Model and Simulation of Heavy Load Carrier

By

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Mechanical Engineering

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CERTIFICATION OF APPROVAL

Model and Simulation of Heavy Load Carrier Mechanism

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS
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May 2012

CERTIFICATION OF ORIGANALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgement, and that the original work contained herein have not have been undertaken or done unspecified sources or person.

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(MUHAMAD BAKHTIAR BIN ISMAIL)

ABSTRACT

Heavy load carrier is a mechanism use to ease the lifting of heavy load by reducing the force need and increase the capacity of the load.The design of the heavy load carrier is to improve the working condition mostly for the labor and personal use. Thus, the heavy load carrier can be used to move the load in short distance without using any vehicle such as lorry or forklift which can reduce the cost of transportation. The heavy load carrier must be applicable in multi terrain which mean can be use on level ground or stair-like terrain. Moreover, the ability of the heavy load carrier which can be used in multi terrain is due to its capability to lift the load in multi method base on applicable terrain. The multi method of lifting the load such as trolley, backpack, wheel bag luggage and other manual lifting had being combined together in this mechanism. The heavy load carrier shape and degree of freedom can be change easily base on the method of lifting. The heavy load carrier installed by tire and handle with steady and sturdy frame. While the heavy load carrier used in level ground the shape of wheel bag luggage can be used, for small quantity of load the heavy load can be push with two tires and string to support the load. While for huge quantity of load the shape of heavy load change to trolley. The handle used to push the heavy load before will be use as the frame to support the load with the help of string.Then the trolley can be pull by the beam as a handle. Furthermore, in stair-like terrain, the heavy load can be change into the back-pack shape which the handle for the bag luggage shape will be use as a support to carry the load from the ground.

ACKNOWLEDGEMENTS

First and for most, I want to express my deepest gratitude to my project supervisor, Pn. RosmawatiBinti Mat Zain who had support, guide and encourage me to successfully completed this project. She always expects for high quality work and this project is no exceptions. She continuously challenges me to learn new thing and come out with new ideas in order to produce a high quality project.

Last but not least, special thanks to family, friends and others who were directly and indirectly involved in helping me to complete this project successfully.

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CHAPTER 1: INTRODUCTION

1.1 Background of project

This project is related to the modeling and analysis of heavy load carrier mechanism. The heavy load carrier is an innovation and combination of other load carrier such as luggage bag, back packing and trolley (*Shozo Takagi, Eugene Anthony Kazmark, Thomas E. Wood,VikramDinubhaiPanchal*). Further study is on the force distribution, vector force and centerof gravity and its effect on the load.

Moreover, by manipulating the shape of the heavy load carrier it can result in reducing the force required to move load (*VikramDinubhaiPanchal*). While, during pulling and pushing, installation of proper tires is crucial in order to reduce the friction between the grounds. The friction is an important parameter since it has significant effect to the force required.

Furthermore, the angle of apply force also has an effect on the force require. Application of force vector is necessary while pushing the heavy load carrier. Proper angle of the heavy load carrier and the ground during pushing is crucial to give the optimum force requires in moving the load. As addition, the frame should be able the load during the process. While carrying the load as a back-pack, carrying load and personnelcenter of gravity can affect the require force. Last but not least, the factor of safety also must be included to reduce occupational hazard and also providing the proper carrying method to reduce back injury

1.2 Problem statement

Transportation such as lorry or forklift is an important method in moving heavy load equipment or material to a specific location. The usage of this method save a lot of time and cost for long distance location, however it is not fully efficient for use in short distance in term of cost and quantity of the item. While, available heavy load carrier mostly is design for specific terrain usage, thus limit the carrying process.It is easier to move the load in smooth ground compare to stair-like terrain. For the stair-like terrain the worker are required to shift and carry the load which mean require more energy compare to smooth ground which commonly trolley-like mechanism be use. For stair-like terrain the use of back-packing method can ease the process. Thus the combination of back-packing and trolley-like mechanism can make the moving faster if the terrain is both smooth and stair-like.

Moreover, cost also has significant effect of this project. The cost can be classified as the cost of available heavy load carrier. Mostly the cost for industrial cart or trolley range from RM 100 and above thus quite expensive for household purpose.Thus it is important to design the heavy load carrier which affordable for household usage or industrial usage. In addition, the cost also can come in the form of workforce in company or workplace.In order to reduce the cost it is important to reduce the workforce, however reducing workforce can result in decreasing of work efficiency in term of cost and time. Thus it is important to increase the capacity for each worker is by mean of using a heavy load mechanism. It is beneficial in term of time, cost, energy use and workforce if a mechanism that can increase the capacity of load and also reducing the force needed can be designedto move the entire require load.

1.3 Significant

- To improvise existing heavy load carrier
- To design multi method and terrain load carrier mechanism
- To ensure the safety by proper lifting method

1.4Objective

- To propose conceptual design (FYP1) and analysis on heavy load carrier (FYP2)

1.5 Relevancy of the Project

- Increase effectiveness of carrying method (range from 75 - 140 kg)
- Improvise existing heavy load carrier
- Reduce cost for moving the load
- Affordable by customer

1.6 Scope of study

The project will be carried out in two semesters consisting of FYP I (Final Year Project I) and FYP II (Final Year Project II). The objective is to conduct a viability study and a lot of research pertaining articles or journals with related contents. For this project, my scope of study is to analyze the mechanism of back-packing, wheel bag luggage and trolley (available heavy load carrier). Data gathering will be conducted to collect useful information of heavy load carrier base on technical paper, existed experiment and invention of heavy load carrier. At the end I should be able to come out with a conceptual design of heavy load carrier.

FYP 1 period

- Review of literature on related topic based on technical papers and journals.
- Review of invention design for modelling purpose
- Propose conceptual design

FYP 2 period

- Proceed to embodiment design
- Propose the design model of heavy load carrier
- Propose detail design of heavy load carrier
- Propose the analysis on the design

CHAPTER 2: LITERATURE REVIEW

2.1 Pushing and pulling force

2.1.1 Two wheels

Pushing and pulling of an object had a significant effect on the require force to move the object. This is due to vector force acting on the object. Base on study the effect of pulling and pushing which is conducted using plastic dustbin with two wheels. The experiment was conducted to investigate the effect of pulling and pushing and the posture during the process to the force required to move the dustbin. It was carried out in the laboratory which situation resembles the daily work activity. During pushing the dustbin was push in front while pulling behind the dustbin. The dustbin was push or pull over the cement floor covered with an artificial 15m long grass mat with a thin layer of sand. This grounding was chosen to increase the rolling resistance while assuming the resistance increase with increasing weight of the dustbin load. The movement of subject then recorded using camera (*B.Schibye, K.sogaard, D.Martinsen, K.Klausen; 17 April 2001*).

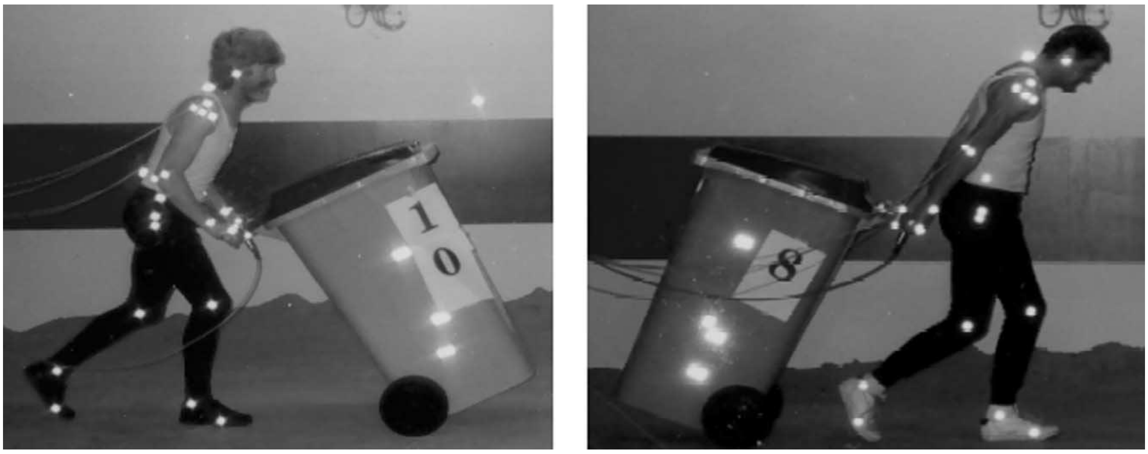

Figure 1: Subject during pushing and pulling a two wheel dustbin

In order to measure the working force during the process the three-dimensional force transducer (*MC3A-6-1000 AMTI, Advance Mechanical Technology,and Watertown, Massachusetts, USA*) was mounted on the handle of the dustbin. This transducer measure both of the magnitude and the direction of the force exert during the process. There are three situations which selected for future analysis which are:

- Tilting of Container: situation as the instant when the first peak in the resultant force on the handle was found.
- The initial phase: situation which defined as the instant after the tilting of the container when the resultant force was largest.
- The sustained phase: this was defined as the instant during walking cycle when the peak resultant force was measure.

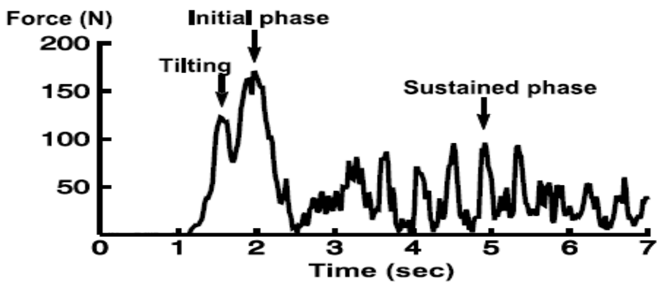

Figure 2: three situations selected for analysis (tilting, initial and sustained phase during pushing process)

Illustration of the sequence of the process during the pulling and pushing was shown below. The number denotes the time(s) from onset of the operation, while the number in frame shown the selected video field for biochemical analysis. While the arrow shown the direction of force and length of the arrow illustrates the size of the force on the handle of the dustbin.

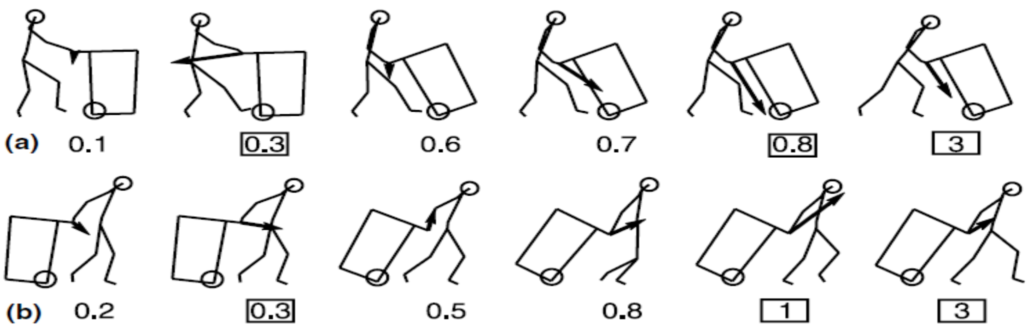

Figure 3: Sequence of the event during (a) pushing and (b) pulling

During pushing and pulling a personnel must generate and apply force in order to move the object. The force exerts usually through the hand onto the handle then distribute to the wheel.The vector force exerts during pushing is downward – forward. During pulling the force direction is upward –forward(*B.Schibye, K.sogaard, D.Martinsen, K.Klausen; 17 April 2001*).

The horizontal component of the force during pushing or pulling is smallest in sustained phase, while it is larger during pulling than pushing both in the initial and sustained phase. In addition, the situation was opposite in tilting phase.

Phase	Method	Amount of waste (kg)	Direction of force (°)	Push/pull force (N)	Horizontal component of force (N)	Forward inclination of trunk (°)
Tilting phase						
	Push	25	−153 (−184–(−127))	118 (80–148)	99 (75–148)	10 (−2–22)
		50	−167 (−187–(−143))	222 (154–330)	211 (54–330)	6 (−4–16)
	Pull	25	−44 (−97–8)	138 (106–194)	70 (2–144)	29 (20–53)
		50	−20 (−50–6)	201 (164–246)	181 (129–246)	31 (14–54)
Initial phase						
	Push	25	−69 (−74–(−49)	219 (154–304)	74 (41–131)	23 (11–37)
		50	−64 (−73–(−57))	276 (210–364)	115 (54–177)	28 (20–41)
	Pull	25	44 (36–52)	179 (130–232)	127 (105–156)	24 (12–41)
		50	43 (32–54)	242 (194–330)	172 (132–225)	25 (10–41)
Sustained phase						
	Push	25	−66 (−71–(−60))	98 (64–116)	39 (32–50)	15 (6–22)
		50	−66 (−88–(−56))	133 (86–162)	53 (5–83)	23 (11–32)
	Pull	25	56 (49–67)	111 (78–154)	62 (30–92)	16 (7–24)
		50	48 (49–56)	142 (108–174)	95 (72–123)	19 (12–27)

Table 1: Force and direction of force and forward inclination of trunk during chosen phase as per figure

According to the data above, the force exert during pushing is greater than during pulling for two wheel dustbin, this is due to resultant force on the dustbin which create a large relieving, external extension torque during pushing thus increase the torque required to move the dustbin, while during pulling this external force was reduce to minimum because the resultant force pass very close to the trunk of the body thus effecting the center of gravity of the personnel body and the dustbin (*B.Schibye, K.sogaard, D.Martinsen, K.Klausen; 17 April 2001*).

2.1.2 Four wheels

The pulling and pushing process for 4 wheels trolley-like mechanism is slightly differ to 2 wheels mechanism. This is due to the coordination of the mechanism which is more stable to 4 wheels compare to 2 wheels (*Darcor. Copyright © 2001 Darcor Limited)*. Moreover, the force acting on 2 wheels mechanism can be vary from forward-upward or downward-backward while for 4 wheels the horizontal push or pull force is matter the most.

According to ergonomic pushing and pulling truck, For 4 wheels mechanism pushing process is more preferable compare to the pulling since itsaffect the personnel posture mostly compare to the container coordination. While for two wheels pulling force is preferable since the coordination of container effect the mass Centre of Gravity (CoG) thus reduce the force requiredto move the container.

This paper is design for smaller female member by assuming if the she can carry out the task so can most other women and men. Base on case study, a manufacturer of silicon chip processing observe that, 4 workers are needed to move the equipment that weight to 7,000 lbs. after that, the engineers established a design goal which intended to scientifically testing the push and pulling force in order to find an optimal solution to move the item. Moreover, they design the new system which involves several dollies with low resistance caster and modified electric pallet jack call as "tugger". Jon Paulsen, Ergonomics Engineering Supervisor (Darcor. Copyright © 2001 Darcor Limited*)* explains that, "We tested six dolly and caster designs and learned that nor all casters are equal. After four design iterations, we arrived at the new dolly design based on ergonomics, safety, usability on all system types and configurations, product damage avoidance and cost. In the end, we were able to reduce the number of technicians needed to push a system by 50%, leaving the other \s to attend their designated work without disruption. When pushing the system straight line, we were able to reduce the push force, distributed between two employees, to 60 lbs and thus avoid using tugger in many areas of our manufacturing lines. Clean room floor space is very expensive, so we wanted to use as little space as possible. A 60 lb, push force for a 7000 lb. piece of equipment is an incredible achievement. We are very pleased with the advances in caster technology that allowed us to achieve this push force. Our time studies show that we increase productivity by almost 400% in terms of man-hours. Plus, there haven't been any injuries related to this task since we instituted the new system over a year ago"

2.2 Factors that affect pushing and pulling force

In order to move a trolley-like mechanism by mean of pushing or pulling the personnel need to overcome the force that resists the motion. To generate and apply the force the personnel need to have adequate friction at least equal to the resisting forces of the equipment, otherwise the personnel feet will slip. Moreover, there are a few factors that define how much the resistance wheeled equipment will produce and how much force a person will generate and apply to move it (*Darcor. Copyright © 2001 Darcor Limited).*

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Figure 4: Factor affecting the pushing force

2.2.1 Rolling resistance

Rolling resistance refer to the force that resists the movement of the wheeled equipment. There is several type of force that resists the movement of the equipment such as:

- Dynamic or inertial forces
- Forces due to physical interference
- Friction forces

In addition, the force required to start the movement is always greater just before the movement begins. It usually refers as the initial force by ergonomist. Then the force require will drop once the acceleration and any mechanical interference is overcome, this state is refer as sustained force. The force becomes lower once its travels in relatively constant speed. While the motion of the equipment change in path the force is refer as turning force (*Darcor. Copyright © 2001 Darcor Limited).*

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2.2.2 Dynamic or inertia

This type of force follows the law of motion. Thus mean it only exists while the equipment is accelerating or decelerating. Usually occur during starting the motion or turning phase(*Darcor. Copyright © 2001 Darcor Limited)*.

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2.2.3 Friction at the wheels/casters

This type of force occurs at between the wheel and the floor. In order to minimize the friction force designation of proper type of wheel is necessary. The ideal wheel that can reduce the friction is hard or smooth wheel which operate on hard or smooth wheel. Other factor that might effecting the friction on the wheel including the diameter, tolerance in the round , material of the wheel, resilience and energy loss during the motion process. The friction can be define as static (starting of motion) and dynamic (during rolling). It is state that the static force is higher compare to dynamic force since we required more fore during starting of the motion (*Darcor. Copyright © 2001 Darcor Limited)*.

Moreover, the type of wheel which is fix and moveable type of wheel, the friction also can be reduced.

There is few type of friction acting on the wheel:

- In the axle-wheel interface
  - Typically the wheel is offer with sealed bearing which required less maintenance. If the bearing is cloth with contaminant or become dirty the rolling resistance for the bearing will increase.
- In the swivel housing (for swivel caster)

- This type of friction occurs when the wheel is already in motion. When the turning phase occur the resistance of friction will be experience by the wheel

- At the ground-wheel interface when a wheel is slid or pivoted on a surface
  - This type of friction occurs at the tips of the wheel. In order to reduce the friction it is necessary to reduce the point of contact between the wheel and the ground.

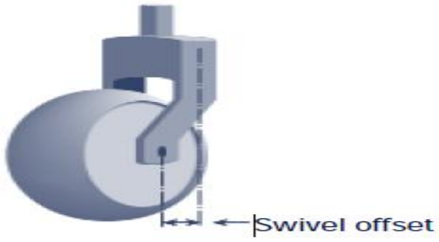


Figure 5: A swivel offset helps pivot the wheel

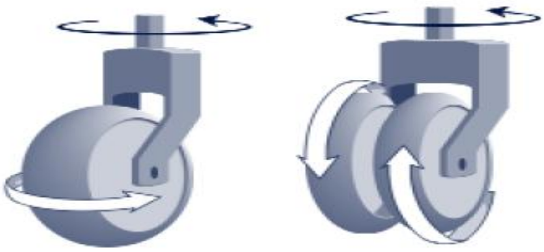


Figure 6: single wheel caster pivot on the wheel surface, leading to increase force due to friction and increase damage. Twin wheeled caster (right) reduce friction and wheel damage by rolling when the caster is rotated

2.2.4 Handholds/ handle

Handholds are important since it is the point of contact between the personnel and the equipment. Thus it sends the signal to the personnel on how to navigate the equipment. The force applies by the personnel also exerted through handholds therefore the personnel can seek the most convenient or mechanically optimum force to the equipment in order to move it (*Darcor. Copyright © 2001 Darcor Limited*).

There are few parameter need to consider when designing the handhold:

- Handhold high
    - High of the handhold is important since it define the posture of the personnel will use. The force exerted to the equipment is significantly related to the posture of the personnel

- Handhold width

    - Personnel should be able to contact handholds as near as safely possible to the outer edge of the equipment to avoid crushing injuries but providing the ample leverage for turning and positioning.

- Handhold type

    - Handhold type can significantly affect the force required to move the equipment. Handholds interface usually refer as coupling. Poor coupling can lead to decrease of effectiveness by 65%. Generally, the handholds should not concentrate pressure on any specific part of hand. The personnel should be able to grip the handholds with power grip (the fingers and palm is with contact with handholds)

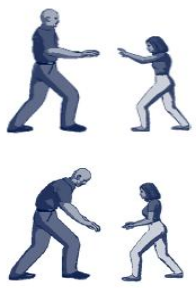


Figure 7: The handhold position affect the posture of the personnel which effect on how much force can generate.

Moreover, during pushing process the location of the handholds should be between elbow and the hip height. While for pulling, handholds height should be between hip height and knee height and the handholds may need to be offset from the equipment to ensure adequate foot clearance.

In addition, body posture also had significant effect on the magnitude of the force required. The human muscular system is essentially a series of mechanical levers. Some of postureare more mechanical advantageous than other posture. The best posture used for starting to move the load is not always a best posture when the load already moving. The force generate by pushing is greater than pulling since the foot positioning during pushing is more stable compare to pulling. (*Darcor. Copyright © 2001 Darcor Limited;IdsartKingma, P. Paul F.M Kuijer, Marco J.M Hoozemans,Jaap H van Dieën, Allard J van der Beek,Monique H.W Frings-Dresen, 20 June 2002)*

2.3 Back-packing

During carrying the load using back the principle is the same as back-packing. There are few factors affecting the force required to carry heavy load which are:

2.3.1 Centre of gravity

Usually for a typical man, the centre of gravity (CoG) is around the stomach. Our movement is based on how CoG moves around. Considering the heavy back-packing, due to heavy loadcarried, our body will bend a bit in order to shift CoG of our body and the load. The body posture will modified so that the vertical projection at the feet of CoGof the man plus the load is same to approximate in position to the CoG of the unloaded man (*Hellebrandt,Fries,Lasren&Kelso,1944*).It also gives a stable support for the bodymoreover, base on study The Effect of Load Carriage on Normal Standing in Man (*D.P.Thomas*,) which carried out to observe on how the body reacts to load on the back. Base on the result shown that, by increasing of load carried on low position, the shoulder displacement increase compare to when carried on high position. While for high position the body becomes more bent forward compare with unloaded man (*D.P.Thomas*).

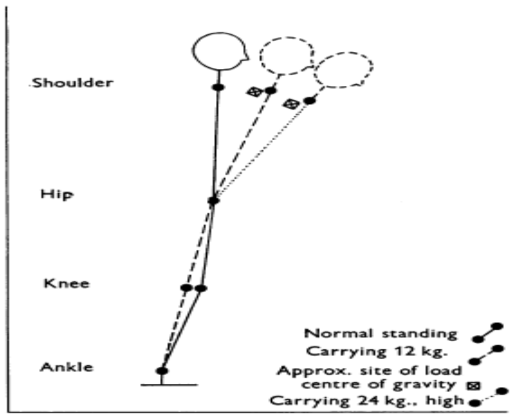


Figure 8: spine posture for different load weight, same load position

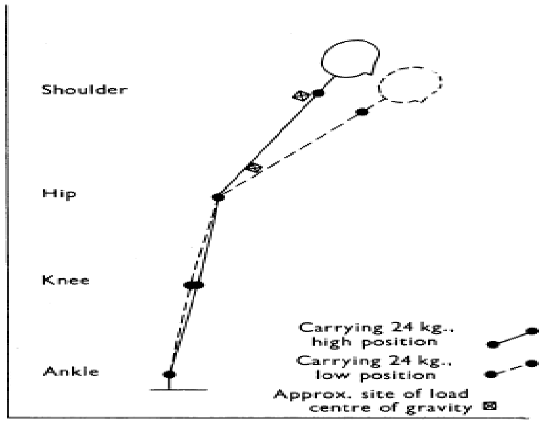


Figure 9: spine posture for same load weight, different load position

In addition, as the load increase , the force exerted to the feet on the ground increase in the downward, forward, rearward and lateral direction (*Hale et al, 1953; Harman et al,1992*). While the vertical force are not increase proportionally to the load (*Harman et al, 1992*) and medial force not clearly affected by load (*Harman et al,1992; Kinoshita ,1995*). Forward bent of the trunk increase with the increasing of load which helps keep the body –plus –pack center of mass over the feet (*D.P.Thomas*).

As the body walking speed increase, the stride length and stride frequency both increase to the same degree. While, other mechanical measure that change with walking speed include percent of double stride, lateral and vertical food-on-ground impulse per stride, braking impulse, peak and average braking , propulsive and medial force , first and second peak vertical forces and all pack acceleration (measured with accelerometer in pack). Yet, average vertical forces barely increase with speed. Toe –off as well as peak vertical, braking and propulsive ground force occur at earlier percentages of the stride as walking speed increases (*Han et al, 1992*).

2.3.2 Torque

Whenever our body moving with the heavy load, the huge impact of inertia will exert to our body, mean the inertia will help the personnel to move forward thus reduce the force required. The idea of the frame to be sturdy and rigid is because with rigid frame it put the least stress on the personnel shoulder. With the sturdy frame the load carried can be support properly to avoid it from moving during carrying process.

2.3.3 Weight distribution

Weight distribution during carrying process is base on the CoG . Having proper weight distribution can result in stability and reduce force requires to movecarryingload. Moreover, the ideal location of most weight distribute should be at the shoulder and less around the hip.Let examine the new CoG base on the type of back- packing[12,13]. The carrying pack actually reduces the postural sway of the body since the body tends to lean. It has been suggested that low load placement might be best for uneven terrain while high load position for stable even terrain which keep CoG almost similar to without load posture (*Bloom and Woodhull-McNeal, 1987*). The importance of load placement becomes more significant when considering the dynamic load with according to static load. the dynamic moment is 40% greater when the load position is high thus give a greater rotational inertia (*Bobet and Norman ,1984*). As the result it was recommended to keep the load placement at the mid –back during walking process. In addition, for back-packing with double pack, it produce fewer deviation, less forward lean on the trunk, produce lesser maximum braking force and greater minimum vertical force which provide more vertical force oriented ground reaction force vector (*Harman et al, 1994; Kinoshita, 1985*). Furthermore for double pack, increasing of load will reduce the length of stride thus reduce stress on the bones of the foot. In contrast with back pack without double packing thus can be harmful (*Harman et al, 1994*)

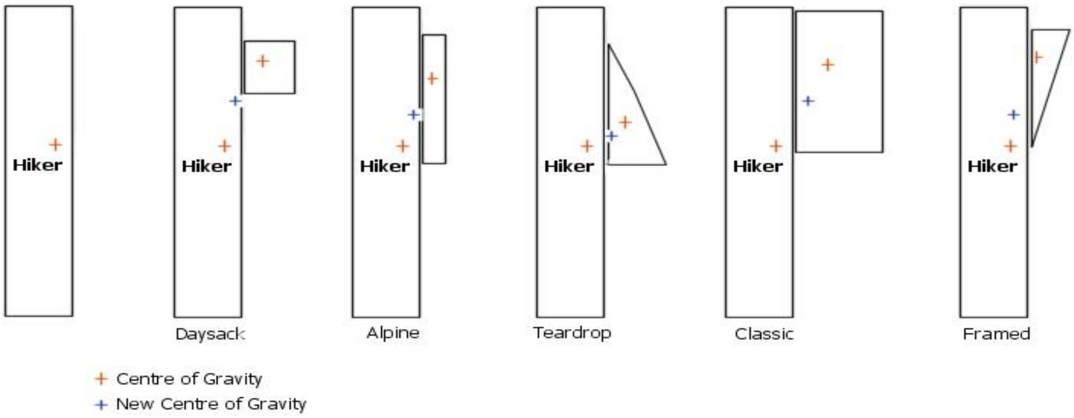


Figure 10: Type of Back-Packing

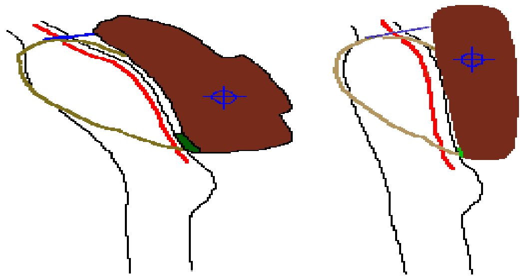
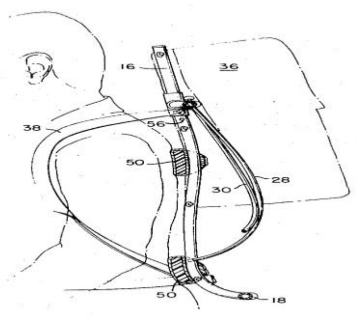
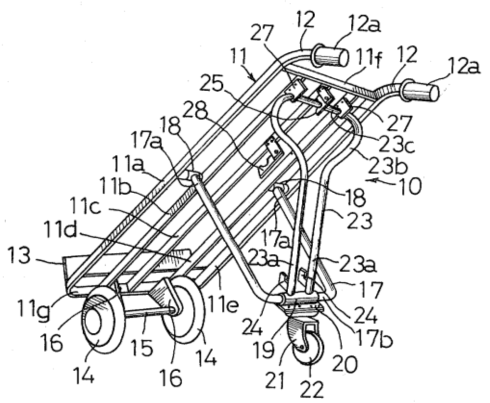
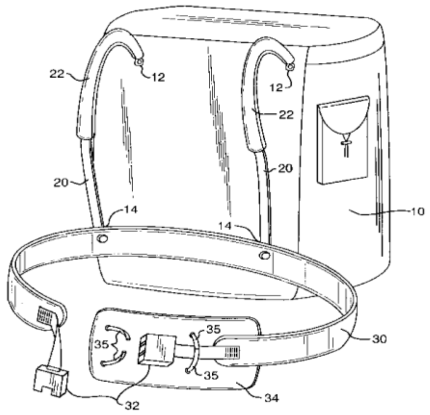


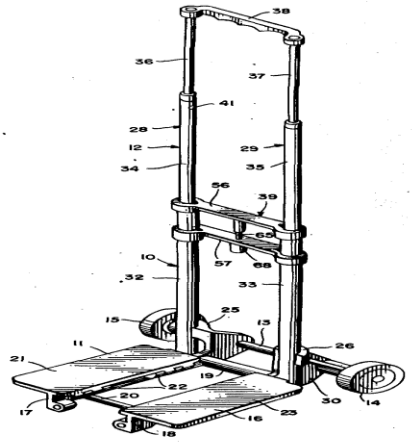
Figure 11: CoG for unframed (left) packing and H-type (right) packing

The picture above showed the CoG of personnel carrying different type of back-packing. The ideal CoGis to bring it as near and centre to the personnel (*Shannell L. Colclough, 2010*).

2.4 example of existed invention of load carrier

Item	Remarks
 **Pack Frame** **Inventor : Thomas E. Wood 3863 41nd N.E.., Seattle ,Wash .98105** **Filed : Feb. 11, 1972**	• A lightweight pack frame constructed of rigid polyvinyl chloride or like material in one embodiment molded U-shape major support member. • The size of pack can be change since mounted with adjustable support member. • Bow like frame to keep the load away from the body.
 **Manual Carrier** **Inventor : ShozoTakagi, no.6-4,6-chome, Ymammoto –cho-minami, Yao-shi,Osaka,Japan** **Filed : May 31, 1974**	• Front wheel support the carrier table mounted on the underside of carrier table. • The u shape arm connected to the portion of the carrier table • By adjusting the support wheel, the carrier can be convert form 3 wheels wheel carrier to 2 wheels carrier. • The 3 wheels carrier can be adjust into

	horizontal 3 wheels carrier by adjusting the support wheel near the u shape arm. • Propose 3 wheels shape for heavy load while 2 wheels for light load.
 **Backpack with Abdominal Support System** **Inventor : David P. Gilmore, Hollis, NH (US);Scott D. Cummings, Bedford, NH(US); William Edward Kols,NewburyPark,MA (US)** **Filed: Apr 19, 2000**	• Provide both internal and external support to increase load bearing capacity • Abdominal support pad and pelvic belt equipped with shoulder strap • Cause the load distributed to shoulder and lower back • Abdominal belt and strap can be attach to different type of load carrier

 **Portable Luggage Carrier With Telescoping Handle** **Inventor: Eugene Anthony Kazmark,SR.,5 Remin Lane, Jokiet ,III. 60433** **Filed : Sept 29, 1975**	• Wheeled portable luggage carrier equipped with telescoping handle can be extended and retracted • Give optional length of handle positioning for various height of body posture • Locking system attached to lock the telescope handle for usage purpose

 **Heavy Load Carrier for Labour** **Inventor: VikramDinubhaiPanchal**	• Adjustable load carrier which can be transform into 3 shape • Can be used as trolley by using installed tire • Can be used as back packing using the handle • Can be used as above-head carrier using the handle and the support foundation rotate on top of the head • Above head carrier for light load • Back packing for medium load • Trolley for heavy load

Table 2: Example of existed heavy load carrier

CHAPTER 3: METHODOLOGY

This section consists of project analysis and data gathering, design concept, material selection and fabricating process to meet the main objective of the project.

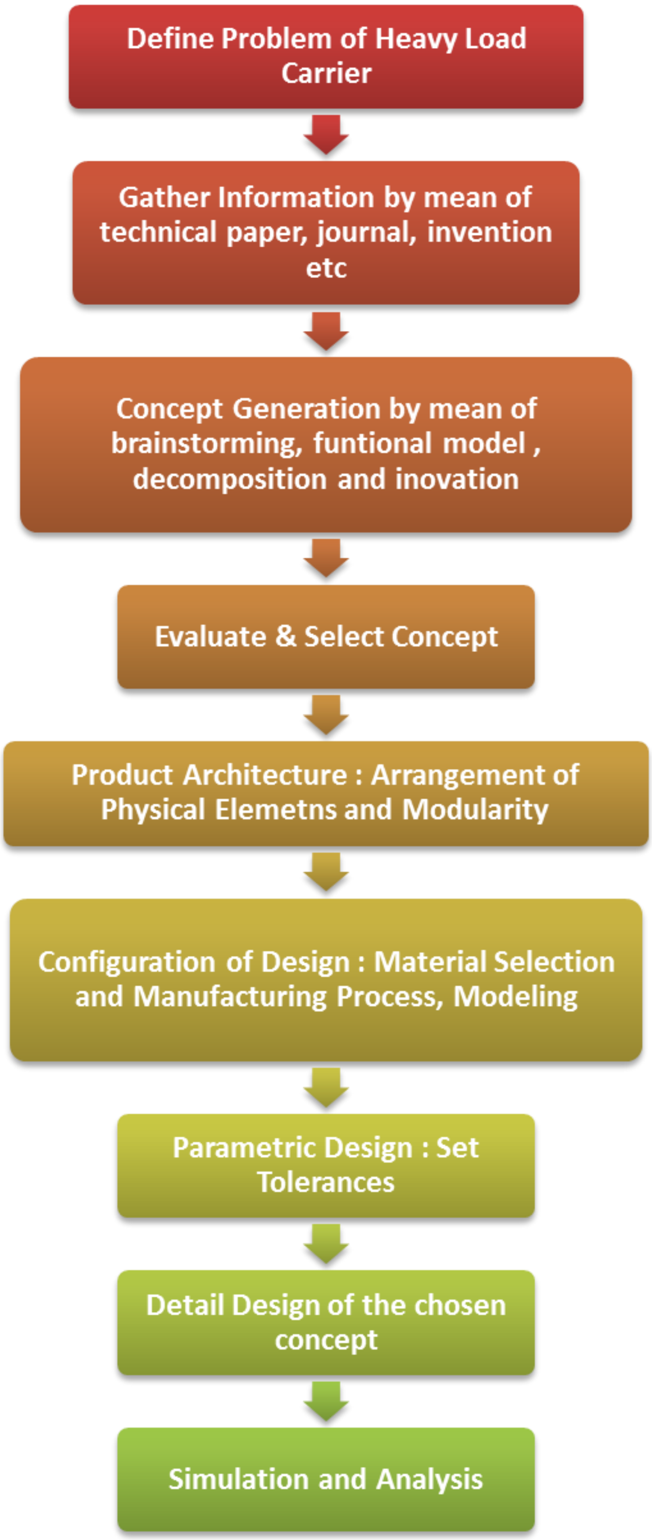
Firstly, analysis and data gathering will be based on research of journal, web source, previous study and design of the heavy load carrier and reference book. The gathering process will required a lot of time in order to verify the theory used and to come out with design concept of heavy load mechanism.

Base on the data gather, morphology chart will be constructing as a reference (Conceptual Design FYP1). The datum of heavy load carrier will be based on back-packing, bag luggage and trolley design. From the morphology chart, I should be able to perform the selection process in order to meet the main purpose of the project. Selection is based on material of the frame, wheel type, lifting method, and degree of freedom of the mechanism and others. Base on the criteria the rating will be done to determine the design concept.

Next, is to determine the type of mechanism for heavy load carrier (Embodiment Design – FYP2). The heavy load carrier should be able to reduce the force require and can be used in multi terrain. Further study of force vector and manipulating should be done in order to verify the best mechanism used.

Then, proceed to analysis and simulation of the model. During the process is should be able to come out with the sketch of heavy load carrier. After that, software such as CAD will be used to further the modeling process. Moreover, after the modeling with CAD, the analysis of force acting on the heavy load carrier will be conducted using the INVENTOR software. The type of material, temperature effect and force distribution will be further study during the process.

3.1 Flow Chart



3.2 Morphology Chart

Feature	Means				
Wheel	Swivel	Fix	Double & Swivel	2 wheels	4 wheels
Frame	Frameless	H-frame	U-frame	Adjustable	
Wheel material	Rubber tube	Tubeless	Solid rubber	Stainless Steel	Polypropylene
Handle	Telescopic	Fix handle	Fix less stress	One handle	Double handle
Back-packing	Strap back-packing	Handle back-packing	Abdominal back-packing	Middle position	Low position
Phase	3 phase	2 phase	1 phase		
Frame material	Stainless Steel	Plastic	Aluminum & Zinc	Alloy steel	Fiber
Advantage	Multi terrain	Adjustable			

Table 3: Morphology chart of the conceptual design

3.3 Design Concept

Feature	Means	Remarks
Wheel	Doubele,2 swivels, 2 fix	• 2 front wheels is fix to the frame, while 2 back (near handle) swivel wheel can be adjust.
Frame	Adjustable	• Adjustable for multi terrain usage
Wheel material	Poly propylene	• Give high strength to the tire • Able to support heavy load
Handle	1 double handle 1Telescopic handle	• Double handle use for pushing /pulling of two wheel trolley and back-packing • Telescopic handle use for 4 wheel cart
Back-packing	Handle back-packing, abdominal belt and middle load position	• Handle will be use during back-packing • Abdominal belt give support to lower body around the pelvic • Middle load position shift the CoG near the body
Phase	3 phase	• Can be used in multi terrain
Frame material	Stainless Steel	• Stainless Steel give sturdy frame • Suitable for manufacturing process which involve welding
Advantage	Adjustable, Multi terrain	• Carrier can be used for multi terrain and easy to adjust for each terrain

Table4: Example of design concept base on morphology chart

3.4 System Requirement

GENERAL SPECIFICATION					
MODEL		HEAVY LOAD CARRIER			
NO	ITEM				REMAKS
1	MATERIAL	BODY FRAME AND SUPPORT		STAINLESS STEEL (SS) G304L	
		CASTOR	FRONT FIX CASTOR	POLYPROPYLENE (PP), SS CASING	
			BACK SWINDLE CASTOR	SS304L	
2	SIZE	FRAME	500 X 250 mm		
		TOE PLATE	250 X220 mm		
		FRONT FIX CASTOR	100 X 38 mm		
		BACK SWINDLE	38 X 15 mm		
3	WEIGHT	±7 kg			
4	CAPACITY	BACK-PACKING	750 N (light)		
		TROLLEY	100 N (medium)		
		CART	140N (heavy)		
5	WORKING CONDITION	Adjustable heavy load carrier can be operate in three different mode which define by the capacity of load carried. It's can be used as back-packing , trolley and cart respectively to light , medium and heavy weight. For purpose of stair-like terrain, back-packing mode is recommended if the weight carried is light.			
6	REMARKS	Further description regarding the dimension, bill of material and net weight refer to attached drawings and descriptions			

Table 5: General Specification of Heavy Load Carrier

3.4 PUGH Concept Selection

Row	Criteria		D	A	C	B
1	Wheel		+	DATUM	=	+
2	Frame		+		=	-
3	Wheel material		+		+	+
4	Handle		+		+	+
5	Back-packing		=		-	-
6	Phase		=		-	=
7	Frame material		+		+	-
8	Advantage		+		+	+
		Pluses	6	0	4	4
		Minus	2	0	2	3

Table6: PUGH matrix method of selection base on datum comparison

PUGHmatrix represents the comparison of the models with existed model which set as datum. The models generated then compare with the datum in term of its advantage and disadvantage. Few criteria had being chosen as comparison criteria to observe which model having higher advantage compare to other models and datum. '+' Sign represent that the model having advantage on compared criteria compare to the datum while '-' sign represent the model having disadvantage in those criteria. Furthermore '=' represent the models is equal in term of those criteria. After comparison had being done, then proceed to evaluate the model by adding up the '+', '-', and '=' signs. The model which shown the higher value of advantage then choose as the model for heavy load carrier.

3.5 Model Generation

3.5.1 Back Packing Mode

Figure 12: Back Packing Mode

During back-packing mode of Heavy load carrier, the loadinghappens by mean of lifting the handle on the back of personnel. Back absorber will act as a reduce stress to the personnel since it consist spring like behavior. During this mode, the load will be support by the toe plate. Direction of force is downward, however due to the nature of human posture which tend to bend over, the CoG of the load will be shifted near the CoG of the personnel thus reduce the stress experience by the body. Few accessories is purpose to be attach to the heavy load carrier such safety belt to support the personnel and load, and polypropylene foam at the handle thus reduce stress at the shoulder.

3.5.2 Cart Mode

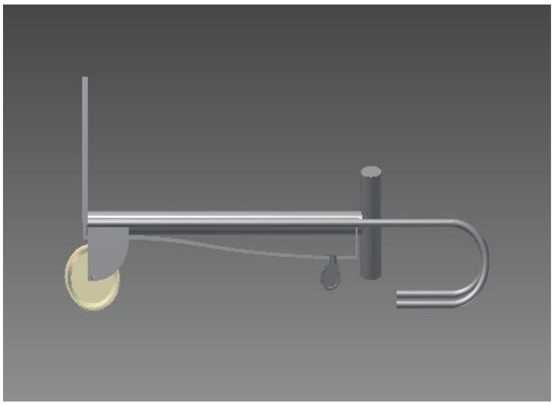


Figure 13: Cart Mode

During this mode, the heavy load waspulled or pushed by the telescopic handle located in the middle of the frame. Pivot join at the telescopic handle allow it to be turn suitable for body posture. The handle which use during back packing can be turn by mean of threading so it can be used to support the load from falling. Forth castor will be used during this mode. This shape is suitable for heavy loading process

3.5.3 Trolley mode

Figure 14: Trolley Mode

During this mode, the heavy load carrier will operate like hand trolley. The load will be support by the body frame and toe plate. Force will be distributed around the frame and toe plate. Two fixed castor were use during this process to support the heavy load carrier. Two handle will be used to navigate the heavy load carrier. It is purpose to attach the safety belt around the load to prevent from falling. This mode is suitable for medium loading process.

3.5.4 Parts

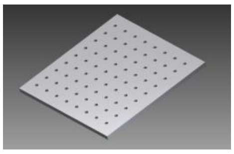
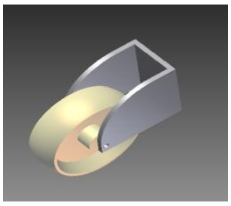
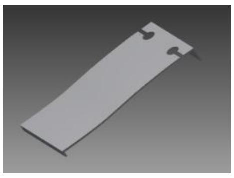
No	Item	Quantity	Dimension	Material	Part	Remarks
1	Frame side hollow rod	2	L=20", ID=0.3" ,OD=0.6"	SS G304L		• Frame main support • Consist of two hollow rod • Join by mean of welding
2	Frame join rod	4	L=10", D=0.3	SS G304L		• Support main frame by mean of welding to the side frame
3	Toe plate	1	L=9", W=10", T=0.4"	SS G304L		• Support the load during back packing and trolley mode
4	Middle telescopic handle	1	L=14.5" D=1"	SS G304L, insulated PP foam at the handle		• Telescopic handle for used during cart mode • Attach with pivot join
5	Back swindle castor	2	D=1.5", T=0.6"	SS G304L		• Small castor for cart mode used
6	Front fix castor	2	D=4" T=1.5"	PP castor, SS G304L casing		• Castor used for trolley mode
7	Back absorber	1	L=20", W=21" ,T=0.2"	Plastic, insulated PP foam		• Reduce strain and stress during back packing mode

Figure 15: Bill of Material

3.6 Material Selection

Mostly major material for Heavy Load Carrier is Stainless Steel. Stainless Steel is type of steel alloy which contains Chromium and Nickel (10% or higher). Stainless steels contain sufficient chromium to form a passive film of chromium oxide, which prevents further surface corrosion and blocks corrosion from spreading into the metal's internal structure, and due to the similar size of the steel and oxide molecules they bond very strongly and remain attached to the surface and in addition alsoimprove the steel properties in term of strength, toughness, corrosion rate and others. Stainless steel can be classify by the different of Chromium contains, thus mean stainless steel come in many grade and family base on existed standard.

After few researches, stainless steel Grade 304L is most likely suitable for fabricating heavy load carrier prototype. Grade 304 is the standard "18/8" stainless steel. it is most versatile and widely used. It has excellent forming and welding characteristics moreover, the balance austenitic structure of the stainless steel enables it to be severe deep drawn without any intermediate annealing. Grade 304 also has outstanding welding characteristics which further improve by introducing grade 304L. Grade 304 L is a low carbon version of Grade 304 which does not require post-weld annealing. Since stainless steel Grade 304 surfer from weld decay when heated to welding temperature. This occur when the chromium combine with carbon at welding temperature leaving the steel short of chromium and therefore unable to self-repair its structure. Thus introducing of Grade 304 L which contain of niobium or titanium had eliminated and stabilized the stainless steel for welding purpose(*AK Steel).*

3.6.1 Material Specification

Material	Stainless Steel 304L
Yield Strength	241 MPa
Density	7900 kg/m^3
Elongation	55
Hardness Rockwell	B80

Table 7: Standard Specification

CHAPTER 4: RESULT AND DISCUSSION

4.1 Design Calculation

4.1.1 Weight Estimation

Material = Stainless Steel 304L	Density = $7900\ {}^{kg}/{}_{m^3}$
Material = Polypropylene	Density = $946\ {}^{kg}/{}_{m^3}$

Table 8 : Material Specification

1) Frame (hollow rod)

Volume

$$\pi({r_o}^2 - {r_i}^2) \times L$$

$$\pi(0.004)^2 \times 0.5 = 6.8405 \times 10^{-5}\ m^3$$

Mass

$$V \times \rho$$

$$6.8405 \times 10^{-5}\ m^3 \times 7900\ {}^{kg}/{}_{m^3} = 0.54kg$$

Mass of 2 frames

$$2 \times 0.54 = 1.08\ kg$$

2) Support bar (solid rod)

Volume

$$\pi(r)^2 \times L$$

$$\pi(0.004)^2 \times 0.25 = 1.257 \times 10^{-5}\ m^3$$

Mass

$$V \times \rho$$

$$1.257 \times 10^{-5}\, m^3 \times 7900\, {}^{kg}/_{m^3} = 0.1\, kg$$

Mass of 4 support rod

$$4 \times 0.1 = 0.4\, kg$$

3) Toe plate

Volume

$$W \times L \times T$$

$$0.01 \times 0.23 \times 0.25 = 5.75 \times 10^{-4}\, m^3$$

Mass

$$V \times \rho$$

$$5.75 \times 10^{-4}\, m^3 \times 7900\, {}^{kg}/_{m^3} = 4.5\, kg$$

4) Back tire

Volume

$$\pi r^2 \times t$$

$$\pi(0.02)^2 \times 0.015 = 1.885 \times 10^{-5}\, m^3$$

Mass

$$V \times \rho$$

$$1.885 \times 10^{-5}\, m^3 \times 7900\, {}^{kg}/_{m^3} = 0.15\, kg$$

Mass of 2 tires

$$2 \times 0.15 = 0.3\, kg$$

5) Front fixed caster

Volume

$$\pi r^2 \times t$$

$$\pi(0.005)^2 \times 0.04 = 3.142 \times 10^{-4}\ m^3$$

Mass

$$V \times \rho$$

$$3.142 \times 10^{-4}\ m^3 \times 946.00\ {}^{kg}/_{m^3} = 0.3\ kg$$

Mass of 2 casters

$$2 \times 0.3 = 0.6\ kg$$

6) Estimation of total mass

$$1.08 + 0.4 + 4.5 + 0.3 + 0.6 = 6.9\ kg$$

4.1.2 Centre of Gravity Estimation

1) Back packing mode

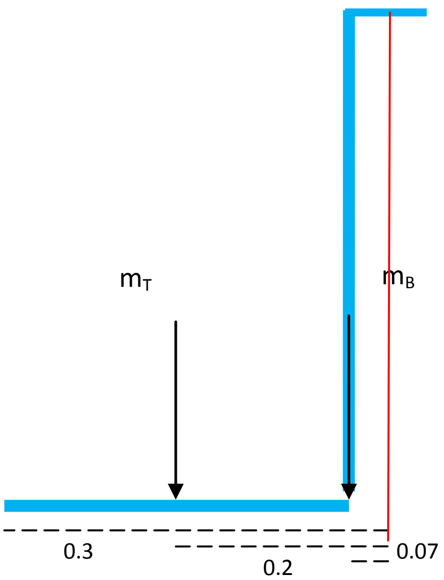


Figure 16: Back packing FBD

$$C_g = \frac{(CM)toe + (CM)side\ frame}{(M)trolley}$$

$$C_g = \frac{(0.2 \times 4.5) + (0.07 \times 1.7)}{(6.2)} = 0.17\ m$$

2) Trolley mode

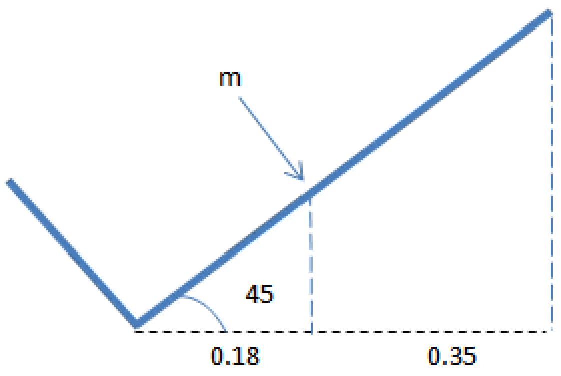


Figure 17 : Trolley FBD

$$Cg = {}^{0.5}/_{2} \cos 45 = 0.18\ m$$

3) Cart mode

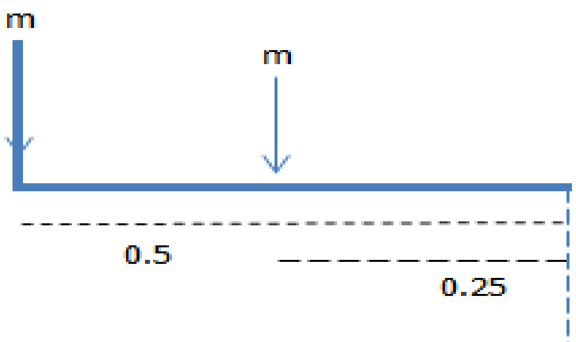


Figure 18: Cart FBD

$$Cg = \frac{Cm_t + Cm_b}{m_{trolley}}$$

$$Cg = \frac{(0.5 \times 4.5) + (0.25 \ \times 1.7)}{6.2} = 0.43\ m$$

Base on calculation, the CoG are shift in there different location according to the mode. The shift of CoG will greatly influent the force distribution of the model.

4.1.3 Force Distribution

Force distribution of the trolley is calculated to find the shear and maximum loading base on mode of heavy load carrier. The free body diagram of heavy load carrier as per figure above. In order to calculate the force distribution few assumptions had being made:

Assume:

M_{Load} = 750N

$M_{trolley}$ = 62 N

1) Back packing mode

Reaction force at trolley;

$$\sum M = 0$$

$$750(0.2) + 62(0.17) - Ra(0.3) = 0$$

$$Ra=160.54$$

$$\sum F = 0$$

$$Ra - 750 - 62 + Rb = 0$$

$$Ra - 750 - 62 + 160.54 = 0$$

$$Ra = 651.5$$

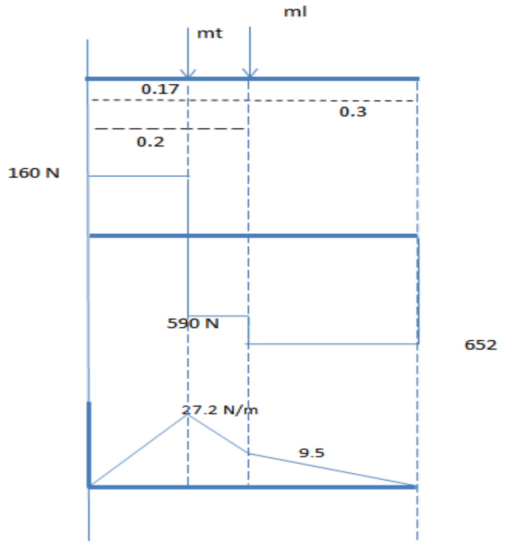


Figure 19: Force and moment diagram of back packing

2) Trolley mode

$$\sum M = 0$$

(750 cos 45) (0.18) + (62 cos 45)(0.18) -Rb = 0

Rb = 103.4.4

$$\sum F = 0$$

Ra - 750 cos 45 - 62 cos 45 + Rb = 0

Ra - 530.3 - 43.8 + 103.4 = 0

Ra = 470.7 N

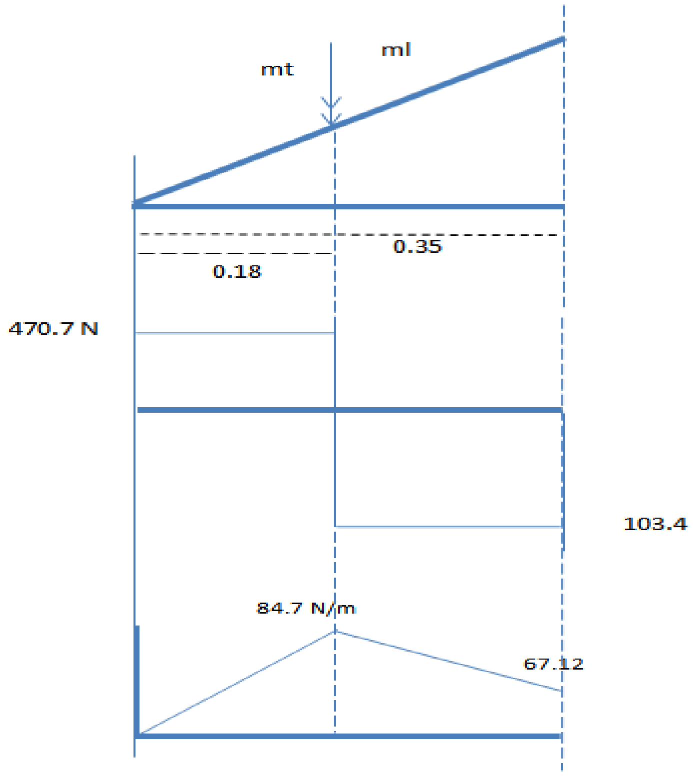


Figure 20: Force and moment diagram of trolley mode

3) Cart mode

$$\sum M = 0$$

750(0.25) + 62 (0.43) - Rb (0.5) = 0

Rb =214.16

$$\sum F = 0$$

Ra -750 - 62 + Rb = 0

Ra - 750 - 62 + 214.16 = 0

Ra =597.8 N

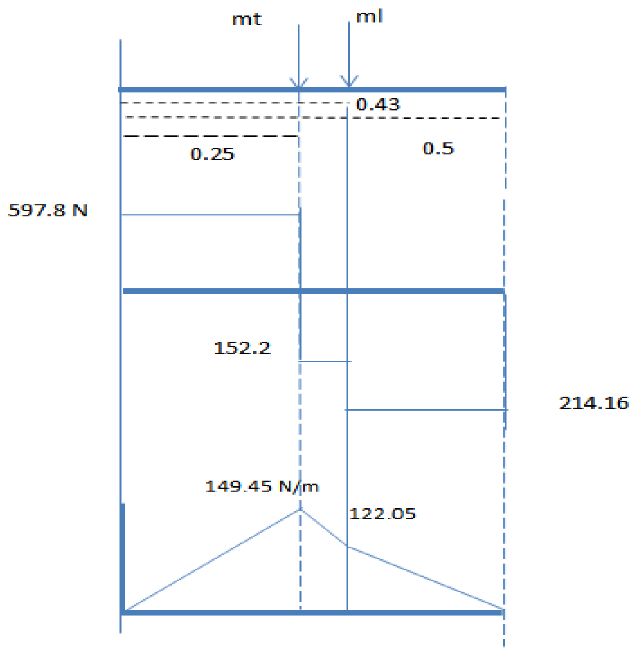


Figure 21 : Force and moment diagram cart mode

Base on calculation of force and moment diagram, the maximum moment for three mode of heavy load carrier differ due to CoG shifting in different position. The maximum moments are 272N, 84.7N and 149.95N respectively.

4.2 Stress Analysis

Stress analysis is conducted using INVENTOR software to analyze the behavior of the frame with regard to the force distribute on it. Stress analysis is a method of study which usually used to determine whether the elements of the model behave as desired. Result of the analysis then interpreted to obtain the result. Force used for this analysis is 750N.

4.2.1 Back packing mode

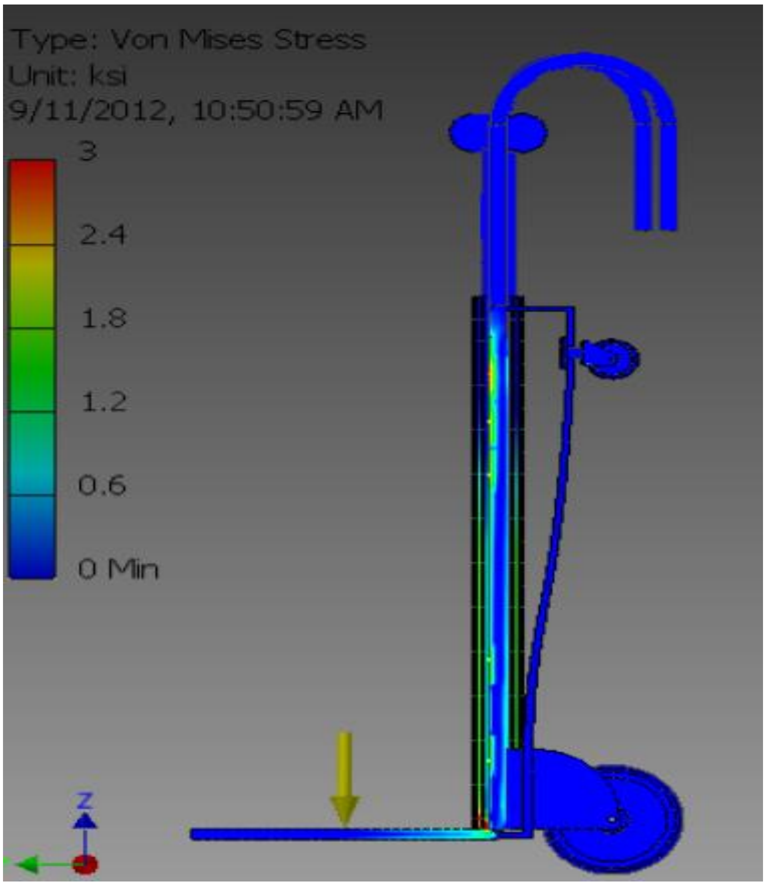


Figure 22: Stress analysis of back packing

Stress analysis shown that, the stress acting on the frame minimum. Thus represent the model can withstand the applied load. However, based on this simulation, it is observe the toe plate experience bending due to the force. It is propose to attach the toe plate with a support beam in order to reduce the bending experience by it.

4.2.2 Trolley mode

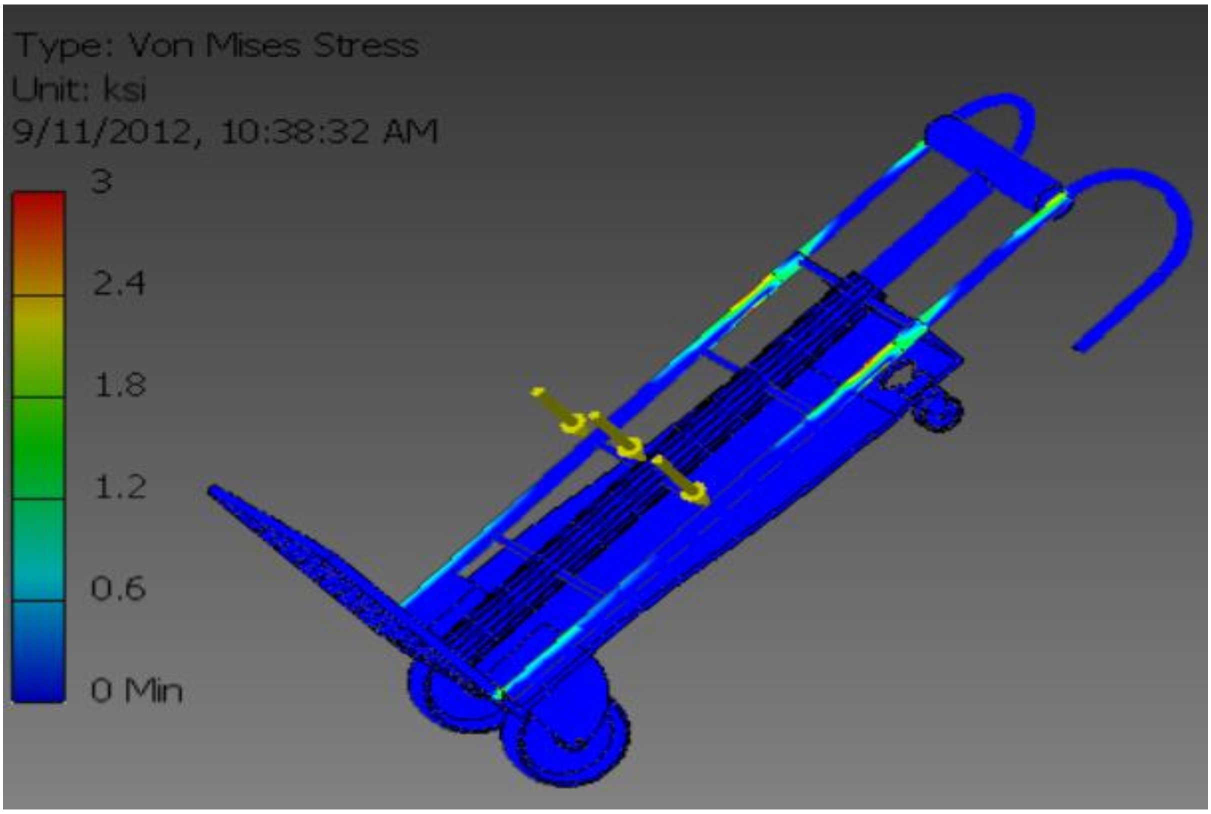


Figure 23: Stress analysis of trolley mode

Based on the stress analysis of trolley mode, the force distribution is applied on the middle of the frame with 45°(angle depend on the posture of human being). It is assumed that the force distribution isdistributed uniformly along the support frame while the fix caster and hand handle is assumed fix. Theresult shown, the frame can withstand the force applied, however it is observe that the frame experience deformation. It is propose to install spring with absorber to reduce the vibration during working.

4.2.3 Cart mode

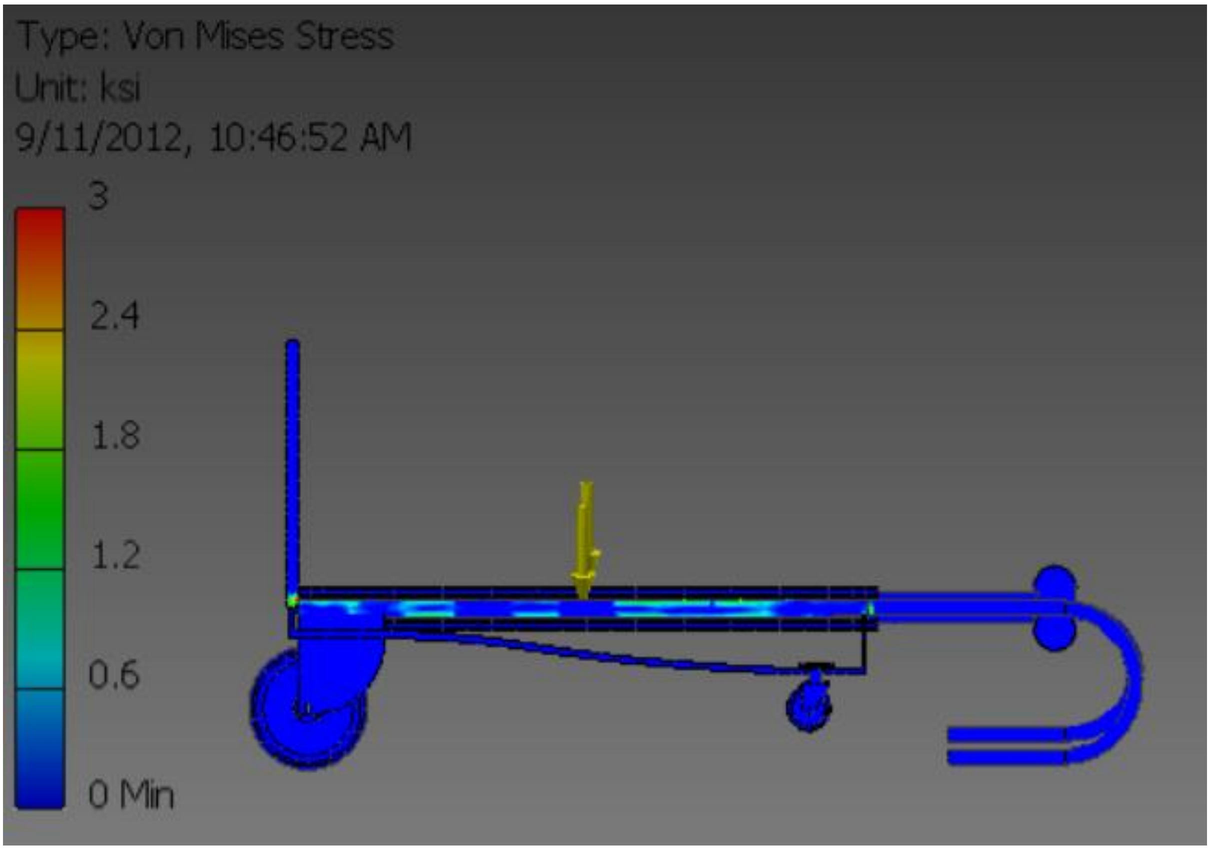
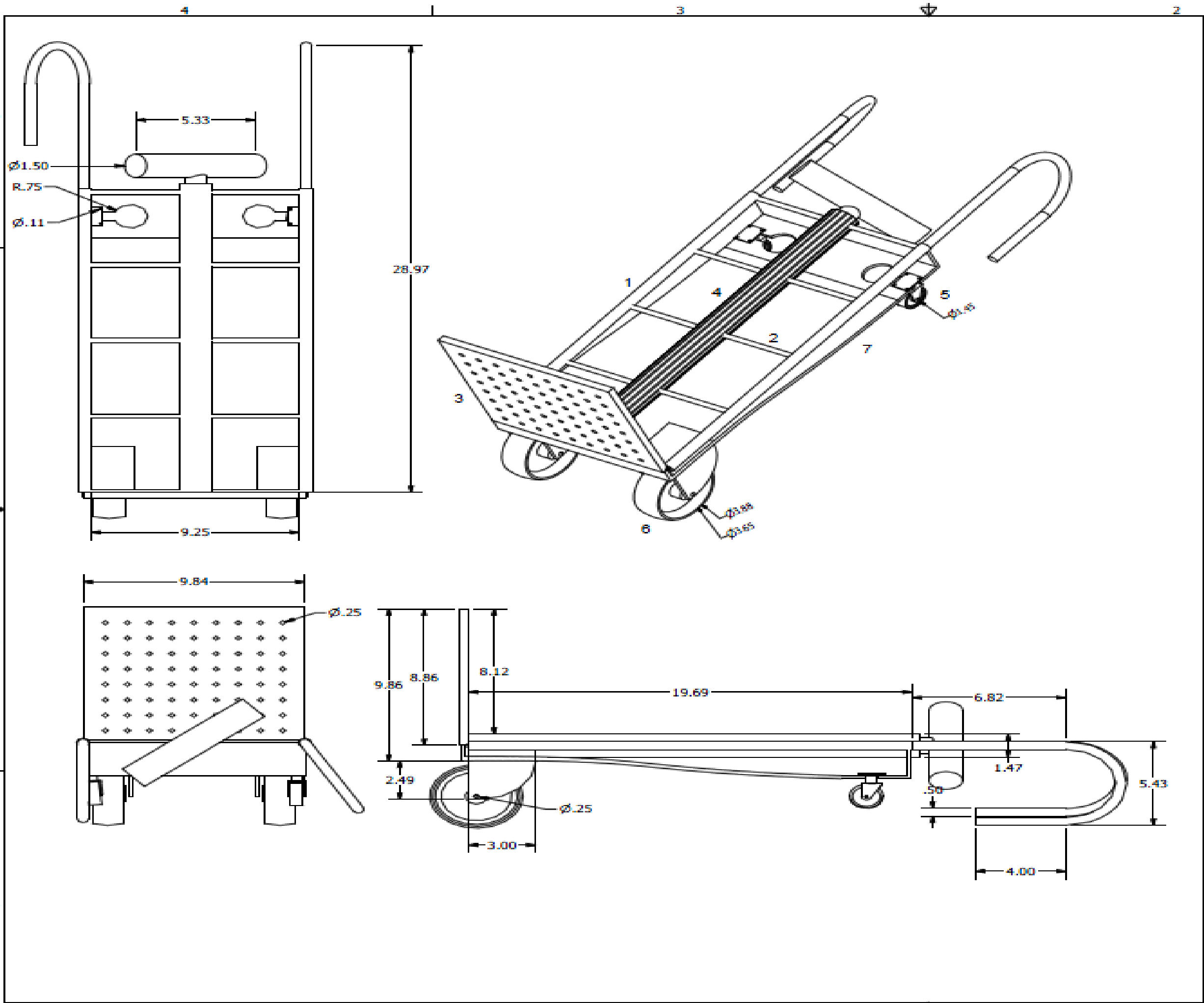


Figure 24: Stress analysis on cart

Based on the stress analysis, the force was distributed uniformly on the middle of the cart. Both end of the caster were assumed fix on the ground. The result shown that the frame can support the apply force by minimum stress acting on it. However, it is observe that the frame experiencing displacement due to the force applied. It is purpose to install spring and absorber to reduce the stress on the body.

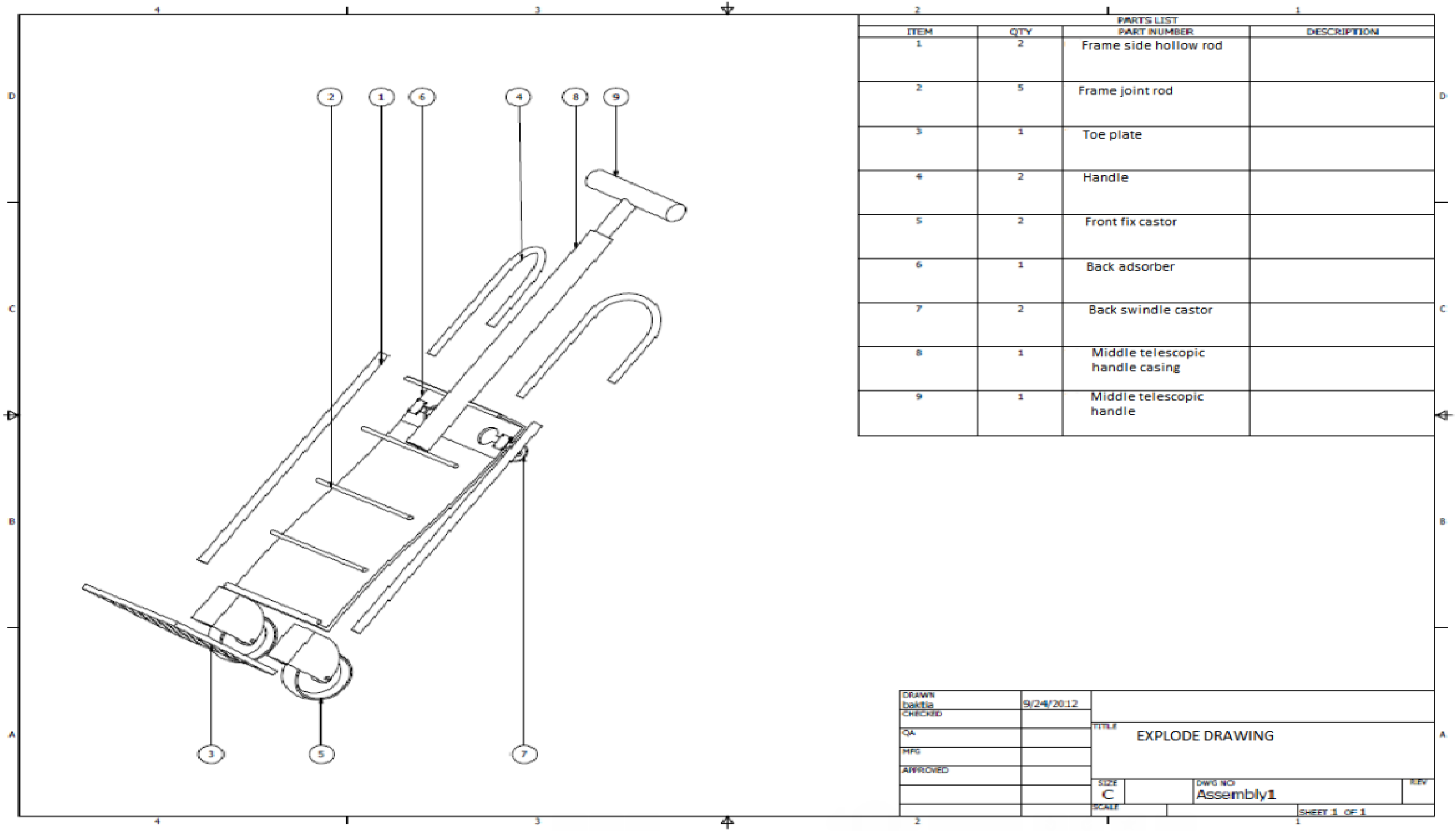
4.3 Engineering drawing



DRAWN Bakhtiar	8/16/2012			
CHECKED		TITLE ASSEMBLY DRAWING OF HEAVY LOAD CARRIER		
QA				
MFG				
APPROVED				
			Assembly 2d	
ITEMS	QUANTITY	SCALE DIMENSION	MATERIAL	REMARKS
1) FRAME SIDE HOLLOW ROD	2	L=20" ID = 0.3" OD=0.6"	SS G304L	
2) FRAME JOIN ROD	4	L=10" D=0.3"	SS G304 L	
3) TOE PLATE	1	L=9" W=10" T=0.4"	SS G304L	
4) MIDDLE TELESCOPIC HANDLE	1	L=14.5" D=1"	SS G304, PP FOAM	
5) BACK SWINDLE CASTOR	2	D=1.5" T=0.6"	SS G 304L	
6) FRONT FIX CASTOR	2	D=4" T = 1.5"	PP CASTOR SS G304L CASING	
7) BACK ABSORDER	1	L=20" W=21" T=0.2"	PLASSTIC PP FOAM	
		SIZE	DWG NO	REV
				SHEET 1 OF 1

Figure 25: Assembly drawing

4.4 Explode drawing



PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	2	Frame side hollow rod	
2	5	Frame joint rod	
3	1	Toe plate	
4	2	Handle	
5	2	Front fix castor	
6	1	Back adsorber	
7	2	Back swindle castor	
8	1	Middle telescopic handle casing	
9	1	Middle telescopic handle	

Figure 26: Explode Drawing

4.5 Gantt chart

Milestone for Final Year Project I

No.	**Detail/ Week**	**1**	**2**	**3**	**4**	**5**	**6**	**7**		**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Selection of the project title entitled : Heavy Load Carrier															
									M							
2	Defined problem and review on papers and statistics gathering								**I** **D**							
3	Conceptual generation								**S**							
									E							
4	Submission of Extended Proposal								**M**							
5	Proposal Defence								**B**							
									R							
6	Advanced papers review and study on invention heavy load carrier								**E** **A**							
									K							
7	Submission of Interim Draft Report															
8	Submission of Interim Report															

Table9: Milestone for Final Year Project I

Milestone for Final Year Project II

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Product architecture								M							
2	Arrangement of physical element								I							
3	Submission of Progress Report 1								D							
4	Configuration Design															
5	Preliminary selection of material								S							
6	AutoCAD modelling of design concept								E							
7	Submission of Progress Report 2								M							
8	Sizing and dimensioning of the part															
9	Parametric and detail design								B							
10	Simulation and Analysis								R							
11	Poster Exhibition								E							
12	Submission of Dissertation Final Draft								A							
13	Oral Presentation								K							
14	Submission of Dissertation (hard bound)															

Table 10: Milestone for Final Year Project II

CHAPTER 5: CONCLUSION

Heavy load carrier is a mechanism that can be used to assist worker in performing basis daily work. It is crucial to reduce the cost of manufacturing the heavy load carrier in order to ensure the market prince is affordable by any people. In order to make sure the heavy load is suitable for multi terrain adjustable frame and multi-phase method of handling the carrier had being propose. As the conclusion, the usage of back-packing method and trolley method can be enhance and improve by designing a mechanism which suitable to carried out the job.

After the modelling and simulation of the heavy load carrier, it is purpose to improve the design:

a) Propose the material selection of heavyload carrier

b) Propose the design concept of heavy load carrier

c) Conduct cost estimation for the propose design concept

b) Propose and define the manufacturing method in the model properly

CHAPTER 6: REFERENCE

1. USA patent ,3872118; Shozo Takagi ,no 6-4, 6-chome, Yamamoto –cho-minami,-yaoshi, Osaka Japan; Manual Carrier design

2. USA patent 3998476; Eugene Anthony Kazmark,Sr.,5 Remin Lane , Joilet ,III 60433- Portable Luggage Carrier with Telescoping Handle Design

3. USA patent 3734366; Thomas E. Wood , 3863 42nd N.E Seattle ,wash 98205 – Frame Pack Design

4. Design For All; A Publication of Design for All institute of India (August 2011vol6,no.8) - Core77 Taps $7 Carryall As Year's Best Product Design by VikramDinubahiPanchal ; Load Carrier for Labour

5. IdsartKingma (2003); Effect of design of two-wheeled containers on mechanical loading

6. Shanell L. Colclough (2010) ; The Effects of Load Distribution and Gradient on Load Carriage

7. B.Schibye, K.sogaard, D.Martinsen, K.Klausen- Mechanical load on the low back and shoulder during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins

8. The Ergonomics of Manual Material Handling- Pushing and Pulling Tasks

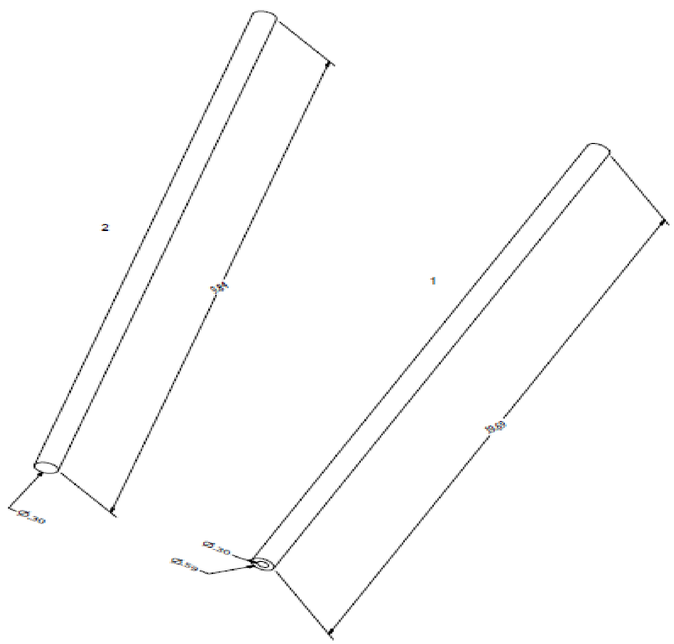
9. J.HumanErgol ..33:55-59,2004 – The effect of the load mass and load position on body way in supporting the load on the back

10. The Effect Of Load Carriage On Normal Standing In Man By D.P. Thomas; Medical Research Council Unit For Research On Climate And Working Efficiency , Department Of Human Anatomy University Of Oxford ,

11. Pushing and pulling in association with low back and shoulder complaints by M J M Hoozemans,A J van der Beek, M H W Frings-Dresen, L H V van der Woude,F J H van Dijk (March 12, 2002);

12. AK Steel; 304/304L Stainless Steel Data Sheet

APPENDIX



DRAWN Bakhtiar — 8/16/2012
CHECKED
QA
MFG
APPROVED

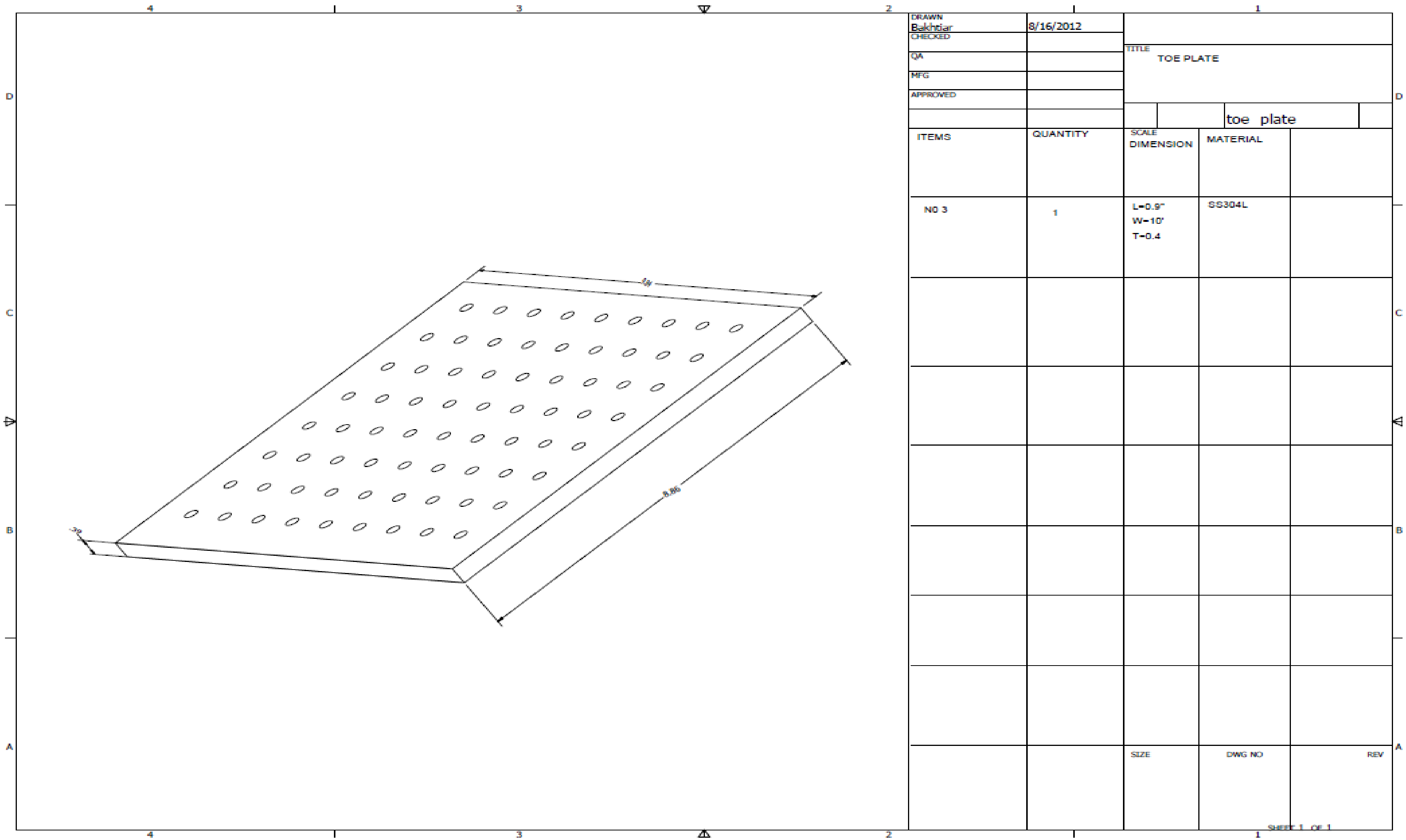
TITLE
1) FRAME SIDE HOLLOW ROD
2)FRAME JOIN ROD

rod silang n tepi

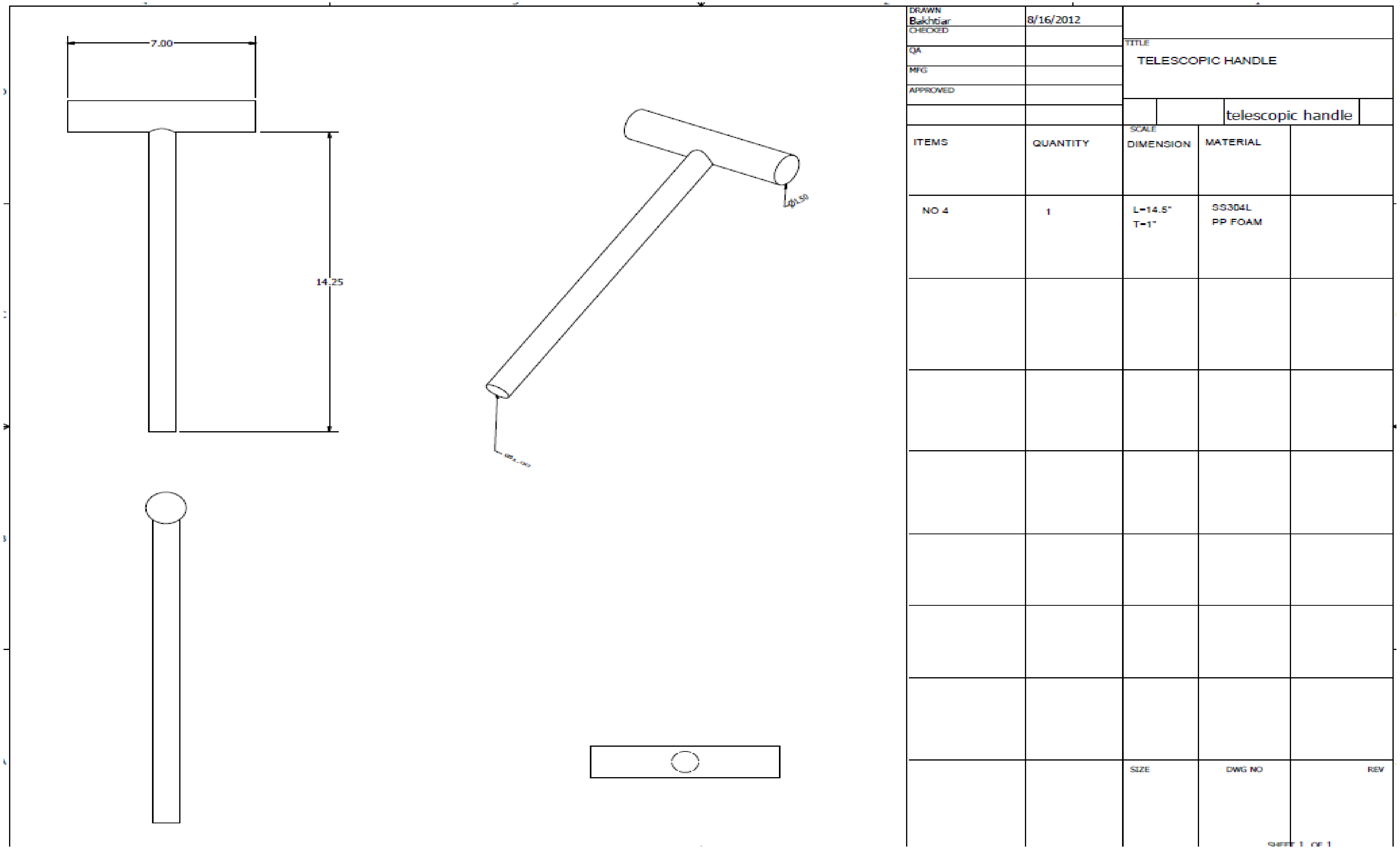
ITEMS	QUANTITY	SCALE DIMENSION	MATERIAL	REMARKS
NO 1	2	L=20" ID=0.3" OD=0.6"	SS 304 L	
NO 2	4	L=10" D=0.3	SS304L	

SIZE DWG NO REV
SHEET 1 OF 1

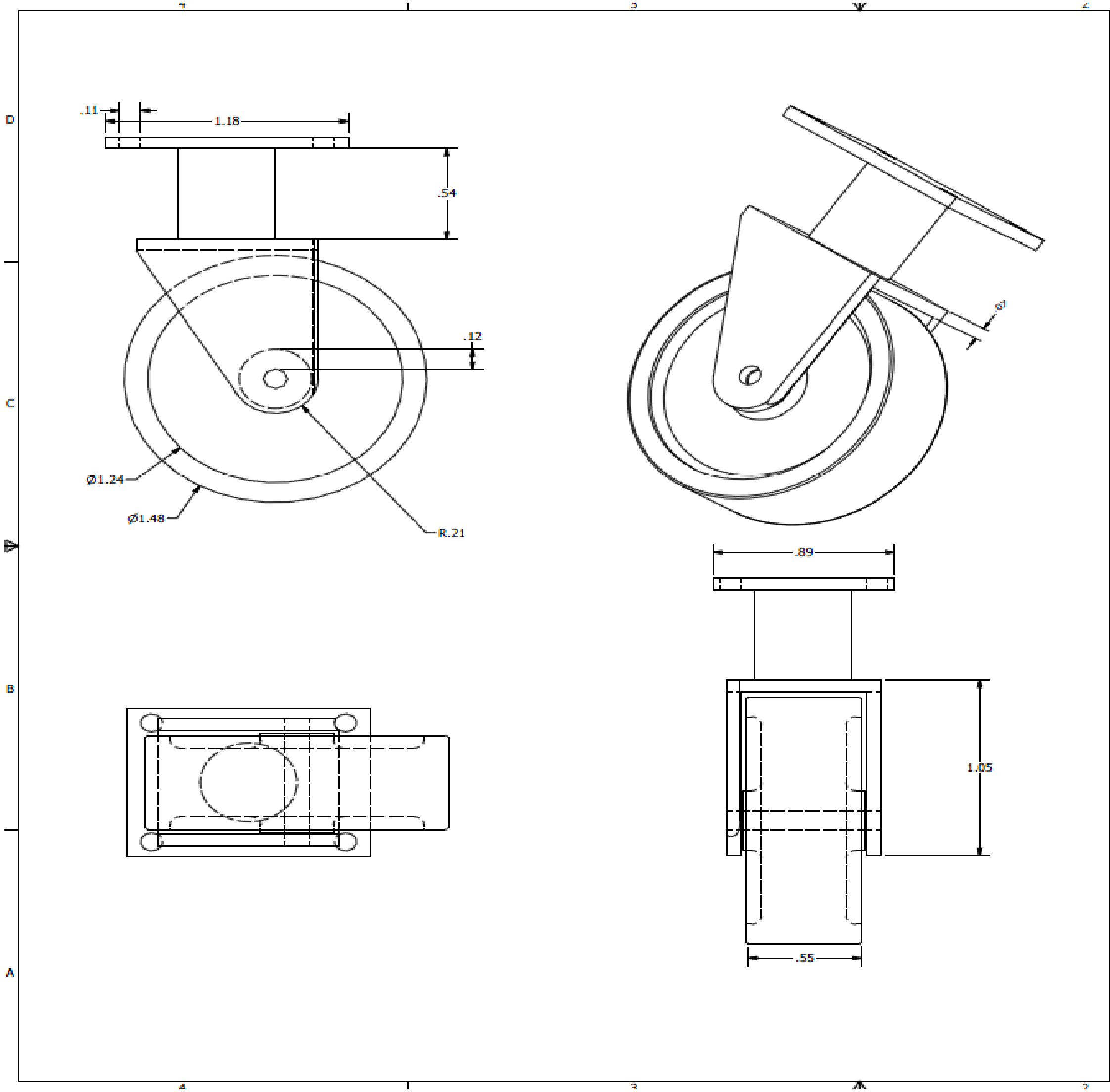
Frame side hollow rod and frame join rod


DRAWN
Bakhtiar
8/16/2012
CHECKED
QA
MFG
APPROVED
TITLE
TOE PLATE
toe plate
ITEMS
QUANTITY
SCALE
DIMENSION
MATERIAL
N0 3
1
L=0.9"
W=10'
T=0.4
SS304L
SIZE
DWG NO
REV
SHEET 1 OF 1
8.86

Toe plate



Telescopic handle



DRAWN Bakhtiar	8/16/2012
CHECKED	
QA	
MFG	
APPROVED	

TITLE: BACK SWINDLE CASTOR

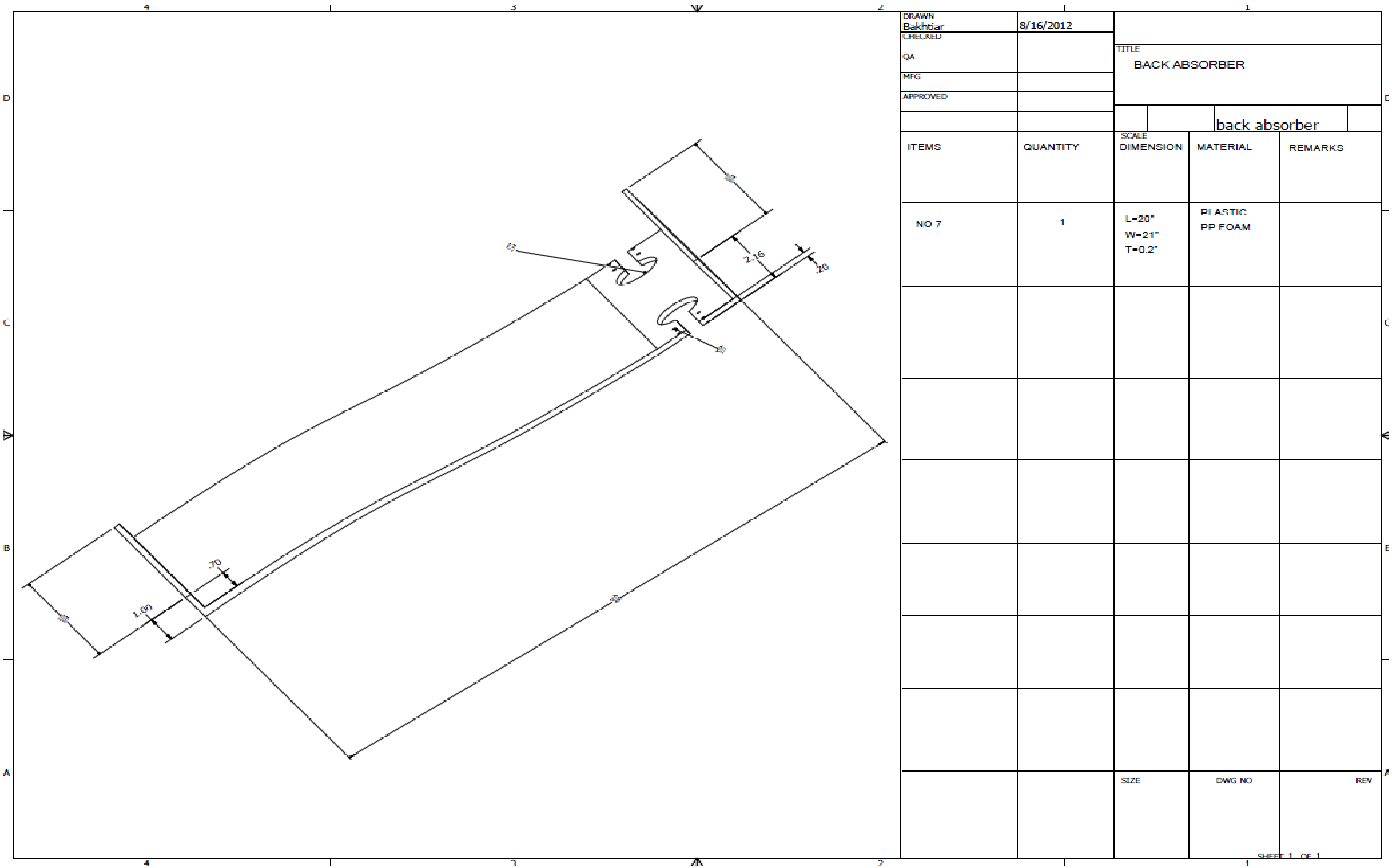
tayar kecik

ITEMS	QUANTITY	SCALE DIMENSION	MATERIAL	
NO 5	2	D=1.5" T=0.6"	SS304 L	

SIZE | DWG NO | REV

SHEET 1 OF 1

Back swindle castor



Back absorber