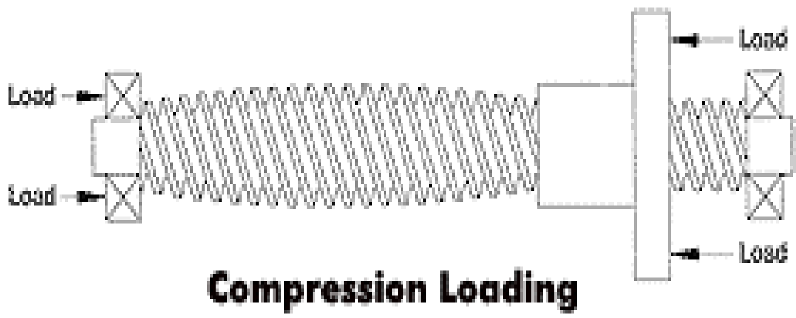


Figure 7.4: Power screw subjected to compression stress

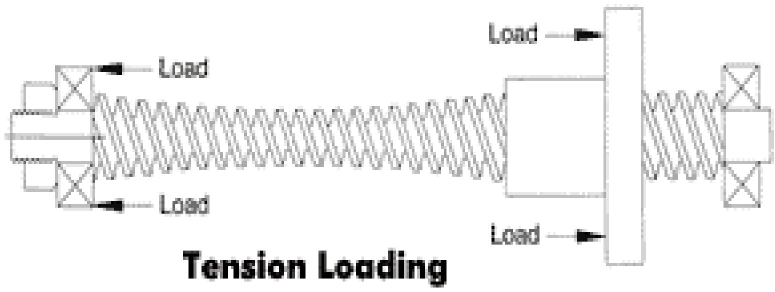


Fig 7.5: Power screw subjected to tension stress

In compression loading, buckling failure and safe column must be investigated. The size and material of screw will be main consideration under compression loading. It is advisable to design the driving system on the axial loading because the screw and nut are loaded in line with central axis. Radial loading and off centre moment loading are detrimental and should be avoided or minimized.

7.3 Speed

Critical speed is the first natural frequency of vibration of a rotating shaft. A rotating screw must be operated below its critical speed to avoid vibration, noise and possible failure. If the rotation is increased and its natural frequency is achieved, failure may be occur. Power screw vibrates once the rotating torque is achieved at its critical speed. Figure 7.6 show this. (www.roton.com, 1980). It is impossible to achieve the critical speed by manual turning, because from I use the manual turn to lift or lower the seat.

Small diameter screw can achieve its critical speed with ease when compared with bigger diameter one, particular for automation turning device. The critical speed can be calculated from its formula, so the safe operating speeds shall be below the value. If the desired rpm is greater than the safe speed, increase the screw diameter or increase the screw lead (and decrease the rpm) or change the end fixity to provide more stiffness.

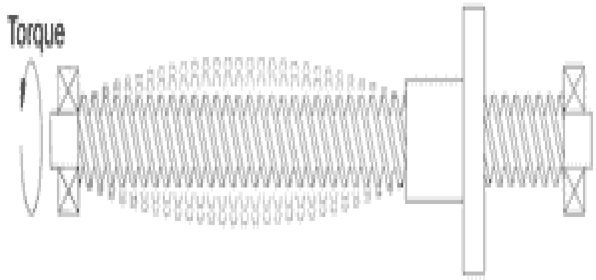


Fig 7.6: Power screw vibrates once the rotating torque is achieved at its critical speed.

7.4 Wear

It is hard to predict the wear of power screw and nut drive system. The number of variables might include load applied, speed, screw material, nut material, surface finishing of contact area, type of lubricant used, duty cycle, operating temperature and environmental factor such as presence of abrasive contaminants, corrosives and vibration and etc. (Roton Engineering, 1980, www.roton.com). A good selection of lubricant can reduce or slow the wear rate.

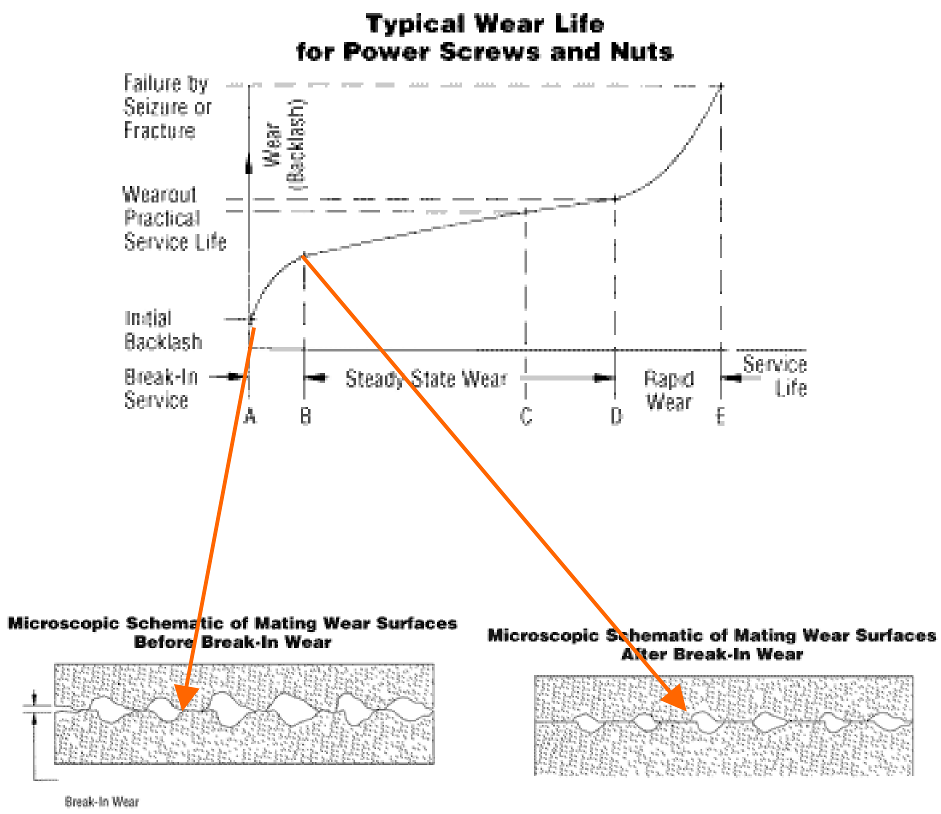


Figure 7.7: Wear life and its microscopic wear surface.

Two surfaces are in contact at their highest microscopic aspersions. Once the contact stress is high enough under the relative motion, the aspersions shear off and become debris. The lower aspersions then come into contact. The rate of wear is increasing. The contact area increases until the unit pressure and the underlying materials shear strength are in balance. Break-in wear has occurred at this initial phase.

After break in phase, a steady and continuous wear pattern begin, as represent by the straight line between point B and D. Unless the surfaces are completely separated with a lubricant film, wear will occur continually as the mating surfaces rub each other in normal service life. Figure 7.7 shows the wear life and its microscopic wear surface.

Designer shall well understand the wear mechanism, so he / she will be able to predict the life of power screw. To simply the process, an assumption is commonly used for predicting the wear of power screw and nut. The wear is always within P*V limits, or proportional to the operating PV. Figure 7.8 shows the relationship of wear life with respect to PV limit.

Wear = K * P * V ------ equation 7.1 (www.roton.com, 1980).

K = factor

P = Load factor

V = Surface speed

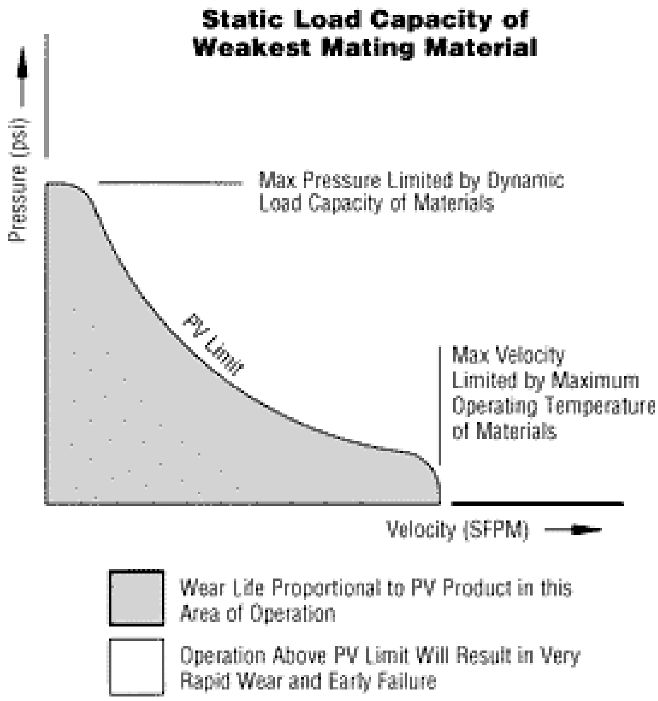


Figure 7.8: Relationship of wear life with respect to PV limit.

There are two important points to note. First, the slope of the linear wear between "B" and "D" is worn over time (Figure 7.7). Local slope on "B" to "D" is the K factor in equation 7.1. Second, Point "C" is the arbitrary point of wear, which was set by judgment of the engineer or designer. A decision is made for the service life of power screw with the consideration of the factor of safety, failure mode and consequences of failure. The wear life in terms of PV limit can be plotted and shown in figure 7.8.

7.5 Lead angle

Lead angle can be defined as $\tan \lambda = \dfrac{L}{\pi \ x \ d_m}$ (Juvinall, 2000).

where, L = lead. For single thread, L = pitch. Pitch, p = 3mm is used here.

d_m = minor diameter, The selected screw d_m = 20.3mm (This is dimension of screw used in my design.)

Hence, $\tan \lambda = \dfrac{3}{\pi \ x \ 20.3}$ and $\lambda = 2.6^\circ$

7.6 Torque

The magnitude of the applied torque for raising and lowering load is different. They are defined as follows: (Juvinall, 2000).

Total torque to lift the load,

$$T = \frac{\frac{Wd_m}{2}\left(f\pi d_m + LCos\alpha_n\right)}{\pi d_m Cos\alpha_n - fL} + \frac{Wf_c d_c}{2}$$

Total torque to lower the load,

$$T = \frac{\frac{Wd_m}{2}\left(f\pi d_m - LCos\alpha_n\right)}{\pi d_m Cos\alpha_n - fL} + \frac{Wf_c d_c}{2}$$

where; a. $\tan \alpha_n = \tan \alpha \tan \lambda$, when $\alpha_n = 14.5^\circ$ for Acme stub screw.

$\tan \alpha_n = \tan 14.5^\circ \tan 2.6^\circ$

$\alpha_n = 0.67^\circ$

b. Normally, the coefficients of friction for screw and collar are expressed as f and f_c. Values of f and f_c ranges from 0.08 to 0.20. Let f = 0.18 and f_c = 0.09 respectively.

c. d_c = collar diameter = 38mm and W = safety load of human weight.

W= k*weight*gravity

W = 1.5 x 100kg x 9.81ms^{-2} = 1471.5N

Total torque to lift the load,

$$T = \frac{\frac{Wd_m}{2}\left(f\pi d_m + LCos\alpha_n\right)}{\pi d_m Cos\alpha_n - fL} + \frac{Wf_c d_c}{2}$$

$$= \frac{\frac{1471.5x0.0203}{2}\left(0.18x\pi x0.203 + 0.003Cos0.67\right)}{\pi x0.0203Cos0.67 - 0.18x0.003} + \frac{1471.5x0.009x0.038}{2}$$

$$= \frac{14.935\ (0.0115 + 0.003)}{0.0638 - 0.00054} + 0.2516$$

T = 3.76 Nm

Total torque to lower the load,

$$T = \frac{\frac{Wd_m}{2}\left(f\pi d_m - LCos\alpha_n\right)}{\pi d_m Cos\alpha_n + fL} + \frac{Wf_c d_c}{2}$$

$$= \frac{\frac{1471.5x0.0203}{2}\left(0.18x\pi x0.203 - 0.003Cos0.67\right)}{\pi x0.0203Cos0.67 + 0.18x0.003} + \frac{1471.5x0.009x0.038}{2}$$

$$= \frac{14.935\ (0.0115 - 0.003)}{0.0638 + 0.00054} + 0.2516$$

T = 2.22 Nm

7.7 Efficiency

Efficiency is defined as the power output per power input. It can be expressed as follow:

The efficiency of power screw, e = Work output / Work input

Expression of efficiency, e can simplify as: (Juvinall, 2000).

$$\text{Efficiency, e} = \frac{Cos\alpha_n - f\tan\alpha}{Cos\alpha_n + fCot\alpha}$$

$$= \frac{Cos0.67^o - 0.18\tan 14.5^o}{Cos0.67^o + 0.18Cot14.5^o}$$

$$= 0.56$$

7.8 Initial Tightening

Normally, the initial tightening force, F_i can be defined as: (Juvinall, 2000).

$$F_i = K_i \text{ x } A_t \text{ x } S_p$$

$$F_i = 1 \text{ x } (353\text{x}10^{-6}) \text{ x } (970\text{x}10^{6}) = 342.4\text{x}10^{3} \text{ N.}$$

Where K_i = constant, usually ranges from 0.75 to 1.0. For the static loading, let K_i = 1.

A_t = tensile stress area of the thread. A_t = 353mm^2 for screw with a nominal diameter of 24mm and pitch = 3mm.

S_p = is proof strength of material. By referring to Table 10.5, fundamentals of machine components design, it was found that Sp = 970 MPa. The proof strength is defined as the maximum tensile force that produces no any plastic deformation on the screw. It was within the elastic deformation zone. Once the force is released, the elastic deformation will be gone.

7.9 Column Loading

If subjected to compression, screws may fail by buckling before they reach their static load limit or compression strength, particularly if their size is slender. The power screw design shall be verified for safe column loading. Generally, if the power screw load (under compression loading) is below the critical force (P_{cr}), it would be considered as elastically stable. The value of P_{cr} can be defined as: (Juvinall, 2000).

$$P_{cr} = \frac{\pi^2 xExI}{L_e^{\ 2}}$$

Where E = modulus of elasticity

I = second moment of inertia with respect to bending axis.

L_e = equivalent length of column (for this case is screw). The equivalent length of columns varies with respective to end conditions.

a. One fixed end and one free end : L_e = 2L;

b. Both ends pined : $L_e = L$;

c. One fixed end and one pinned end : $L_e = 0.7L$;

d. Both end fixed : $L_e = 0.5L$

Manual Calculation for P_{cr} of Power Screw:

e. From my design, the end condition is "one fixed end and one free end". So $L_e = 2L$;

Given that steel screw with nominal diameter, $d_n = 24mm$; pitch, P = 3mm and minor diameter, $d_m = 20.3mm = 20.3 \times 10^{-3}$ (m) and length, L = 0.5(m)

The second moment of inertia, $I = \frac{\pi x d^4}{64}$

$$= \frac{\pi x (20.3x10^{-3})^4}{64}$$

$$= 8.336 \times 10^{-9} \ (m^4)$$

The critical load for selected Power Screw,

$$P_{cr} = \frac{\pi^2 xExI}{L_e^2}$$

$$= \frac{\pi^2 x207x10^9 x8.336x10^{-9}}{(2x0.5)^2}$$

= 17.03 kN. (Maximum allowable force for selected power screw)

The average weight of human, m =100kg; gravity, g = 10m/s^2 and let the safety factor, k =1.5

Hence, the human weight, $P_{applied}$ = k * m * g = 1.5*100*9.81 =1.4715kN

Since $P_{cr} >> P_{applied}$. And P_{cr} is about 10 times of $P_{applied}$. It is safe to use the selected power screw.

7.10 Material Selection

In order to reduce the cost of wear and tear in the power screw, it is preferred to use the following combinations, e.g. nuts are made of softer material and screws are of harder materials. This to ensure that nuts will be worn easily compared with screw. Screw will remain relatively wear free. Nuts are usually less expensive than screws. Typically, bronze or plastic nuts are mated with carbon or stainless steel screws.

Note: Plastic nuts offer the long life at low loads with minimum used of lubrication. However, bronze and copper alloy nuts are preferred where the load is high.

Here, are some important keys to maximum the service life for power screw.

- Maintain low surface contact pressure

  By increasing screw and nut size to increase the contact area, the thread contact area will be reduced.

- Maintain low surface speed

  Increasing the screw lead will reduce the surface speed for the same linear speed.

- Keep the contact surface well lubricated

  The better the quality of the lubricant, the longer will be the service life for power screw.

- Keep the contact surface clean

Dirt, especially from hard particle can be easily embedded in the soft nut. The established dirt will act as a file and ready to abrade the mating screw surface. When the contact surfaces heat up, they become much softer and easily worn away.

8.0 Horizontal transfer mechanism

Roller is a traditional tool or device to transfer things or goods from one place to another. An example of its operating method is like car, motorbike even the wheelchair, their wheels is circular in shape. The initial idea was to use steel roller to transfer the seat from wheelchair to bed or vice versa. However, it was found that a better mechanism existed to affect horizontal transfer of the seat, in terms of safety, weight, simplicity of overall design and cost. This is the task of engineer or designer to find a way to keep their final design to be simple, easy to utilize and safe. The change of design for horizontal transfer will be described in detail at the Table 8.1.

Design	Main Component	Features	Safety Precaution
Option A	Four steel rollers	a. Centre of gravity is higher, it cause the seat is relative unstable during transfer. b. The steel roller is reliable and longer service life. But cause the overall design relative heavy. c. Caregiver shall be slowly pulling the seat for safety purpose. d. Heavy, because 4 steel rollers been used.	From Section 6.2, it shows that it is not advisable to use this option.
Option B	Two "C" beam	a. Lower centre of gravity. It is relative stable compare to Option 1. b. Lighter compare Option 1. c. Not slippy as roller.	a. Design safety lock to lock the beams. b. Use canvas to hold the wheelchair and bed.
Option C	One "C" and one "U" beam	a. Centre of gravity is same as Option 2, relative stable if compare to Option 1. b. Lighter than Option 2, because used less material. c. Not slippy as roller.	As option 2.

Table 8.1 describe the change in design of horizontal transfer

8.1 "U" Beam

This is a general calculation for "U" beam. Calculated the maximum stress, deflection of "U" beam, when it supports the weight of disabled people. Figure 8.1 shows the detail dimension of "U" beam.

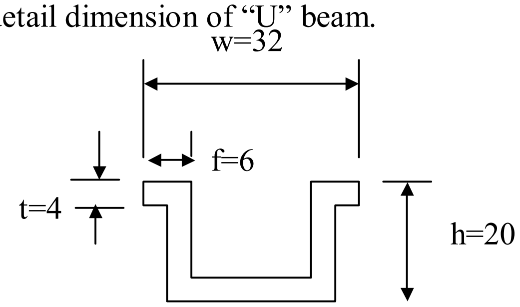


Figure 8.1 : Detail dimension of "U" beam(All dimension in mm)

However, the bottom of "U" beam is support by a rectangle plate for reinforce purpose. The followings are the assumptions:

1. Beam is uniform cross section area.
2. The properties of material are isotropic.
3. The beam is free from defects; otherwise the defect may weaken the beam. They will act as stress concentration.
4. The load (weight) applied is static.

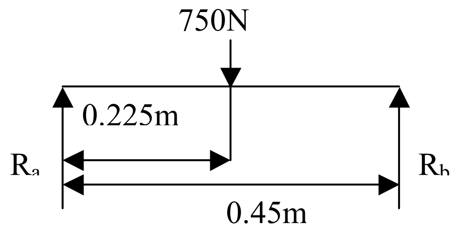


Figure 8.2: Concentrated center load

The load acts at the center with two supports at the ends as depicted in Figure 8.2. (Juvinall, 2000. Appendix D2, page871)

Figures 8.3 and 8.4 show vertical force and bending moment distributed along the beam.

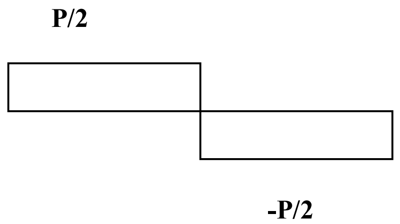


Figure 8.3: Vertical force Distributed along the beam

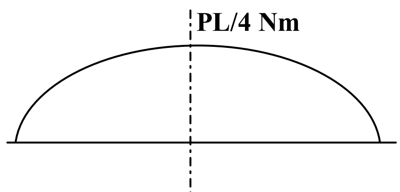
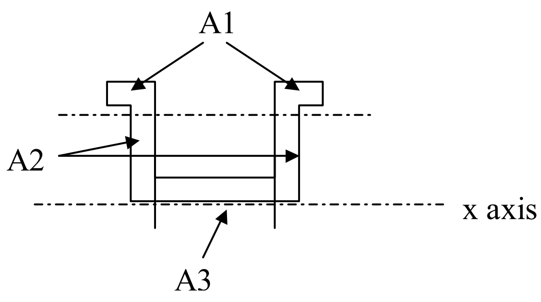


Figure 8.4: Bending Moment distributed along the beam



The maximum bending moment, Mmax = PxL/4

Where, P = Applied load = k x w/2 x g = 1.5 x 100/2 x 9.81 = 735.75 N

k = safety factor = 1.5; w = weight of human = 100kg; g = gravity

So, Mmax = 82.77Nm

Calculations of the second moment of area for "U" beam

Area	Area, mm^2 as divided to three portions	Ỹ, mm vertical distance from centroid of respective areas to x axis	ỸA, mm^3
A1	48	18	864
A2	128	8	1024
A3	80	2	160

∑ Areas = 256 mm^2 ∑ ỸA = 2048 mm^3

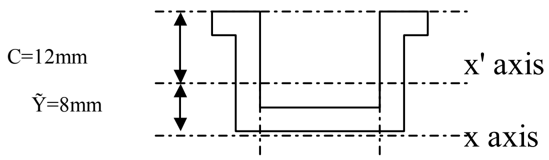
Since Ỹ ∑ A = ∑ ỸA

Therefore Ỹ = (∑ ỸA)/ ∑ A

= 2048 / 256 mm

= 8 mm

The maximum distance of centroid: c = 20-8 =12mm.



Second moment of area (respective areas) to axis x:

For Second moment of area with respect to axis x, Ix = 2 x $\left(\frac{1}{12}\right)$ x b x h^3.

Note: Let x axis always allocated at bottom of area.

where b = width of rectangle

h = height of rectangle

Area mm^2	Ix, mm^4. The x-axis predefined allocated on the bottom line for respective area.	d, mm. This is distance between the overall centroid to the centroid of respective area.	Axd^2
A1=48	64	10	9600
A2=128	2730.7	0	0
A3=80	106.67	6	2800

Second moment of inertia with respect to overall centroid axis, Ix is define as: (Fredinand, 2002)

$$Ix' = \sum (Ix + Ad^2)$$

$$= (2 \text{ x } \left(\frac{1}{12}\right) \text{ x } 6 \text{ x } 4^3 + 2 \text{ x } 48 \text{ x } 10^2)$$

$$+ (2 \text{ x} \left(\frac{1}{12}\right) \text{x } 2 \text{ x } 16^3 + 2 \text{ x } 128 \text{ x } 0^2)$$

$$+ (\left(\frac{1}{12}\right) \text{x } 20 \text{ x } 2^3 + 80 \text{ x } 6^2)$$

$$= 15381 \text{ mm}^4$$

$$= 1.5381 \text{ x } 10^{-8} \text{ m}^4$$

$\sigma_{max} = M_{max} / S$

where $S = I / C = 1.5381 \times 10^{-8} / 12*10^{-3} = 1.28 \times 10^{-6}\ m^3$

The maximum bending stress, $\sigma_{max} = 82.77/(1.28 \times 10^{-6}) = 64.57$ MPa.

The maximum deflection, $\delta max = \dfrac{PxL^3}{(48xExI)} = \dfrac{735.75 \times 0.45^3}{(48x207x10^9x1.5381x10^{-8}.)}$

$= 438.7 \times 10^{-6}$ m

Selected U beam is safe for its application, as the material selected is Carburizing Steel, 1015a, which its yield strength is 317Mpa. (Juvinall, 2000, Appendix C-7, pg852)

8.2 "C" Beam

This is a general calculation for "C" beam. Calculated the maximum stress, deflection of "C" beam, when it supports the weight of disabled people. Figure 8.5 shows the detail dimension of "C" beam.

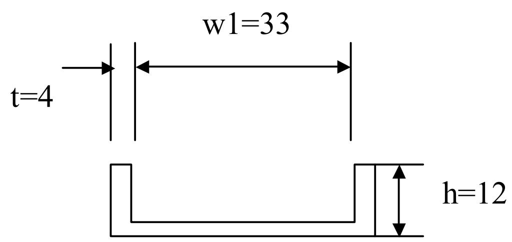


Figure 8.5 : Detail dimension of "C" beam. (All dimension in mm)

However, the bottom of "C" beam is support by a rectangle plate for reinforce purpose. The followings are the assumptions:

1. Beam is uniform cross section area.

2. The properties of material are isotropic.

3. The beam is free from defects; otherwise the defect may weaken the beam. They will act as stress concentration.

4. The load (weight) applied is static.

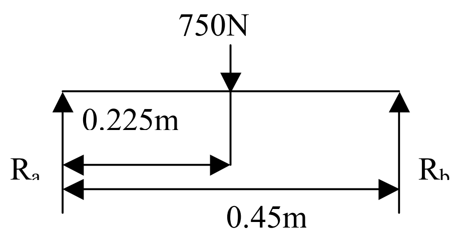
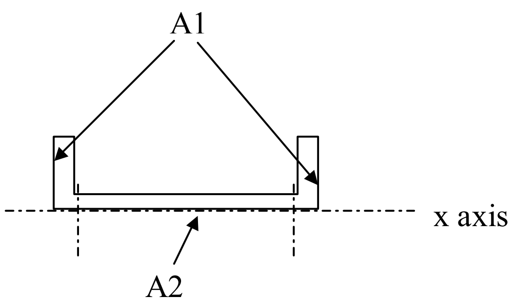


Figure 8.6: Concentrated center load

The load acts at the center with two supports at the ends as depicted in Figure 8.6. (Juvinall, 2000. Appendix D2, page871)



The maximum bending moment, Mmax = PxL/4

Where, P = Applied load = k x w/2 x g = 1.5 x 100/2 x 9.81 = 735.75 N

k = safety factor = 1.5; w = weight of human = 100kg; g = gravity

So, Mmax = 82.77Nm (same as U beam)

Calculations of the second moment of area for "C" beam

Area	Area, mm^2 as divided to three portions	$\tilde{Y}$, mm vertical distance from centroid of respective areas to x axis	$\tilde{Y}A$, mm^3
A1	96	6	576
A2	132	10	1320

$\sum$ Areas = 228 mm^2 $\sum \tilde{Y}A$ = 1896 mm^3

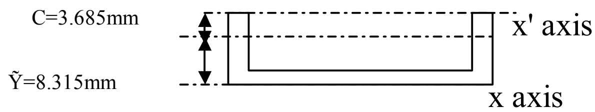
Since $\tilde{Y} \sum A = \sum \tilde{Y}A$

Therefore $\tilde{Y} = (\sum \tilde{Y}A)/\sum A$

= 1896 / 228 mm

= 8.315 mm

The maximum distance from centroid: c = 8.315mm



Second moment of area (respective areas) to axis x:

For Second moment of area with respect to axis x, $I_x = 2 \times \left(\frac{1}{12}\right) \times b \times h^3$.

Note: Let x axis always allocated at bottom of area.

where b = width of rectangle

h = height of rectangle

Area mm^2	Ix, mm^4. The x-axis predefined allocated on the bottom line for respective area.	d, mm. This is distance between the overall centroid to the centroid of respective area.	Axd^2
A1=96	1152	2.315	1029.7
A2=132	176	1.685	374.42

Second moment of inertia with respect to overall centroid axis, Ix is define as: (Fredinand, 2002)

$$Ix' = \sum (Ix + Ad^2)$$

$$= (2 \times \left(\frac{1}{12}\right) \times 4 \times 12^3 + 2 \times 96 \times 2.315^2)$$

$$+ (\left(\frac{1}{12}\right) \times 33 \times 4^3 + 2 \times 132 \times 1.685^2)$$

$$= 2732.1 \text{ mm}^4$$

$$= 2.732 \times 10^{-9} \text{ m}^4$$

$\sigma_{max} = M_{max} / S$

where $S = I / C = 2.732 \times 10^{-9} / 8.315 * 10^{-3} = 0.328 \times 10^{-6} \text{ m}^3$

The maximum bending stress, $\sigma_{max} = 82.77/(0.328 \times 10^{-6}) = 252.34$ MPa.

The maximum deflection, $\delta max = \frac{PxL^3}{(48xExI)} = \frac{735.75 \times 0.45^3}{(48 \times 207 \times 10^9 \times 2.732 \times 10^{-9})}$

$$= 2.47 \times 10^{-3} \text{ m}$$

Selected C beam is safe for its application, as the material selected is Carburizing Steel, 1015a, which its yield strength is 317Mpa. (Juvinall, 2000, Appendix C-7, pg852)

8.3 Fatigue

A phenomenon resulted in a sudden fracture of a component after a period of cyclic loading in the elastic regime. Failure is the end result of a process involving the initiation and growth of a crack, usually at the site of a stress concentration on the surface. (Juvinall, 2000). Normally, maximum stress applied to work piece that does not exceed the elastic limit, and work piece will return to its initial condition when the load is removed. However, if a given loading is repeated many cycles, up to millions of cycles, fatigue will occur. It may happen at a stress much lower than the static breaking strength. Fatigue is a brittle in nature, even if the material is ductile. As a designer or engineer, he or she must consider fatigue. Variations in the stress ratios can significantly affect fatigue life. The presence of a mean stress component has a substantial effect on fatigue. When a tensile mean stress is added to the alternating stresses, a component will fail at lower alternating stress than it does under a fully reversed stress.

The most effective method of improving fatigue performance are improvements in design:

a. Eliminate or reduce stress raisers by streamlining the part.

b. Avoid sharp surface tears resulting from punching, stamping, shearing, or other processes.

c. Prevent the development of surface discontinuities during processing.

d. Reduce or eliminate tensile residual stresses caused by manufacturing.

e. Improve the details of fabrication and fastening procedures.

Metal fatigue is a significant problem because it can occur due to repeated loads below the static yield strength. This can result in an unexpected and catastrophic failure while in service. Most engineering materials contain discontinuities and most metal fatigue cracks initiate from discontinuities in highly stressed regions of the component. The failure may be due to the discontinuity, design, improper maintenance or other causes. A failure analysis can determine the cause of the failure. Fatigue fracture normally begins at a microscopic crack at critical area of high local stress. This always happens at a geometric stress raiser or stress concentration area. Table 8.2: Pictures of typical fatigue failure. (Open University, http://materials.open.ac.uk/mem/mem_mf.htm)

	This is the classic reverse bending fatigue of a steel s from a road vehicle. Notice cracks have grown from 8 o'clock upwards and to a lesser extent from 2 o'clock downwards. The rough central region is the final ductile rupture.
	This high tensile steel bolt failed under low stress high cycle conditions with a fatigue crack running from 9 o'clock as shown by the beach marks. The SEM image of the fatigued surface (shown left) is found to have no striations due to the high yield strength and high cycle conditions.
	This 100 mm diameter steel shaft failed after a long period of service on a large dumper truck. The keyway terminated in a circumferential groove approximately half the depth of the keyway. Fatigue cracks initiated at both corners of the keyway had propagated into the cross section at 900 to the shaft axis, following the sharp corner of a circumferential groove. The crack arrest fronts are close together and the surface fairly smooth, showing that the propagation was slow at first but progressively increasing as the effective cross sectional area decreased.
	Thermal fatigue damage on cast iron clutch plate caused by rapid heating and cooling of disc by friction material.

Table 8.2: Pictures of typical fatigue failure

9.0 Modelling

I create the model and drawing for the designed wheelchair by Pro-E. They are:

a. Figure 9.1: Complete Model of Designed Wheelchair
b. Figure 9.2 : Model of Rear Wheel
c. Figure 9.3 : Model of Front Wheel
d. Figure 9.4 : Model of Horizontal Components
e. Figure 9.5: Drawing of Designed Wheelchair
f. Figure 9.6 : Drawing of Rear Wheel
g. Figure 9.7 : Drawing of Front Wheel
h. Figure 9.8 : Drawing of Horizontal Components
i. Figure 9.9 : Drawing of Scissor Lift
j. Figure 9.10 :Drawing of Footrest

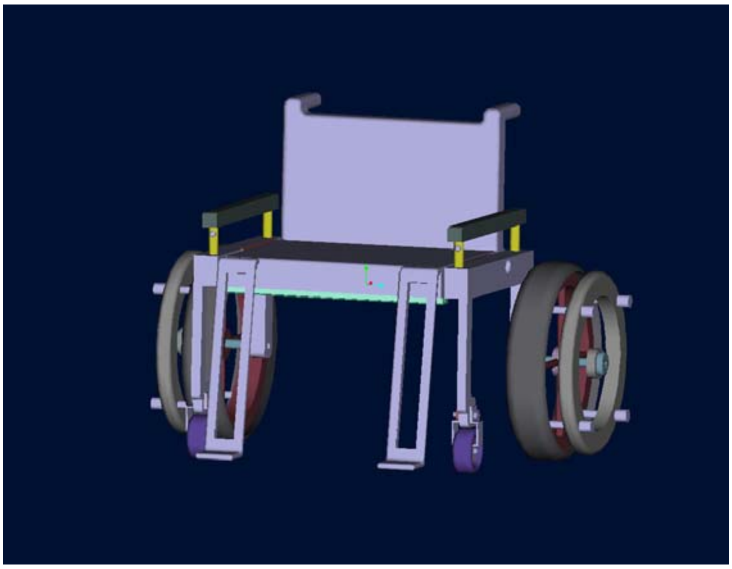


Figure 9.1: Complete Model of Designed Wheelchair

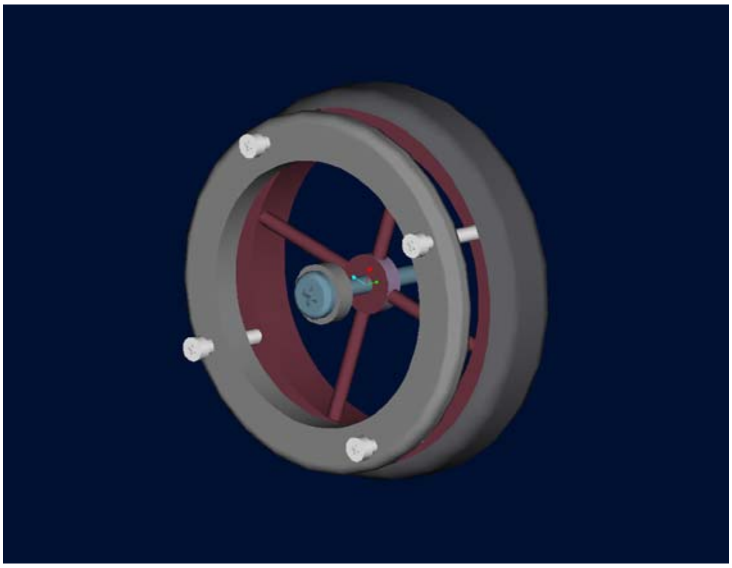


Figure 9.2 : Model of Rear Wheel

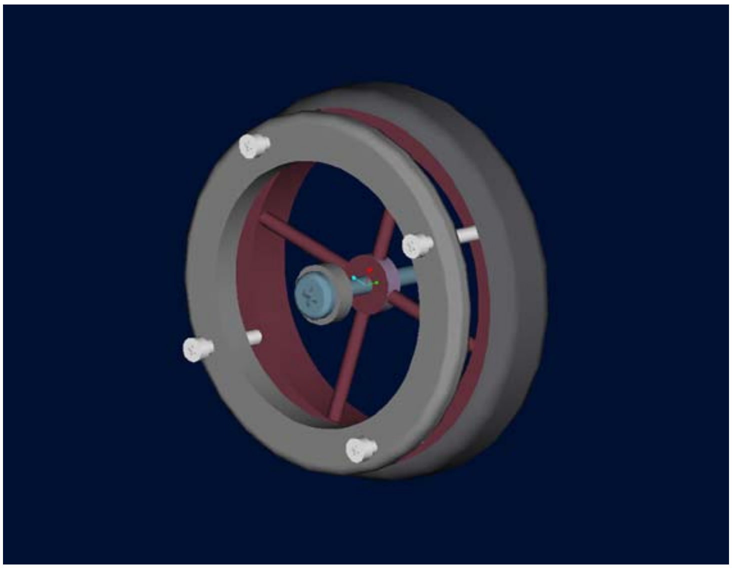


Figure 9.3 : Model of Front Wheel

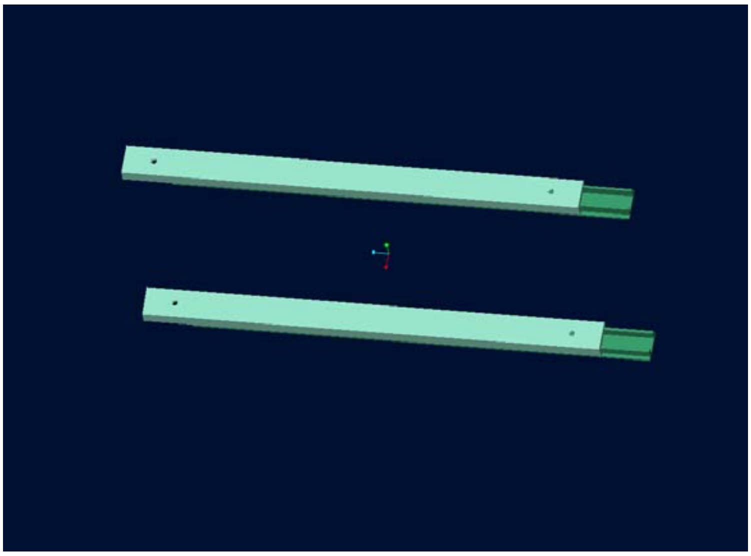


Figure 9.4 : Model of Horizontal Components

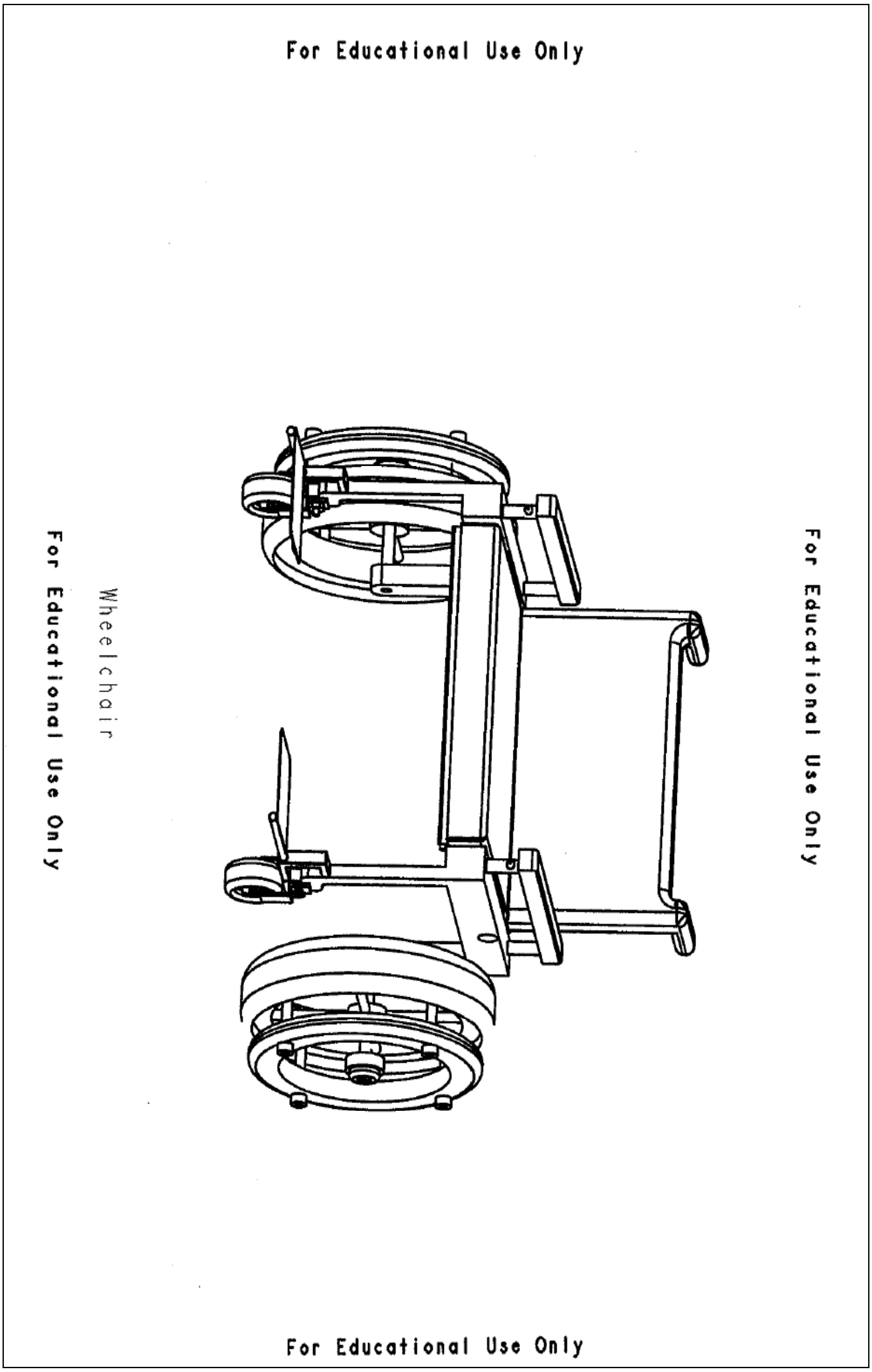


Figure 9.5: Drawing of Designed Wheelchair

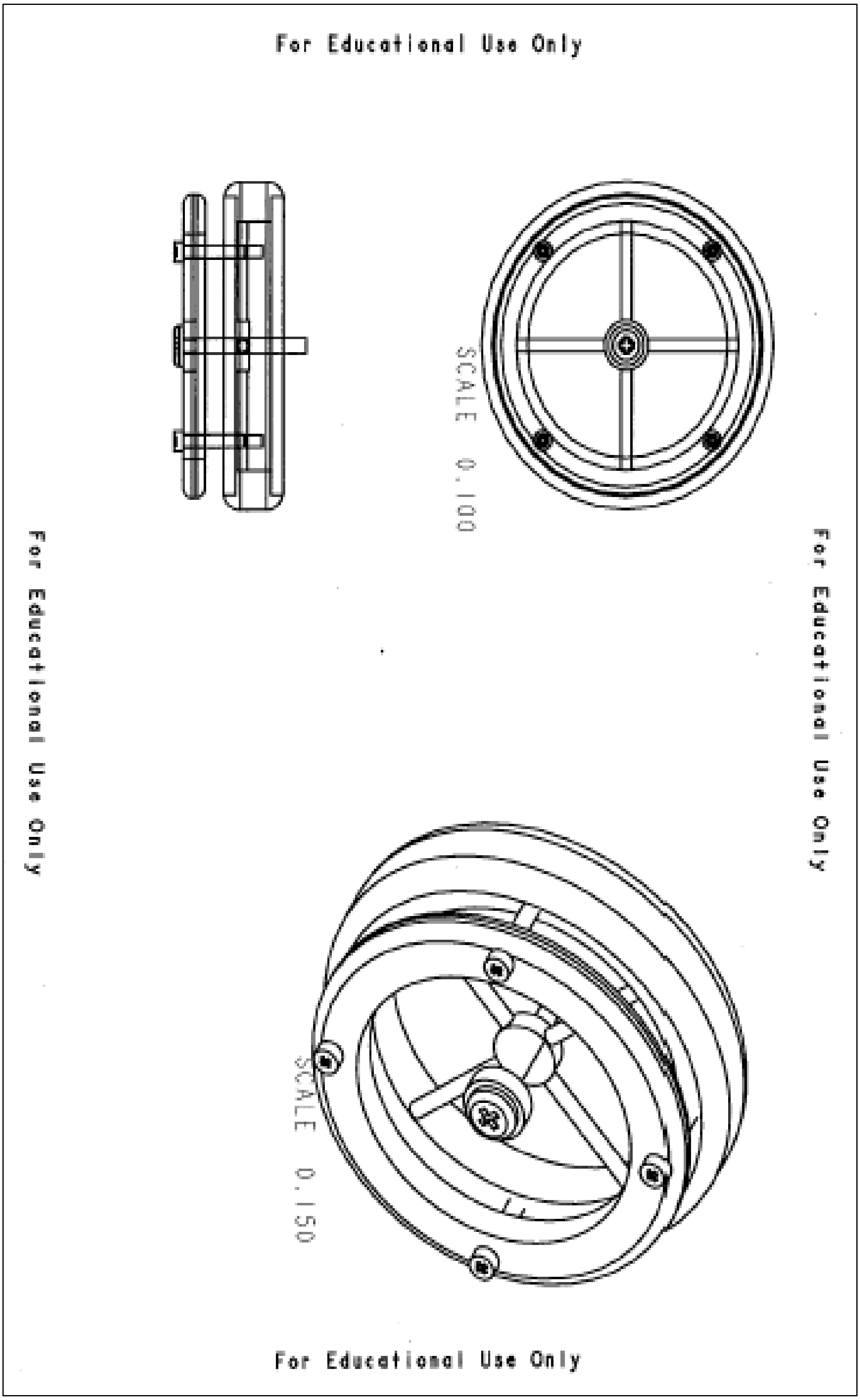


Figure 9.6 : Drawing of Rear Wheel

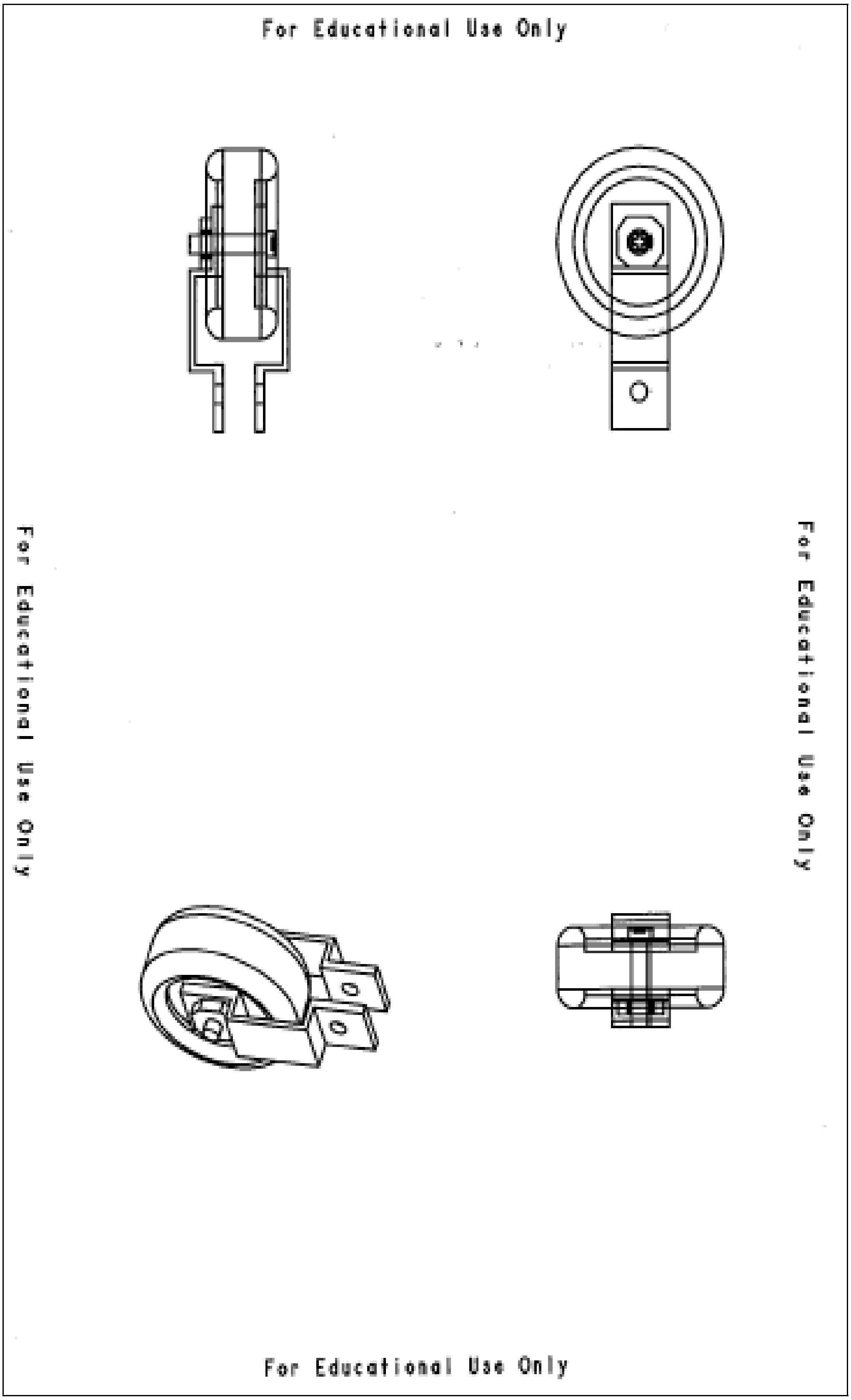


Figure 9.7 : Drawing of Front Wheel

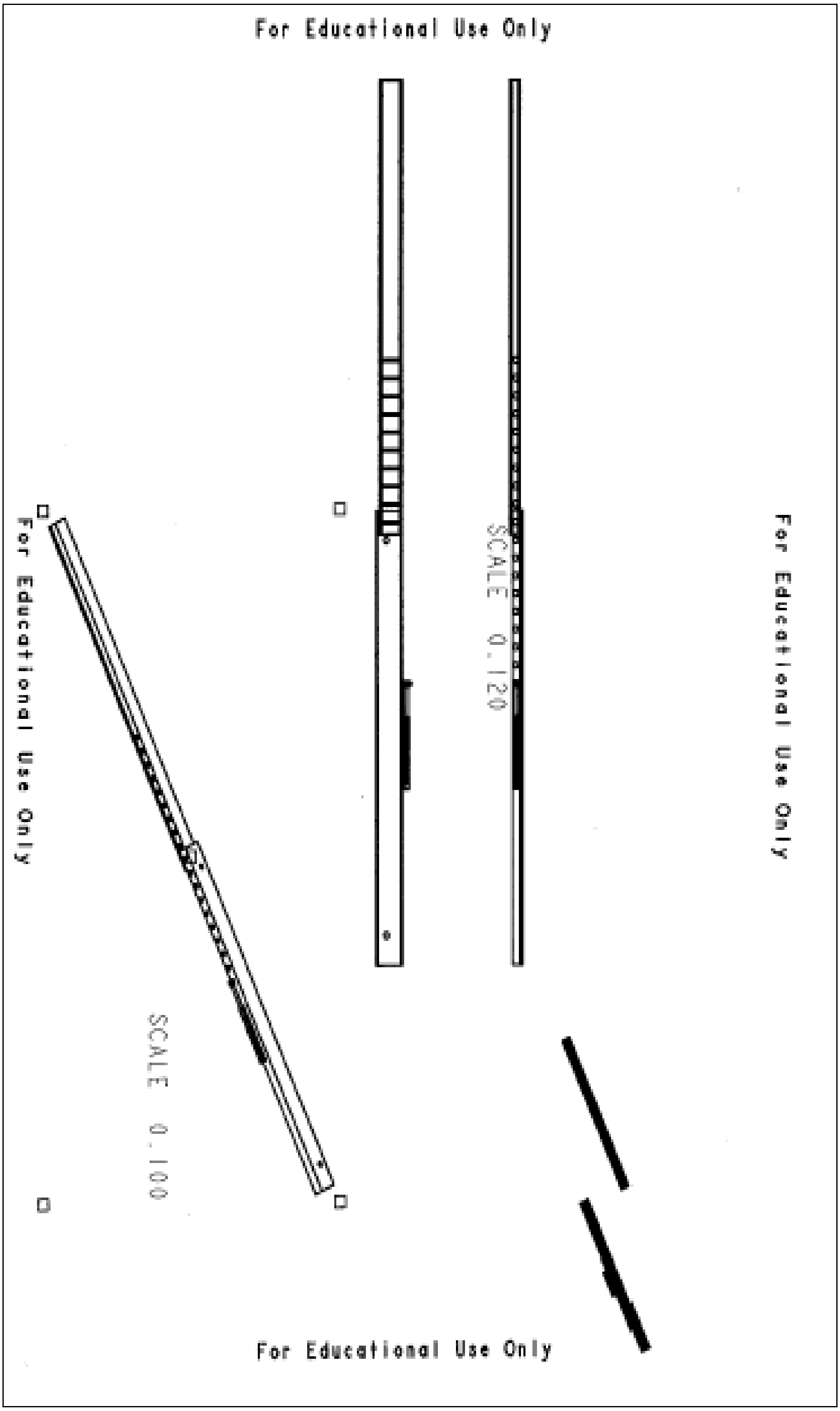


Figure 9.8 : Drawing of Horizontal Components

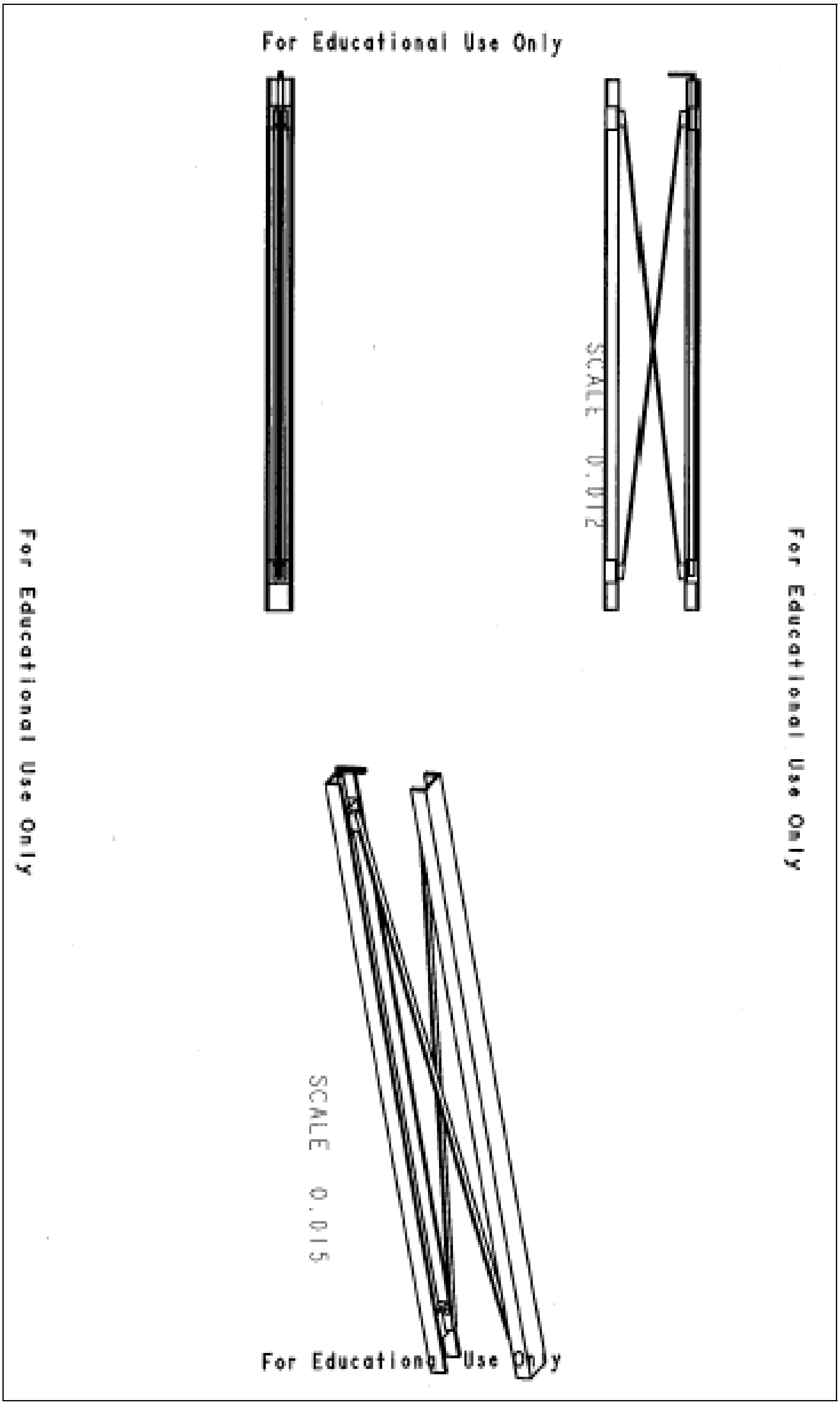


Figure 9.9 : Drawing of Scissor Lift

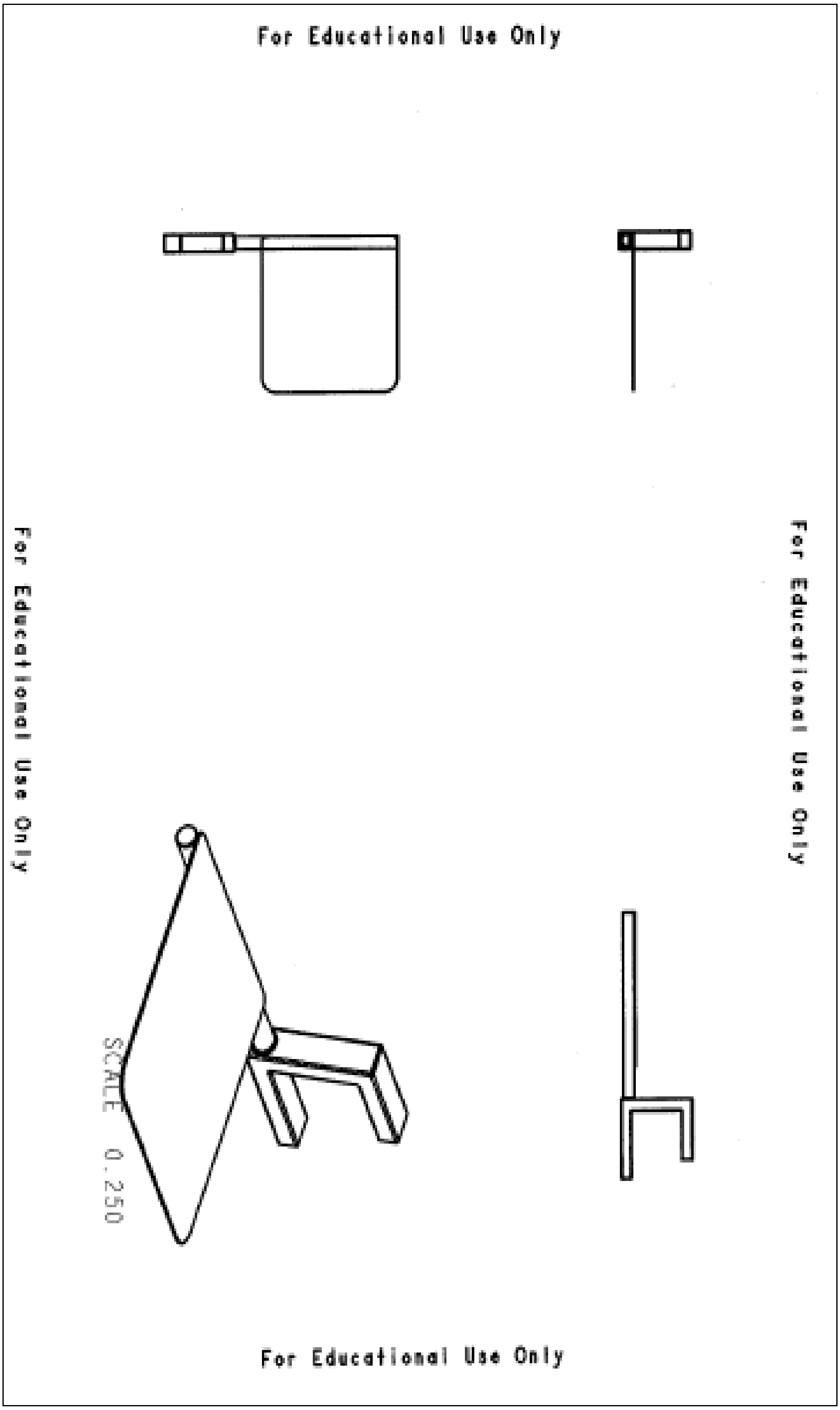


Figure 9.10 :Drawing of Footrest

10.0 ANSYS Analysis

The result from ANSYS is approximate. It can be used to compare with the result from manual calculation.

From the picture show on ANSYS can be a good indicator for designer which location subject to highest or lowest limit if load is applied. The area subject highest force or load should be more allocated more meshes.

10.1 ANSYS for the U beam

Constraint condition: Fix all degree of freedom at both ends. Applied total load is 73.725N that located at the middle of "U" beam. Load applied approximate 24.525 N per nodes acting downward, since at middle layer of "U" beam has 30 nodes. Figure 10.1: Model of U beam subject to center concentrated load.

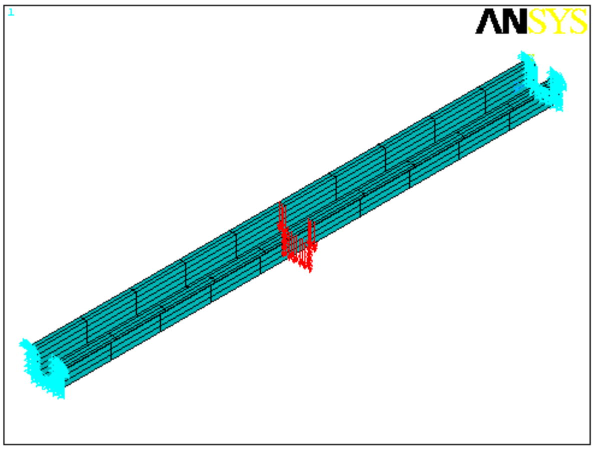


Figure 10.1: Model of U beam subject to center concentrated load.

ANSYS analysis for U beam is perform as :

a.Displacement analysis for “U” beam show on Figure 10.2. From figure, it show that the middle of beam subject maximum displacement.

b.Stress analysis for the “U” beam by von Mises method show on Figure 10.3.

c. Stress analysis for the “U” beam in Z direction show on Figure 10.4.

They is two warning message prompt by the ANSYS for this analysis. The warning messages show that shape testing revealed that 70 of 176 new or modified elements violate shape limits and Node 29 on element 1 is unselected.

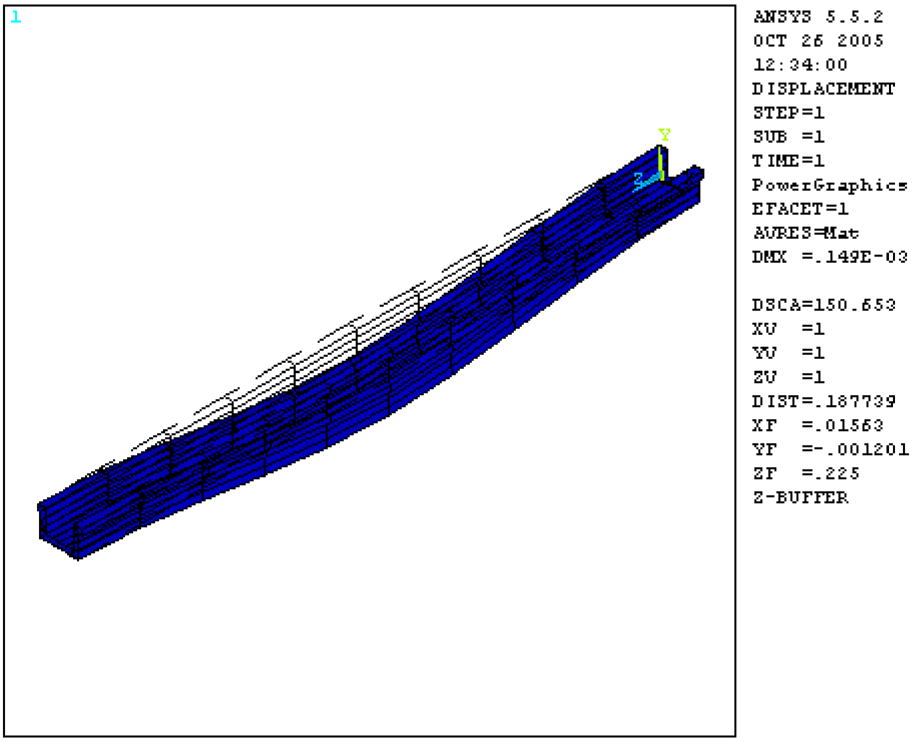


Figure 10.2:Displacement analysis for "U" beam

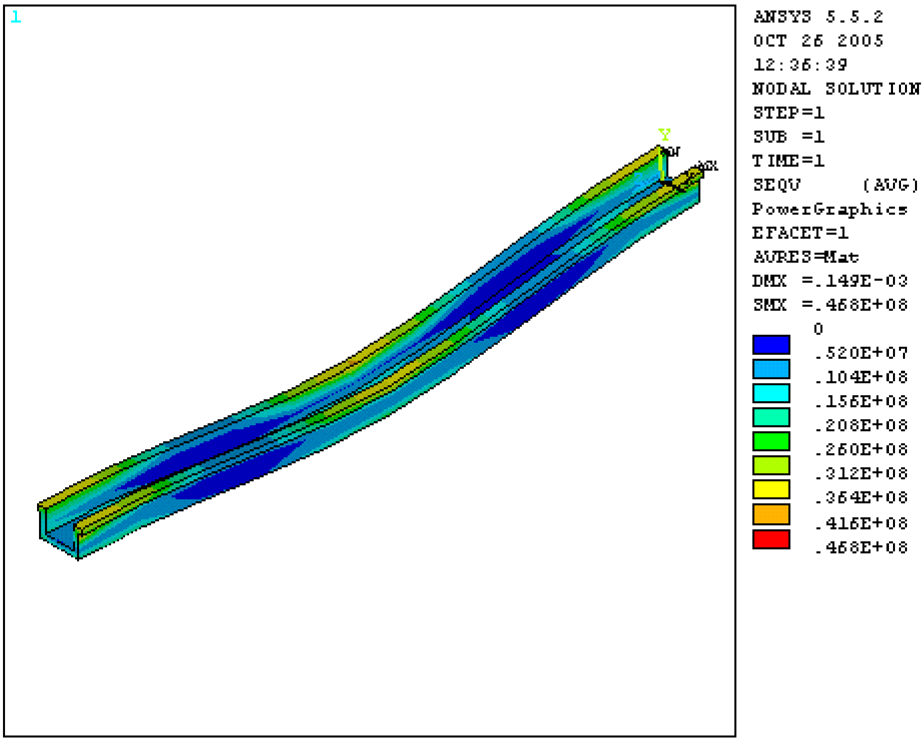


Figure 10.3: Stress analysis by von Mises.

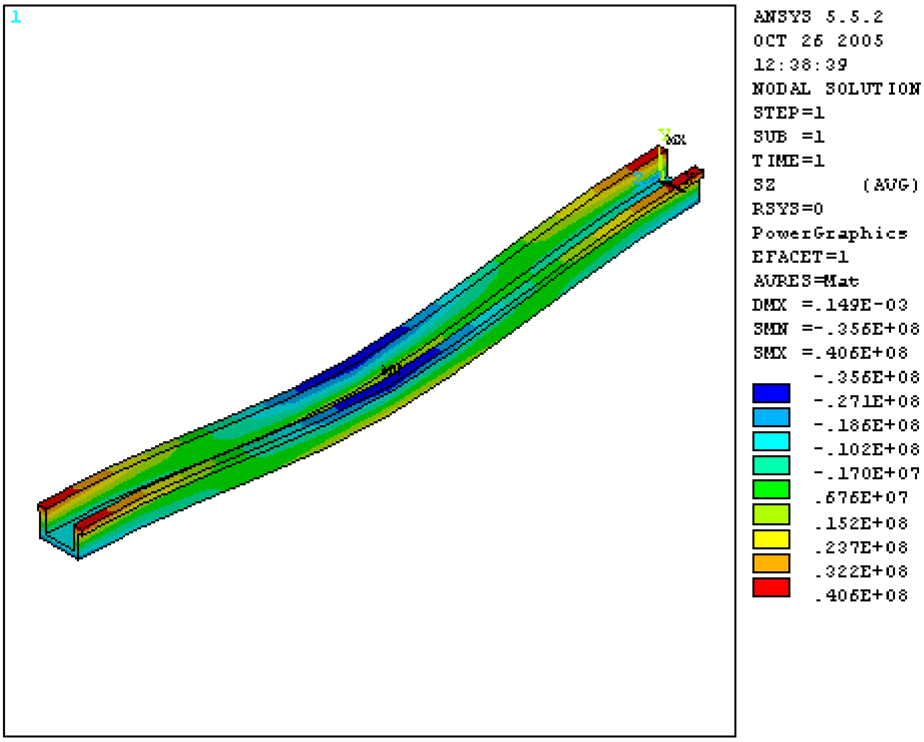


Figure 10.4:Stress analysis for the “U” beam in Z direction

10.2 ANSYS for the C beam

Constraint condition: Fix all degree of freedom at both ends. Applied total load is 73.725N that located at the middle of “U” beam. Load applied approximate 1.12 N per nodes acting downward, since at middle layer of “U” beam has 66 nodes. Figure 10.5: Model of U beam subject to center concentrated load.

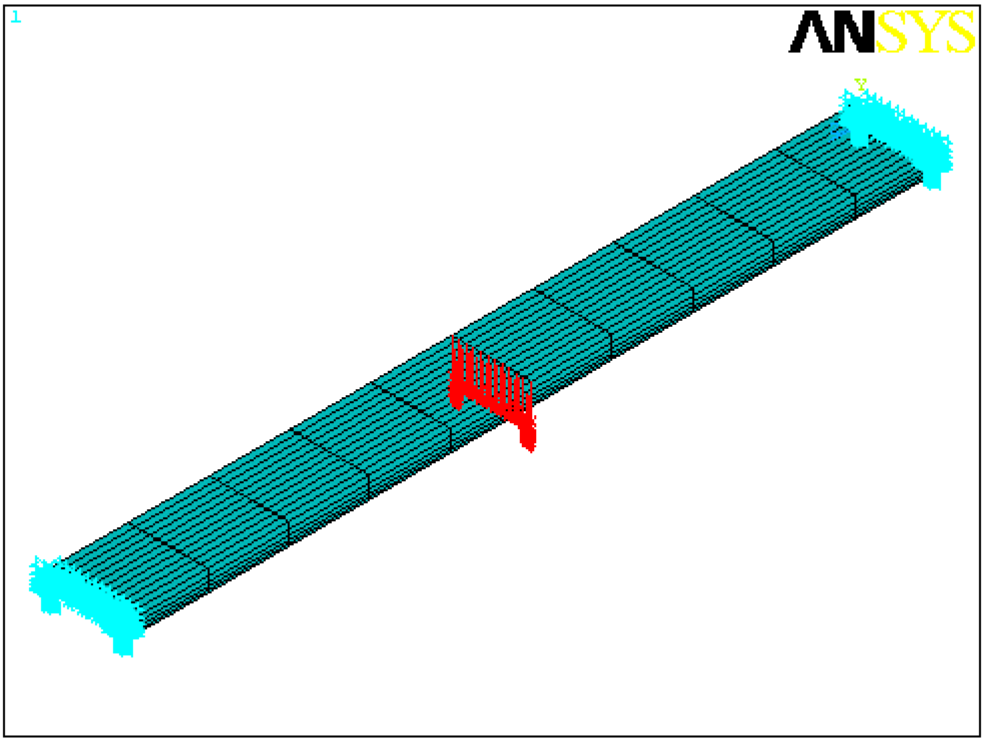


Figure 10.5: Model of C beam subject to center concentrated load.

ANSYS analysis for C beam is perform as :

a.Displacement analysis for "C" beam show on Figure 10.6. From figure, it show that the middle of beam subject maximum displacement.

b.Stress analysis for the "C" beam by von Mises method show on Figure 10.7.

c. Stress analysis for the "C" beam in Z direction show on Figure 10.8.

They is two warning message prompt by the ANSYS for this analysis. The warning messages show that shape testing revealed that 351 of 451 new or modified elements violate shape limits and Node 1 on element 1 is unselected.

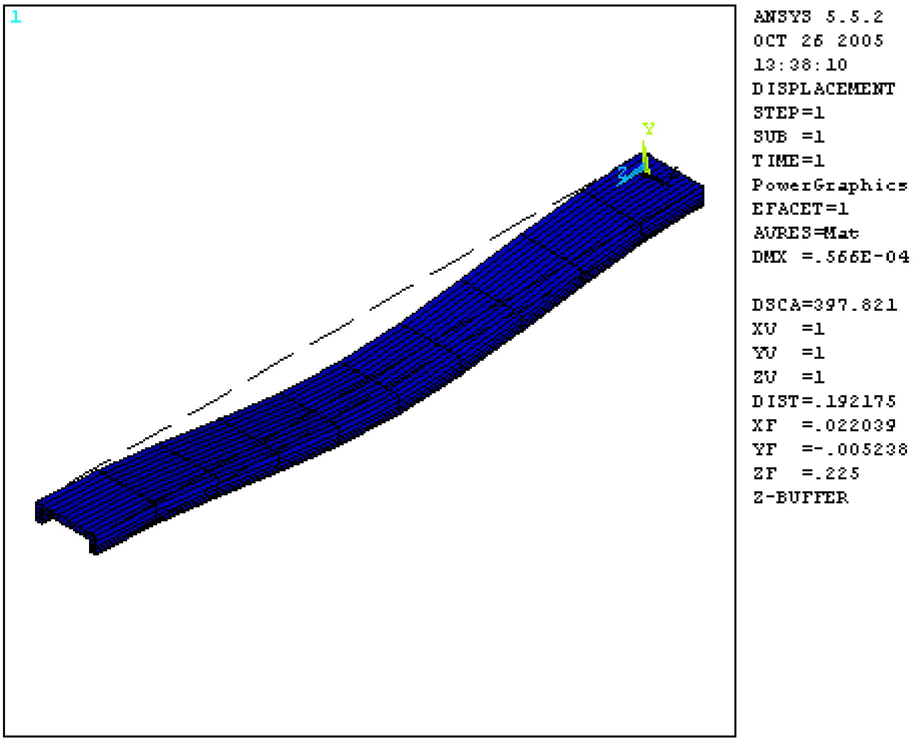


Figure 10.6:Displacement analysis for "C" beam

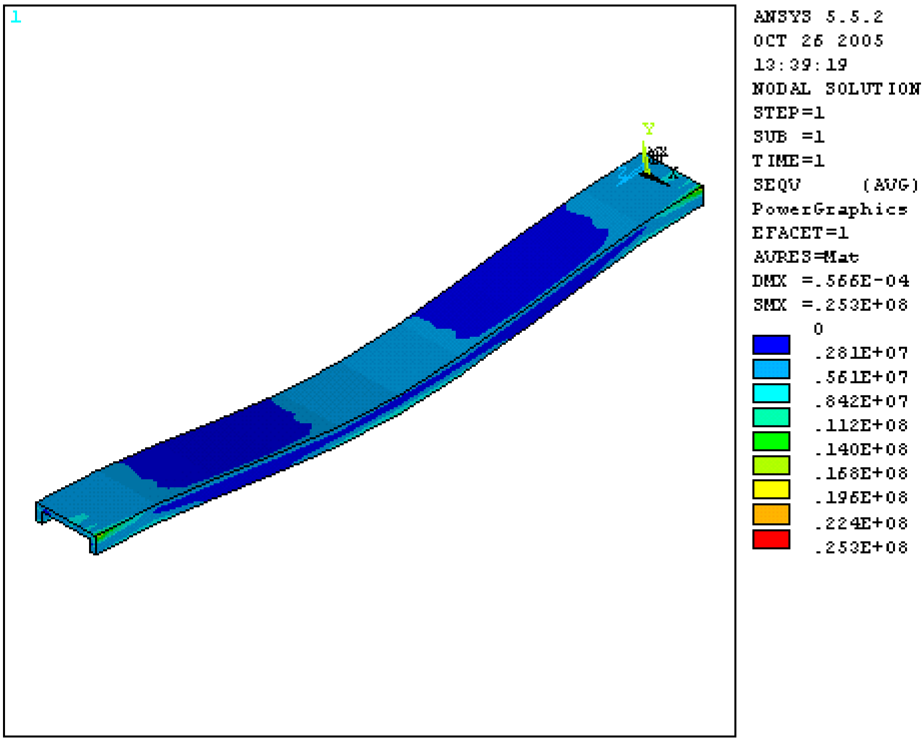


Figure 10.7: Stress analysis by von Mises.

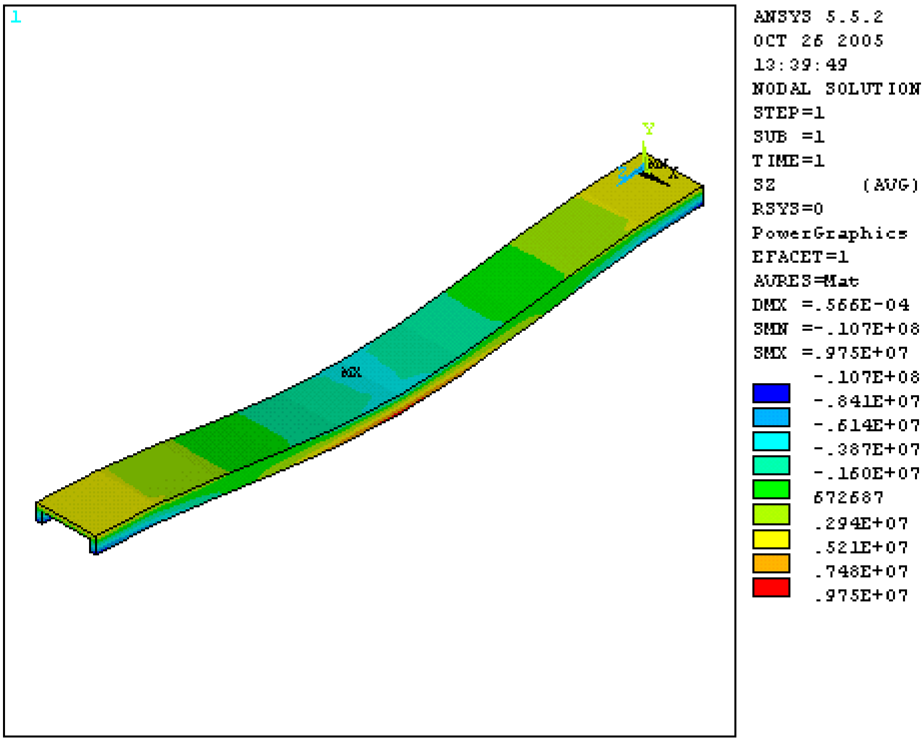


Figure 10.8:Stress analysis for the "C" beam in Z direction

11 MATLAB

MATLAT is a powerful software program for problem solving. I used it to calculate whether the designed component can be used for its application.

11.1 MATLAB For Power Screw

The program below is mainly to verify whether the selected component size is free from bucking failure. If the result is negative, program will be prompt the warning message to designer. So, he/she cans re-entry the bigger size of power screw. Diameter of power screw can be refer to table .

```
%University of Southern Queensland
%FACULTY OF ENGINEERING AND SURVEYING

%Research Project   : Lifting Mechanism for Wheelchair
%Course Number      : ENG4111 / ENG4112
%Prepared by        : Teo Chin Teng, Student ID =0050001146
%Supervisor         : Dr. Harry Ku and Dr. Wen Yi Yan

%Objective of this Matlab Program :
%a.Calculate the critical load for the Power Screw
```

```
clear,clc
E=207*10^9;  %Modulus of Elasticity, N/m^2

g=10; %gravity, m/s^2
weight = 100; %Average human weight, kg
k=1.5; %safety factor
%Calculate the force,N applied to U beam.
%They are two U beams is design. So, the weight is divided by two.
P=k*weight*g;


%If the dimension given is out of specification, the designed component
%become not logic.
%Entry the minor diameter of power screw as per its dimensional
%specification as show on Table 7.1


%Please used the correct unit for every data entry!
dm = input ('Please enter the minor diameter (mm) of power screw, it shall be
34.1mm<dm<2.39mm ');
while (dm <=2.39) | (dm >=34.1)
   disp('Minor diameter shall be 34.1mm<dm<2.39mm')
   dm= input ('Please enter the value of minor diameter (mm) again, dm ');
end

%Calculate the second moment of inertia, I for the power screw
I=3.142*(dm^4)/64;

I=I*10^-12;   %Convert the unit to m^4

L = input ('Please enter the Length (m) of power screw, it shall be
0.6m<L<0.45m ');
while (L <=0.45) | (L >=0.6)
   disp('Length shall be 0.6m<L<0.45m')
   L= input ('Please enter the value of length (m) again, L ');
end


% The end conditions power screw are "fix-free". Le=2L
Le=2*L;

Pcr=(3.142^2)*E*I/Le;

disp ('The critical load (N)for the selected power screw, Pcr is ')
Pcr
```

```
if Pcr>P;
   disp('Selected Power Screw is safe for its application.')

else Pcr<P;
   disp ('Warning :Selected Power Screw is NOT safe for its application.')
   disp ('Please run this program again with using bigger diameter.')

end %End of Program
```

I test run the program with small size of power screw. Below is the result from this program.

Please enter the minor diameter (mm) of power screw, it shall be
34.1mm<dm<2.39mm 2
Minor diameter shall be 34.1mm<dm<2.39mm
Please enter the value of minor diameter (mm) again, dm 40
Minor diameter shall be 34.1mm<dm<2.39mm
Please enter the value of minor diameter (mm) again, dm 2.39
Please enter the Length (m) of power screw, it shall be 0.6m<L<0.45m 0.45
The critical load (N)for the selected power screw, Pcr is

Pcr =

3.6371

Warning :Selected Power Screw is NOT safe for its application.
Please run this program again with using bigger diameter.

Now, I entry the diameter of power screw as dm = 20.3mm and length = 0.5m.

(This is the size used in my design.) The result below shows it is safe for its application.

Please enter the minor diameter (mm) of power screw, it shall be
34.1mm<dm<2.39mm 20.3
Please enter the Length (m) of power screw, it shall be 0.6m<L<0.45m 0.5
The critical load (N)for the selected power screw, Pcr is

Pcr =

1.7037e+004

Selected Power Screw is safe for its application.

11.2 MATLAB For “U” and “C” beam

The program below is mainly to verify whether the selected component size is free from bucking failure. If the result is negative, program will be prompt the warning message to designer. So, he/she cans re-entry the bigger size of beam.

```
%University of Southern Queensland
%FACULTY OF ENGINEERING AND SURVEYING

%Research Project   : Lifting Mechanism for Wheelchair
%Course Number      : ENG4111 / ENG4112
%Prepared by        : Teo Chin Teng, Student ID =0050001146
%Supervisor         : Dr. Harry Ku and Dr. Wen Yi Yan

%From the dimension inputs, the programme will calculate
%a.The Second Moment of Area, I (m^4)
%b.The maximum bending stress, (N/m^2)

%Assumption :
%a. The calculation is based on concentrated centre load
%b.Beam is uniform cross section area.
%c.The properties of material are isotropic.
%d.The beam is free from defects; otherwise the defect may weaken the beam.
%They will act as stress concentration.
%e.The load (weight) applied is static.

clear,clc

%Calculate the "U" beam with thickness from 1mm to 5mm
%Divide the "U" beam into three rectange area.
%Please refer figure  for the used symbol for t, h, w, and f.

%If the dimension given is out of specification, the designed component
%become not logic.
%Use While Looping to meet the dimensional specification for U beam
%All dimension entry shall be mm.

%Please used the correct unit for every data entry!
%Entry the thickness,t of U beam as per its dimensional specifcation.
t = input ('Please enter the thickness (mm) of U beam, it shall be
8mm<t<2mm ');
while (t <= 2) | (t >= 8)
   disp('Thickness (mm) shall be 8mm<t<2mm')
   t= input ('Please enter the value of thickness (mm) again, t ');
end
```

```
%Entry the height,h of U beam as per its dimensional specifcation.
h = input ('Please enter the Height (mm) of U beam, it shall be 30mm<h<5mm ');
 while  (h <= 5) | (h >= 30)
        disp('Height (mm) of U beam shall be 30mm<h<5mm')
     h= input('Please enter value of height (mm) again, h ');
  end

%Entry the width,w of U beam as per its dimensional specifcation.
  w = input ('Please enter the width (mm) of U beam, it shall be 40mm<w<15mm ');
 while  (w <= 15) | (w >= 40)
        disp('Width of U beam shall be 40mm<w<15mm');
     w= input('Please enter value of width (mm) again, w ');
  end

%Entry the f of U beam as per its dimensional specifcation.
  f = input ('Please enter the f (mm) of U beam, it shall be 10mm<f<5mm ');
 while  (f <= 5) | (f >= 10)
        disp('Width,f (mm) of U beam shall be 10mm<f<5mm');
     f= input('Please enter value of f (mm) again. ');
  end

%Calculate respective areas and its area centroid height.
a1=2*f*t;       % Calculate for area 1
a2=2*(h-t)*t;    % Calculate for area 2
a3=(w-2*f)*t;    % Calculate for area 3
y1= h-(t/2);     % Calculate for centroid height for area 1
y2=(h-t)/2;     % Calculate for centroid height for area 2
y3=t/2;        % Calculate for centroid height for area 3

% Calculate for overall centroid height for U beam.
cy=((a1*y1) + (a2*y2) + (a3*y3))/(a1+a2+a3);

%Calculate second moment of area for respective areas.
I1=2*f*(t^3)/12;        %Calculate second moment of area 1
I2=2*t*((h-t)^3)/12;    %Calculate second moment of area 2
I3=(w-(2*f))*(t^3)/12 ;  %Calculate second moment of area 3


%Calculate distance difference between centroid height of respective areas to
%overall centroid height of U beam.
d1=y1-cy; %Calculate distance difference between area 1 to overall centroid height
d2=y2-cy; %Calculate distance difference between area 2 to overall centroid height
```

```
d3=y3-cy; %Calculate distance difference between area 3 to overall centroid
height

x1=2*a1*(d1^2);
x2=2*a2*(d2^2);
x3=a3*(d3^2);
%Calculate second moment of area for U beam.
I=(I1+x1) + (I2+x2) + (I3+x3);
I=I*10^-12  %Convert the unit from mm^4 to m^4


g=9.81; %gravity, m/s^2
weight = 100; %Average human weight, kg
k=1.5; %safety factor
%Calculate the force,N applied to U beam.
%They are two U beams is design. So, the weight is divided by two.
P=k*weight/2*g ;

L=0.45; % Length of U beam, m
E=207*10^9;  %Modulus of Elasticity, N/m^2

%Select the max distance of overall centroid height
cy1=h-cy;
if cy1>cy
   cy=cy1;
end
%For the on Concentration Centre Load
M=P*L/4 %The max bending moment, M is located at centre of beam
def=P*(L^3)/(48*E*I) %max deflection, def is at the centre of beam
Stress = M*cy*10^-3/I

ystress = 310*10^6; %yield strength of 1015a carburizing steel
if Stress<ystress;
   disp('Selected U beam is safe for its application.')

else Stress>ystress;
   disp ('Warning :Selected U beam is NOT safe for its application.')
   disp ('Please run this program again with using bigger thickness.')

end %End of Program



%For the C beam
%Please used the correct unit for every data entry!
%let thickness for both C and U beams is same
```

```
%Entry the height,h of C beam as per its dimensional specifcation.
hc = input ('Please enter the Height (mm) of C beam, it shall be 20mm<hc<5mm ');
 while  (hc <= 5) | (hc >= 20)
          disp('Height (mm) of U beam shall be 20mm<hc<5mm')
      hc= input('Please enter value of height (mm) again, hc ');
   end

%Let the width of C beam is w1
   w1 = w + 1 + (2*t) ;% let the width of C beam become default value after we
   %entry for U beam. The gap between U and C beams is 1mm.


%Calculate respective areas and its area centroid height.
ac1=2*hc*t ;        % Calculate for area 1
ac2=(w1-2*t)*t;     % Calculate for area 2
yc1=hc/2 ;      % Calculate for centroid height for area 1
yc2=(hc-t)+(t/2);      % Calculate for centroid height for area 2

% Calculate for overall centroid height for C beam.
ccy=((ac1*yc1) + (ac2*yc2))/(ac1+ac2);

%Calculate second moment of area for respective areas.
Ic1=2*t*(hc^3)/12 ;        %Calculate second moment of area 1
Ic2=(w1-2*t)*(t^3)/12 ;  %Calculate second moment of area 2


%Calculate distance difference between centroid height of respective areas to
%overall centroid height of U beam.
dc1=yc1-ccy ;%Calculate distance difference between area 1 to overall centroid height
dc2=yc2-ccy ;%Calculate distance difference between area 2 to overall centroid height

xc1=2*ac1*(dc1^2);
xc2=ac2*(dc2^2);
%Calculate second moment of area for U beam.
Ic=(Ic1+xc1) + (Ic2+xc2) ;
Ic=Ic*10^-12  %Convert the unit from mm^4 to m^4


%Select the max distance of overall centroid height
ccy1=hc-ccy;
if ccy1>ccy
    ccy=ccy1;
```

```
end

%For the on Concentration Centre Load
cdef=P*(L^3)/(48*E*Ic) %max deflection, def is at the centre of beam
cStress = M*ccy*10^-3/Ic


if cStress<ystress;
    disp('Selected C beam is safe for its application.')

else cStress>ystress;
    disp ('Warning :Selected C beam is NOT safe for its application.')
    disp ('Please run this program again with using bigger thickness.')

end %End of Program
```

Now, I entry the size of U and C beams, as per Figure 8.1 and 8.5. (This is the size used in my design.) The result below shows it is safe for its application.

```
Please enter the thickness (mm) of U beam, it shall be 8mm<t<2mm 4
Please enter the Height (mm) of U beam, it shall be 30mm<h<5mm 20
Please enter the width (mm) of U beam, it shall be 40mm<w<15mm 32
Please enter the f (mm) of U beam, it shall be 10mm<f<5mm 6

I =

  1.5381e-008


M =

   82.7719


def =

  4.3869e-004


Stress =

  6.4576e+007
```

Selected U beam is safe for its application.
Please enter the Height (mm) of C beam, it shall be 20mm<hc<5mm 12

Ic =

2.7321e-009

cdef =

0.0025

cStress =

2.5194e+008

Selected C beam is safe for its application.

12.0 Conclusion

The designed wheelchair is mainly modified from conventional manual wheelchair. So, fundamental structure will be remaining the same, like the seat width and seat depth. Table 12.1 shows the major characteristics with respect to manual wheelchair, electric wheelchair and my designed wheelchair. The total weight of design wheelchair is slightly increased to 28 kg, if compared to conventional wheelchair. This is due to some components are added to conventional manual wheelchair. They are scissor lift; “U” and “C” beam. Scissor lift is mainly for vertical height adjustment, where as “U” and “C” beams are used for horizontal transfer the seat of wheelchair to bed or vice versa. However, it makes the designed wheelchair non foldable.

	Manual Wheelchair	Electric Wheelchair	My Designed wheelchair
Weight Capacity (kg)	Up to 100	Up to 200	Up to 100
Seat Width (mm)	0.45	0.61	0.45
Seat Depth (mm)	0.41	0.56	0.41
Total Weight of Wheelchair	20	128	28
Speed (km/hr)	As walking speed	8km/hr	As walking speed
Flexibility	Foldable	Rigid	Rigid

Table 12.1 shows the major characteristics with respect to manual wheelchair, electric wheelchair and my designed wheelchair.

Caregiver shall be ensuring that the safety precaution is implement before or during transferring the disabled person from wheelchair to bed or vice versa. It is very dangerous to transfer disabled person without implement the safety precaution, as the accident may be occur. In the worse scenario, disabled people may fall down from the bed or wheelchair. Applied safety lock and canvas, it will be reduce the hazard to minimize level. From time to time, the caregiver shall perform self-inspection.

My designed wheelchair can reduce handling process if compared to conventional wheelchair. Directly, it can be minimize the pain generate on the under arm due to improper handling by caregiver. At same time, it makes the job much easier for caregiver. He or she might not complaint about their back problem. This will be made the caregiver job more attractive and easy. As the population of elderly increase fast, this will be definitely increasing the caregiver demand. With the aid of my designed wheelchair, these shall be no problem of hardly to find people to serve this professional job. In short, the objectives (refer to Chapter 4) for this research project are meet.

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University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG 4111/4112 Research Project
PROJECT SPECIFICATION

FOR: FRANCIS TEO CHIN TENG

TOPIC: LIFTING MECHANISM FOR WHEELCHAIR

SUPERVISORS: Dr. Harry Ku
Dr. Wenyi Yan

ENROLMENT: ENG 4111 – S1, D, 2005
ENG 4112 – S2, D, 2005

PROJECT AIM: This project seeks to design a lifting mechanism for wheelchair, in order to reduce the pain of the disabled or elderly person while being transferred from wheelchair to bed or vice-versa.

SPONSORSHIP: OWN

PROGRAMME: **ISSUE 3, 18 Mar. 2005**

1. Research the background information and specifications of existing wheelchair on the market. Verified the need of elderly persons at the old fold's home. Obtain the ideas or proposal for modification of existing wheelchair.

   Begin : 20th Jan 2005
   Completion : 10th Mar 2005
   Approx. Hours : 60 hours

2. Conceptually design a lifting mechanism for wheelchair that transfers the user horizontally and vertically. This includes the components, cost, performance characteristic (weight of user, lifting efficiency and etc), maintenance, safety and product life.

   Begin : 11th Mar 2005
   Completion : 30th April 2005
   Approx. Hours : 100 hours

3. Use Pro-E to create individual component, and assemble them into a complete set.

Begin	: 25th April 2005
Completion	: 15th July 2005
Approx. Hours	: 120 hours

6. Analyse or simulate the product performance with different material selection or different design by ANSYS (software of finite element analysis).

Begin	: 15th July 2005
Completion	: 30th July 2005
Approx. Hours	: 50 hours

7. Prepare the Project Appreciation (assignment 3) as per request by ENG 4111.

Begin	: 5th April 2005
Completion	: 15 May 2005
Approx. Hours	: 50 hours

8. Draw up conclusions.

Begin	: 6th Aug 2005
Completion	: 10th Aug 2005
Approx. Hours	: 20 hours

9. Partial Draft Dissertation

Begin	: 1st Aug 2005
Completion	: 15th Sep 2005
Approx. Hours	: 80 hours

10. Final draft of thesis, to incorporate modifications suggested by supervisor.

Begin	: 20th Sep 2005
Completion	: 30th Sep 2005
Approx. Hours	: 30 hours

11. Complete the thesis in requested format

Begin	: 1st Oct 2005
Completion	: 20th Oct 2005
Approx. Hours	: 100 hours

As time permits:

12. Prepare the assembly process drawing, assembly instruction, assembly techniques and manufacturing specifications for production purpose.

AGREED: ________(Student) ________, ________(Supervisors)

05/04/2005 ___/___/___ 13/04/05