Case 5: Load Carrying Device

Team members: Vedika Y. Kulkarni

Introduction

I have decided to take up the problem of load-carrying materials such as cement in the construction industry. For this project, I have researched multiple types of load-carrying devices used in the labour industry, the farming industry and even those used in homes. I also researched biomechanics and awkward positions, also why previous load-carrying devices had failed. After researching these topics, I found the core summary points which, I thought, were not addressed in the previous designs. Due to COVID restrictions, my interactions with the labourers were limited but I tried to make up for that by speaking to people who worked on previous designs in the report. Keeping the summary points in mind, I conceptualized a basic holder for the metal containers used in construction work. I have not been able to test the prototype as of yet due to inaccessibility to building materials.

Problem Statement Development

Chaitan Sir gave us multiple parameters to judge our problem statements on. At the beginning of class, the problem statement we came up with was:

“How to make load carrying easier for a versatile set of people at low cost and equivalent efficiency?”

<table>
<thead>
<tr>
<th>Goal</th>
<th>The goal is to make carrying the tagari easier for labourers.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gap</td>
<td>The gap was that the tagari, along with the material in it, isn’t safe to be carried on the head.</td>
</tr>
<tr>
<td>Quantifiable</td>
<td>The mass carried by the labourer and the time taken to transport the tagari along with the material in it.</td>
</tr>
<tr>
<td>Neutral :</td>
<td>It is neutral considering the user persona is the labour. And possible ways of tackling the problem, and possible ways of solving the problem could all be addressed.</td>
</tr>
<tr>
<td>Narrow :</td>
<td>Load-carrying devices have been done before, and this is not a revolutionary problem. But targeting the labour and choosing one or two types of load, makes the problem statement narrow enough.</td>
</tr>
</tbody>
</table>

By the process of constantly redefining and judging our statement, we came up with

“How to reduce physical strain caused to labourers by the manual carriage of tagari on their head?”

Mind Map
Problem Specific Research

User Research
(Secondary Research after talking to Mr Soumil Panwar)\(^2\)

Physiological

- Load lifting on the head leads to acute pain in the neck, shoulder, and back
- High incidence of finger injuries amongst workers from lifting activities
- Labourers collapse due to heat and lack of water
- Observed incidence of headaches among excavation workers
- Significant incidence of arthritis and various other conditions in the bones and joints
- Faster ageing among construction workers
- High incidence of early deaths
- Elderly in the industry have been found to have weak musculoskeletal structures

Mental

- Lack of ambition or will to grow
- High incidence of social ills like alcoholism and gambling
- Hopelessness among older workers

Family

- Children on sites do not go to school while the workers are working
- High incidence of children engaging in labour work from early ages
- Entire families get involved in the same industry instead of aiming for growth
- Lack of sanitation and housing infrastructure leads to poor family lives

Systemic

- Suppression of unionisation leads to lack of labour law enforcement
- Corruption among government safety inspectors leads to worsening conditions
- Lack of training to labourers leads to bad working practices
- Improper working tools provided for cost-cutting leads to accidents
Stakeholder Analysis

The stakeholders are:

1. Labourer: The primary stakeholder would be the labourer. A better tagari handle would facilitate their work and help in reducing strain on their bodies while the work is in progress.

2. The Family of the labourer: The labourer is bonded emotionally with his/her family. They take a personal interest in the well being of the labourer and will be impacted directly by any problems the labourer may face.

3. Co-workers: The labourer has a kinship with his/ her co-workers. They boost each other’s morale and help and support each other.

4. The Labour Contractor: The labour contractor is the direct superior of the labourer. They will impact and be impacted by the quality of the labourer's work and be the one who decides the wages and when to pay them. They also handle holidays and sick leaves.

5. The Main Contractor: This is a secondary stakeholder who is impacted by the performance of all the labourers involved in the construction of that particular site. This stakeholder impacts the behaviour of the labour contractor with the labourers by giving time pressure and managing the accounts.

6. The Building Firms: Another secondary stakeholder, the building firms pay for the construction and set construction deadlines.

7. The Customer (people who purchase flats): These are the tertiary stakeholders who pay for houses/shops to the building firm and the building firm delivers those facilities to them.

Primary Research

As a part of the primary research, I looked up patents on available load-carrying devices to get an idea of what was already available and if the solutions had failed, why. I also started researching the ergonomics of load-carrying and the impact of gender difference, which I have detailed out.
Ergonomics

Ergonomics is a vast topic but we have tried as much as possible to condense it to what is relevant to the problem. Benefits of good ergonomics in industries:

- Reduce ill-health
- Improve productivity
- Reduce ergonomic risks resulting from repetitive or manual handling tasks
- Ensure tasks are conducted in the easiest way possible

A major health problem that occurs to those working in labour sectors could be MSD. The following research is based on what causes MSD and the possible ways of tackling this issue.

The following images are designed to highlight the effect that awkward postures have on muscle activity for the wrist, elbow, shoulder, and lower back.

Awkward Postures
Risk factors related to work activity and ergonomics can make it more difficult to maintain this balance. The major workplace ergonomic risk factors to consider are:

- **Forceful Exertions**: Many work tasks require high force loads on the human body. Muscle effort increases in response to high force requirements, increasing associated fatigue which can lead to MSD. Eliminating excessive force requirements will reduce worker fatigue and the risk of MSD formation in most workers. Using mechanical assists, counterbalance systems, adjustable height lift tables and workstations, powered equipment and ergonomic tools will reduce work effort and muscle exertions. Work process improvements such as using carts and dollies to reduce lifting and carrying demands, sliding objects instead of carrying or lifting, and eliminating any reaching obstruction to reduce the lever arm required to lift the object. Workers should be trained to use proper lifting and work techniques to reduce force requirements.

- **Repetitive/Sustained Awkward Postures**: Awkward postures place excessive force on joints and overload the muscles and tendons around the
affected joint. Joints of the body are most efficient when they operate closest to the mid-range motion of
the joint. Risk of MSD is increased when joints are worked outside of this mid-range repetitively or for sustained periods of time without adequate recovery time.

Eliminate or reduce awkward postures with ergonomic modifications that seek to maintain joint range of motion to accomplish work tasks within the mid-range of motion positions for vulnerable joints. Proper ergonomic tools should be utilized that allow workers to maintain optimal joint positions.

Work procedures that consider and reduce awkward postures should be implemented. In addition, workers should be trained on proper work technique and encouraged to accept their responsibility to use their body properly and to avoid awkward postures whenever possible.

* High Task Repetition: Many work tasks and cycles are repetitive in nature, and are frequently controlled by hourly or daily production targets and work processes. High task repetition, when combined with other risk factors such as high force and/or awkward postures, can contribute to the formation of MSD. A job is considered highly repetitive if the cycle time is 30 seconds or less.

Eliminating excessive force and awkward posture requirements will reduce worker fatigue and allow high repetition tasks to be performed without a significant increase in MSD risk for most workers.

Providing safe & effective procedures for completing work tasks can reduce MSD risk. In addition, workers should be trained on proper work technique and encouraged to accept their responsibilities for MSD prevention.

A lot of these solutions focus on training workers but a lot of the times the workers don’t want to adapt, due to which a lot of well intentioned programs fail. Therefore, apart from building a device for workers safety:

* Management needs to commit to worker safety too
• Workers’ attitudes towards safety and compliance to safety norms needs to be observed
• If there is a negative attitude towards safety, it needs to be changed and the right attitude needs to be enforced.  

An ergonomics intervention may look great on the drawing board, it may be rendered ineffective if employees choose to perform the wrong behaviors. A powerful tool for getting employees to voluntarily, willingly, and enthusiastically execute desired behaviors is a behavioral based safety process.  

**Gender Difference**

In this section, we would like to specify how men and women experience the workplace environment differently.

- 96% of the women workforce in India is in the unorganised sector and 30% of the labour force.  
- They are two times more susceptible to musculoskeletal disorders due to the fact that most labour equipment is developed keeping men in mind, making the equipment harder to use. Apart from that, women handle the households and children, putting more strain on their bodies.  
- Women in construction are more likely to be exploited and such stress puts even more strain on their bodies.  
- Women are more likely to have manual carriage jobs (unskilled labour) making them prone to chronic back and knee problems.  
- Women have different body dimensions as compared to men, and most equipment is not suited for that.  

There is a clear need to address the problems faced by women labourers, but we don’t have a solution yet.

**Prior solutions**

<table>
<thead>
<tr>
<th>Design</th>
<th>Main problems, we think, are the reason these designs failed</th>
<th>Images</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>Description</td>
<td>Details</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Load carrying device&lt;br /&gt;The device carries the load directly on the head and can be overloaded, which still can cause headaches and spinal problems</td>
<td><img src="image1.jpg" alt="Diagram" /></td>
</tr>
<tr>
<td>2</td>
<td>Load carrying protection of women&lt;br /&gt;This device is for comfort while load carrying and isn’t for actual load carrying</td>
<td><img src="image2.jpg" alt="Diagram" /></td>
</tr>
<tr>
<td>3</td>
<td>Load Carrying Device for Bricks By: Rohit, Anshuman, Ankit and Ajay - 2018&lt;br /&gt;This device fails as it can’t prevent overloading. It takes up too much space and therefore climbing with it is hard. It was also not widely acceptable to the labour</td>
<td><img src="image3.jpg" alt="Image" /></td>
</tr>
<tr>
<td>4</td>
<td>LOAD CARRYING DEVICE&lt;br /&gt;Aniket Singh, Arpit Kabra, Chintan Mehta and Rashi Jain&lt;br /&gt;May 2016&lt;br /&gt;Too complex to use, too many moving parts. Overloading can’t be prevented. Shoulder width needs to be adjustable for men and women</td>
<td><img src="image4.jpg" alt="Image" /></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Loading and Unloading was troublesome.</td>
</tr>
<tr>
<td>---</td>
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</tr>
<tr>
<td>5.</td>
<td>Improvised Load Bearing Device by Sreenath Mallela, Sai Sidharth</td>
<td>The width has to be adjustable for women. Overloading can't be prevented which may cause failure of device. Hard to load and unload just by self.</td>
</tr>
<tr>
<td>7.</td>
<td>Device for carrying Gas Cylinders</td>
<td>Can promote wrong posture</td>
</tr>
<tr>
<td></td>
<td>Description</td>
<td>Details</td>
</tr>
<tr>
<td>---</td>
<td>----------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>8.</td>
<td>Load carrying</td>
<td>Back load carrying is more preferable than front. Restrictions mobility somewhat.</td>
</tr>
<tr>
<td>9.</td>
<td>Load carrying device for bucket shaped objects</td>
<td>Carrying materials up the stairs will be a task. Takes up space. Can be adjusted to size restrictions.</td>
</tr>
<tr>
<td>11</td>
<td>Belt clip for paint containers</td>
<td>Very small loads. Most load carried on the hip which is not ideal.</td>
</tr>
</tbody>
</table>
Design Requirements And Summary Statements

Based on a thorough review of previous load carrying solutions, I noted down core and preliminary design requirements

| 12   | Carry strap[^24] | Specific to buckets
Can slip
Load centered to be carried by hand, thus can’t be very heavy. |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>Soumil Panwar’s Thesis[^26]</td>
<td>Mr. Soumil Panwar made multiple prototypes for solving the problem of load carrying in construction. We added the images for the ones we found most relevant to our problem.</td>
</tr>
</tbody>
</table>
1. The design should have a firm grip
2. It should be cheap enough that the labourers can afford it and the contractors will be willing to buy it
3. **The design shouldn’t add to the weight of the load**
4. It should be easy to load and unload: loading and unloading without bending or detaching the device from the body
5. The device should be such that the user can unload without the help of a second person
6. Design should be adaptable with materials that are available locally
7. Materials used should be able to hold the load and not bend or break
8. The device should be able to carry a weight of at least 25kg
9. The design should not take up space
10. The design should not restrict movement or cause injury while in use
11. The design should be more efficient than the previous way of load carrying
12. Design should be adaptable to any weather/terrain
13. Design should be incremental in a way that it is intuitive to the workers
14. **Should prevent awkward hand positions and postures (specified previously)**
15. **Should ideally distribute load on shoulders if the load is very heavy**
16. Design should be adjustable at shoulder and waist support so that both men and women can use it
17. Design should have a height such that it should be usable by people of all ages and frames
18. **Weight should preferably be kept away from the head**
19. **Turning and climbing on stairs should not be restrictive due to the device**

**Summary statements**

Overloading: Oftentimes, I have observed that labourers tend to overload the given device beyond its capacity. For example, if a back or shoulder-based load distribution device is overloaded, the frame of the person bends and the load is applied on the hips instead which is still dangerous.

Labour acceptance: Some of the devices looked amazing on paper but the labour refused to adapt these devices as they were a take away from what they are used to. Another reason was that some labourers weren’t very interested in the safety
provided by the new designs. For this purpose, an incremental device needs to be built that is intuitive to the labourers. This can be accomplished by doing multiple iterations of a device and also incentivising labour safety.

Implications of gender: As mentioned elsewhere, women are twice as likely to get musculoskeletal disorders as compared to men. This is even more prevalent in physical labour as biologically, men can apply more force for a task than women can. So, women end up over-exerting themselves while using tools meant for men. They also end up doing most of the manual carriage jobs in construction. Moreover, some devices that I had found during the prior art search did not have adjustable shoulder/waist bands, making them unsuitable for women’s use.

**Designing and Prototyping**

**Design Process**

I wanted to design a device that was easily adaptable to a construction environment and incremental to the objects workers already used. As I did my research, I realized that some of the solutions were actually pretty good, and can be made better and more adaptable for the user (the labourers). For this reason, I shortlisted two solutions that could be incremented in some way, but also matched the criterias I had set.

They were:

<table>
<thead>
<tr>
<th>PROTOTYPE 1</th>
<th>PROTOTYPE 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Prototype 1" /></td>
<td><img src="image2.png" alt="Prototype 3" /></td>
</tr>
</tbody>
</table>
| **Addition of a handle to the traditional tagari:**  
  - Easier/Faster Passing of material  
  - Weight is kept away from the head  
  - Less vertical lifting of load  
| **A cloth bag that is held on the back with two straps:**  
  - Easier/Faster Passing of material  
  - Weight is kept away from the head  
  - Weight is distributed on the back, shoulder and hands  |

I contacted the designer of these devices, Mr. Soumil Panwar[^26], and he gave me inputs on both of these designs. He said the main problem with the load transfer bag was that workers felt
awkward being in such close proximity and that the bag tore when he tried to test it on site. About the tagari holder, he said that the concept was to shift the load of the tagari (which is traditionally carried on the head) and make material transport more efficient. Ultimately, I decided to go with the tagari handle.

Features of the tagari

<table>
<thead>
<tr>
<th>Size</th>
<th>16 inch, 14 inch, 18 inch, 20 inch, 22 inch, 24 inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Galvanized Iron</td>
</tr>
<tr>
<td>Colour</td>
<td>Silver</td>
</tr>
<tr>
<td>Shape</td>
<td>Round</td>
</tr>
<tr>
<td>Weight (approx)</td>
<td>840gm</td>
</tr>
</tbody>
</table>

Design Decisions

I wanted to work on two facets that I found absent in the old design:

1. Making the design more accommodating to the user capabilities
2. Making sure that the user remained in a natural posture while using the device, ideally using both hands to lift the device.

I felt that in the old tagari handle model, the user will have to place their forearm at an angle with their arm, and constantly carrying the device will tire their arms. Loads carried with just one arm put strain on the spine. So, I wanted to solve this issue and design an alternative to solve this problem.

Material Specifications for the model

<table>
<thead>
<tr>
<th>Use</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handle</td>
<td>Bamboo/ Rubber/ Cotton Cloth</td>
</tr>
<tr>
<td>Frame</td>
<td>Steel Rods/ Basalt Raber/ Fiberglass</td>
</tr>
</tbody>
</table>

Comparative analysis of materials used for the handle

<table>
<thead>
<tr>
<th>Property</th>
<th>Bamboo</th>
<th>Vulcanized Rubber</th>
<th>Cotton Cloth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property</td>
<td>Steel</td>
<td>Fiberglass$^1$</td>
<td></td>
</tr>
<tr>
<td>------------------------</td>
<td>----------------</td>
<td>---------------</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>Rs.150/Kg</td>
<td>Rs.250-650 (depending on composition)</td>
<td></td>
</tr>
<tr>
<td>Tensile strength</td>
<td>420MPa</td>
<td>300-320GPa</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>8.04 g/cc</td>
<td>2 g/cc</td>
<td></td>
</tr>
<tr>
<td>Brinell Hardness</td>
<td>121</td>
<td>31.5-47</td>
<td></td>
</tr>
<tr>
<td>Compression Strength</td>
<td>250MPa</td>
<td>900-1000 MPa</td>
<td></td>
</tr>
</tbody>
</table>

I have listed materials that can possibly be used in the final version. I intend to do more detailed research on materials once I have gone through multiple iterations of prototyping and field testing for this device. CAD Model
Beam: Intended to be held either with one or both hands to carry the device. Upper and lower halves: These parts have been designed separately so that the labourer can adjust the device according to their load-carrying capacity. This distinction also makes it harder for the device to be misused.

Hook: the hook has been designed so that the lower half can be attached to the upper half.

Metal rings: The Tagari comes in various diameters. The ring diameter is chosen such that most of them can be carried using the device. Height has been adjusted accordingly too.

**Possible Problems**

The possible problems with my design are:

1. When held and used, the device may cause injury to the knee and thigh of the user.
2. The device might not be very effective and tire the user if he/she tries to climb stairs with both the top and lower half in use.
3. With the addition of the lower half, the design may be too much in height or become unsteady.

**Future Scope**

- I would like to make field visits and get a better idea of how my product does and how feasible it is in that environment
- Available construction can be researched in detail to develop the best version of this design
- Making the product so that the labourers can recreate it on their own with whatever material they have. **Acknowledgements**

I would like to thank Prof. Anil Gupta for his valuable inputs throughout the development of the project. This project would have been incomplete without the help of Mr. Soumil Panwar who very generously took out the time to help me with the prior art search. I would also like to thank my peers Mr Musaiyab Ali Mirza, Mr Ananay Garg and Mr Diptanshu Mistry for contributing their valuable time and energy to helping me develop the CAD design and giving their valuable design inputs.

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