International Journal of Advance and Applied Research
www.ijaar.co.in
ISSN – 2347-7075 Impact Factor – 7.328
Peer Reviewed Bi-Monthly
Vol. 11 No. 5 May-June 2024

Design and Analysis of Robust Portable Wheel Chair Ramp

Santosh Shivraj Gulave[1], **Dr. Atul Shripad Aradhye**[2]
[1]M.Tech. Mechanical (Design) Engineering
[2]Assistant Professor, Department of Mechanical Engineering, SKN Sinhgad College of Engineering, Korti, Pandharpur
Corresponding Author: Santosh Shivraj Gulave
Email: santoshgulave220974@gmail.com

DOI-10.5281/zenodo.12233298

Abstract:

In the pursuit of enhancing mobility and accessibility for individuals with mobility challenges, the design of a portable wheelchair ramp becomes paramount. This study delves into the intricate aspects of crafting a robust and user-centric portable wheelchair ramp, aiming to empower users with confidence and independence in navigating various elevations. Key design parameters crucial for wheelchair users are meticulously examined and integrated into the development process. Leveraging the capabilities of ANSYS software, comprehensive analyses are conducted to ensure structural integrity and performance optimization. Through Design of Experiment methodologies, response parameters are meticulously tabulated, providing invaluable insights into the ramp's behavior under different conditions. To facilitate the creation of tailored solutions, a smart design tool is engineered within the framework of mass customization. This tool empowers potential customers to customize their portable ramp according to their specific needs and preferences, fostering inclusivity and user-centric design principles. The optimization journey is further enriched by employing Multi-Criteria Decision-Making (MCDM) tools. By leveraging Overall Design Criteria and corroborating findings with TOPSIS, the most effective design configuration is discerned. Notably, a 15 mm thickness with three support structure emerges as the optimized solution, validated through rigorous analysis and comparison. In essence, this holistic approach amalgamates engineering precision with user-centric design, culminating in the creation of portable wheelchair ramps that transcend mere functionality, offering individuals with mobility challenges new found freedom and independence.

Introduction:

Designing a robust portable wheelchair ramp involves creating a solution that combines durability, ease of use, safety, and adaptability to various environments. A well-engineered portable wheelchair ramp must cater to the needs of individuals with mobility challenges, ensuring they can navigate different elevations with confidence and independence. This introduction outlines the key considerations and design principles essential for developing a high-quality, reliable, and user-friendly portable wheelchair ramp. By integrating these considerations and principles, the design of a robust portable wheelchair ramp can significantly enhance mobility and accessibility, empowering users with greater freedom and independence. This study presents design parameters of portable wheelchair ramps, which are important for wheelchair users, and creates a smart design tool that helps potential customers to design a portable ramp within the mass customization concept.

Wheelchair users try to reach a wide range and a large number of destinations in their daily lives, such as banks, stores, religious buildings, workplaces, friends' and relatives' homes, and health professionals' offices. As they try to reach their destinations, wheelchair users encounter many different barriers like curbs, lack of ramps or ramps that are too steep, There are many kinds and different brands of portable ramps in the world market This study presents design parameters of portable wheelchair ramps, which are important for wheelchair users, and creates a smart design tool that helps potential customers to design a portable ramp within the mass customization concept. A wheelchair ramp is an inclined plane installed in addition to or instead of stairs. Ramps permit wheelchair users, as well as people pushing strollers, carts, or other wheeled objects, to more easily access a building, or navigate between areas of different height. Ramps should be 36 inches wide at minimum to accommodate a wheelchair. Ramps should have a running slope no steeper than 1:12, meaning there should be no more than 1 inch of rise for every 12 inches of length. The rise for any ramp run should be 30 inches maximum.

Literature review from previous research:

Many research works have been done in the field of school wooden platform. Following is the literature review of some papers giving more information about their school platform and wheel chair ramp

Arish Ibrahim *et.al* [1] reported that the manual wheel chairs are widely used because of its availability and economic factors. Even if it faces the limitation of accessing curbs and stairs. Some of the advanced electronic wheelchairs having the climbing feature but those wheel chairs are not affordable to common people and not suitable for daily usage in rough terrains. Author proposed a ramp attachment design that makes the normal wheelchair to climb the curbs on the streets and accessing the buildings without ramp facility. The design concept doesn't make any modifications in the basic design of wheelchair as it involves just an attachment of ramp and sliding mechanism. The proposed design can also applicable to shopping carts or any other people transferring devices for meeting the specific needs. Barbara Tewksbury *et.al* [2] focused on a pedagogical approach to geoscience education. Ramp is a teaching method developed by Tewksbury that emphasizes the importance of engaging students in reading scientific literature and exploring real-world geological features, such as mountains, to enhance their understanding of earth science concepts. Phillip G Resor *et.al* [3] focused on a pedagogical approach to geoscience education. Ramp is a teaching method developed by Tewksbury that emphasizes the importance of engaging students in reading scientific literature and exploring real-world geological features, such as mountains, to enhance their understanding of earth science concepts. Jennifer M. Wenner *et.al* [4] outlined the rationale behind adopting ramp, in her teaching practices, highlighting the benefits it offers in terms of promoting active learning, critical thinking, and the application of theoretical knowledge to real-world geological scenarios. She might describe specific instructional strategies and activities used to incorporate ramp into her courses, such as guided reading assignments, field trips, and hands-on investigations. Author discussed the outcomes and impacts of using ramp in the classroom, including its effects on student engagement, comprehension of geological concepts, and development of scientific skills.

Research Methodology:

The methodology for the robust design of an optimized school platform is designed to be systematic, comprehensive, and iterative, encompassing various phases from initial research to final validation. This approach ensures the creation of a school platform that not only meets but exceeds the needs and expectations of users.

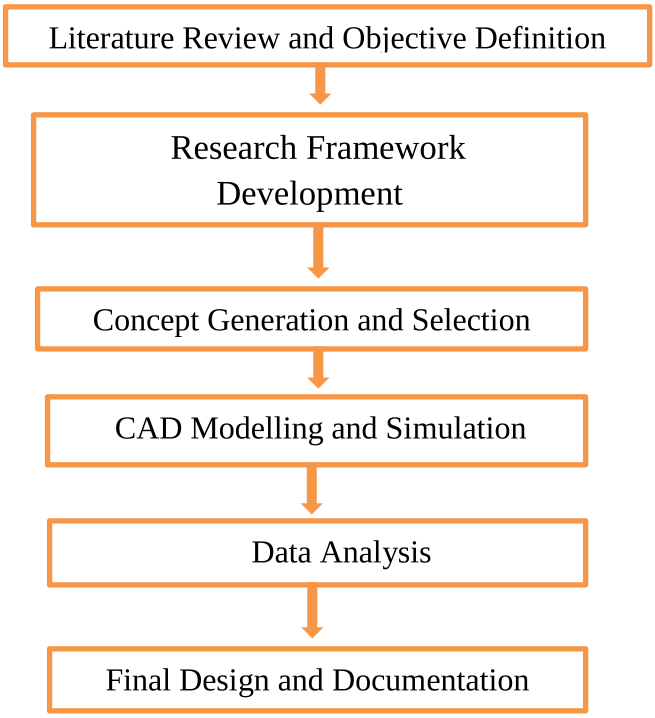


Fig. Number

- **Literature Review and Objective Definition:**
  A thorough literature review is conducted to understand existing designs, materials, and considerations in wheelchair ramp construction. The main objectives for the present work are defined based on gaps identified in the literature and the desired outcomes for the new ramp design.
- **Research Framework Development:**
  A research framework is developed to guide the entire design process. This framework outlines key stages, methodologies, and deliverables.
- **Concept Generation and Selection:**
  Multiple design concepts are generated through brainstorming sessions, considering

factors such as usability, portability, durability, and accessibility. These concepts are evaluated against predetermined criteria to select the most promising design direction.

CAD Modeling and Simulation:

The selected design concept is translated into detailed CAD models, considering all relevant dimensions and features. Finite Element Analysis (FEA) simulations are performed using ANSYS software to assess structural integrity, load-bearing capacity, and overall performance under various conditions.

Experimental work:

To study the impact of different parameters on wooden platform design, a variety of techniques have been employed. These methods are elaborated upon in the subsequent point concerning the design of experiments (DOE). The capability of DOE aids in process improvement by effectively screening factors to discern those crucial for elucidating process variation. Once these factors are identified, suitable tools facilitate comprehension of their interactions and influence on the design process. Subsequently, DOE can determine the optimal factor settings that yield the most effective design.

Design of Experiment:

Carefully planned experiments yield considerably more information and frequently demand fewer iterations compared to unplanned ones. Moreover, a meticulously designed experiment guarantees thorough evaluation of the identified important effects.

Factors:

In this experimentation, factors are categorized into two groups: controllable and uncontrollable. The controllable factors include the thickness of the material and the number of central supports. The thickness of the material is varied from 12 mm to 25 mm, while the number of central supports encompasses four values ranging from none to three internal supports. . Accordingly, set the levels of the controllable variables:

Thickness of Material : [12, 15, 18, 25]
Number of Central Support : [0, 1, 2, 3]

Table Number 1

Ex. No.	Material thickness	Number of supports
1	12	0
2	12	1
3	12	2
4	12	3
5	15	0
6	15	1
7	15	2
8	15	3
9	19	0
10	19	1
11	19	2
12	19	3
13	25	0
14	25	1
15	25	2
16	25	3

Response Parameters:

With two controllable factors each having four levels, a total of 16 experiments are conducted, falling within the feasible range for a full factorial design. Models are constructed using Computer-Aided Design (CAD), and the resulting response parameters are documented as outputs. The response parameters are as below.

- Maximum Principal Stress
- Von-Misses or Equivalent Principal Stress
- Maximum Deformation
- Average Deformation
- Cost

The response parameters for all the experiments are recorded in the following table number 2

Table Number- 2 Experimental Reading

Ex. No	Max Principle Stress (N/Mm^2)	Equivalent Principle Stress (Pa)	Max. Deflection	Avg. Deformation	Cost
1	26043000	2550000000	0.974	0.039	2160
2	22789000	2250000000	0.924	0.035	2160
3	19636000	1890000000	0.916	0.031	2200
4	16282000	1590000000	0.918	0.02	2250
5	25502000	2500000000	0.874	0.029	2450
6	22670000	2220000000	0.824	0.025	2450
7	19839000	1920000000	0.616	0.021	2500
8	17070000	1690000000	0.418	0.01	2550
9	24020000	20037000	0.774	0.019	3280
10	21337000	1980000000	0.714	0.015	3280
11	18572000	17800000	0.614	0.011	3350
12	16007000	16800000	0.414	0.005	3400
13	22520000	2220000000	0.674	0.09	4300
14	21200000	2100000000	0.514	0.08	4300
15	17000000	1780000000	0.314	0.07	4350
16	14000000	1330000000	0.214	0.03	4400

Optimization:-

Optimization entails identifying the optimal solution from a set of potential options to a given problem. It finds extensive application across various domains such as engineering, economics, and computer science, among others. Optimization aims to either maximize or minimize an objective function while adhering to specific constraints. The objective function represents the quantity to be maximized or minimized, such as profit, efficiency, or cost, while the constraints denote the limitations or conditions within which the optimization occurs. In this scenario, optimization is necessitated by the presence of five factors: maximum principal stress (in N/mm^2), equivalent principal stress (in Pa), maximum deflection (in mm), average deformation (in mm), and cost (in rupees). The goal is to minimize the values of all response parameters. Therefore, an optimization process is essential to achieve this objective.

MCDM, or Multiple Criteria Decision Making, addresses the challenge of decision-making in situations where multiple conflicting criteria must be taken into account. Real-world scenarios often involve balancing various objectives that may conflict with one another. MCDM offers methodologies and techniques to analyze, evaluate, and rank alternatives based on these multiple criteria. Initially, we aim to optimize the decision-making process using Overall Evaluation Criteria (OEC). The determined weightage factors are as follows:

Table Number 3 Weightage

Sr. No	MPS	Deformation	Cost
Case1	33	33	34
Case 2	25	25	50
Case 3	25	50	25
Case 4	50	25	25

Optimization by TOPSIS;

Technique for Order Preference by Similarity to Ideal Solution is a multi-criteria decision-making method used to determine the best alternative from a set of options based on multiple criteria. Here are the steps involved in TOPSIS:

- **Define Criteria and Alternatives**: Identify the criteria (attributes) that will be used to evaluate the alternatives. Also, list the available alternatives that will be compared.
- **Normalize the Decision Matrix**: Normalize the decision matrix to ensure that all criteria are on the same scale and to remove the influence of different measurement units. This is typically done by dividing each value in the matrix by the sum of squares of all values in the same column.
- **Determine Weighted Normalized Decision Matrix**: Assign weights to each criterion based on their relative importance. Multiply each normalized value in the decision matrix by its corresponding weight to obtain the weighted normalized decision matrix.
- **Determine Ideal and Negative-Ideal Solutions**: Identify the ideal solution (best performance for each criterion) and the negative-ideal solution (worst performance for each criterion) by taking the maximum and

minimum values across all alternatives for each criterion, respectively.

- **Calculate the Distance of Each Alternative from the Ideal and Negative-Ideal Solutions**: Calculate the Euclidean distance of each alternative from both the ideal and negative-ideal solutions. This distance represents how similar each alternative is to the ideal or negative-ideal solution for each criterion.
- **Determine the Proximity to the Ideal Solution**: For each alternative, calculate the relative proximity to the ideal solution by dividing the distance to the negative-ideal solution by the sum of distances to both the ideal and negative-ideal solutions.
- **Rank the Alternatives**: Rank the alternatives based on their proximity to the ideal solution. The alternative with the highest proximity value is considered the most preferred solution.
- **Sensitivity Analysis (Optional)**: Conduct sensitivity analysis to assess the robustness of the results by evaluating how changes in criteria weights affect the ranking of alternatives.

By following these steps, TOPSIS provides a systematic approach for decision-making in situations involving multiple criteria and alternatives.

Imperial Case Study;

Now, let's delve into an imperial case study focusing on case1. The significance of imperial case studies lies in their capacity to offer depth, nuance, and context to our comprehension of imperialism and its enduring effects. By honing in on specific cases, researchers can unearth obscured histories, challenge prevailing narratives, and contribute to a more comprehensive understanding of the intricacies of imperialism. For the first case, the weightages are distributed as follows: 50% for Maximum Principal Stress, 25% for Maximum Deformation, and 25% for the remaining factor, which is Cost. The values of Equivalent Principal Stress and Average Deformation exhibit a parallel trend to Maximum Principal Stress and Maximum Deformation, respectively. These normalized Matrix of all response factors—Maximum Principal Stress, Equivalent Principal Stress, and Cost—are tabulated in Table 4

Normalized Matrix:

To remove the influence of different measurement units, the decision matrix is normalized to ensure that all criteria are on the same scale. The same values are tabulated in table number 4

Table Number 4

Ex. No.	Deformation in meter	Equivalent Stress in Pa	Maximum Principle Stress in Pa	Average Deformation	Cost
1	0.344	0.307	0.316	0.237	0.169
2	0.327	0.258	0.277	0.212	0.169
3	0.324	0.217	0.239	0.188	0.172
4	0.325	0.342	0.198	0.121	0.176
5	0.309	0.303	0.310	0.176	0.192
6	0.291	0.262	0.275	0.152	0.192
7	0.218	0.231	0.241	0.127	0.195
8	0.148	0.003	0.207	0.061	0.199
9	0.274	0.270	0.292	0.117	0.256
10	0.252	0.002	0.259	0.091	0.256
11	0.217	0.002	0.226	0.067	0.262
12	0.146	0.303	0.195	0.030	0.266
13	0.238	0.287	0.274	0.546	0.336
14	0.182	0.243	0.258	0.485	0.336
15	0.111	0.182	0.207	0.425	0.340
16	0.076	0.000	0.170	0.182	0.344

Weighted Normalized Decision Matrix:

Each normalized value in the decision matrix is multiplied by its corresponding weight to obtain the weighted normalized decision matrix. The table number 5 reflects the weighted normalized decision matrix.

Table Number 5

Ex. No	Deformation in meter	Maximum Principle Stress in Pa	Cost
1	0.08608	0.1582	0.0422
2	0.08166	0.1385	0.0422
3	0.08096	0.1193	0.0430

4	0.08113	0.0989	0.0440
5	0.07724	0.1549	0.0479
6	0.07283	0.1377	0.0479
7	0.05444	0.1205	0.0489
8	0.03694	0.1037	0.0498
9	0.06840	0.1459	0.0641
10	0.06310	0.1296	0.0641
11	0.05427	0.1128	0.0655
12	0.03659	0.0973	0.0665
13	0.05957	0.1368	0.0841
14	0.04543	0.1288	0.0841
15	0.02775	0.1033	0.0850
16	0.01891	0.0851	0.0860

Ideal and Negative-Ideal Solutions

Table Number 6

Expriment Number	Positive	Negative
1	0.07853	0.02424
2	0.06107	0.03159
3	0.04955	0.04574
4	0.04461	0.06362
5	0.07080	0.02083
6	0.05463	0.03067
7	0.03008	0.05226
8	0.01000	0.07525
9	0.06214	0.02166
10	0.04723	0.03676
11	0.03311	0.05544
12	0.02424	0.07853
13	0.06200	0.03835
14	0.05314	0.05318
15	0.04413	0.08226
16	0.04877	0.10123

Distance of Each Alternative from the Ideal and Negative-Ideal Solutions

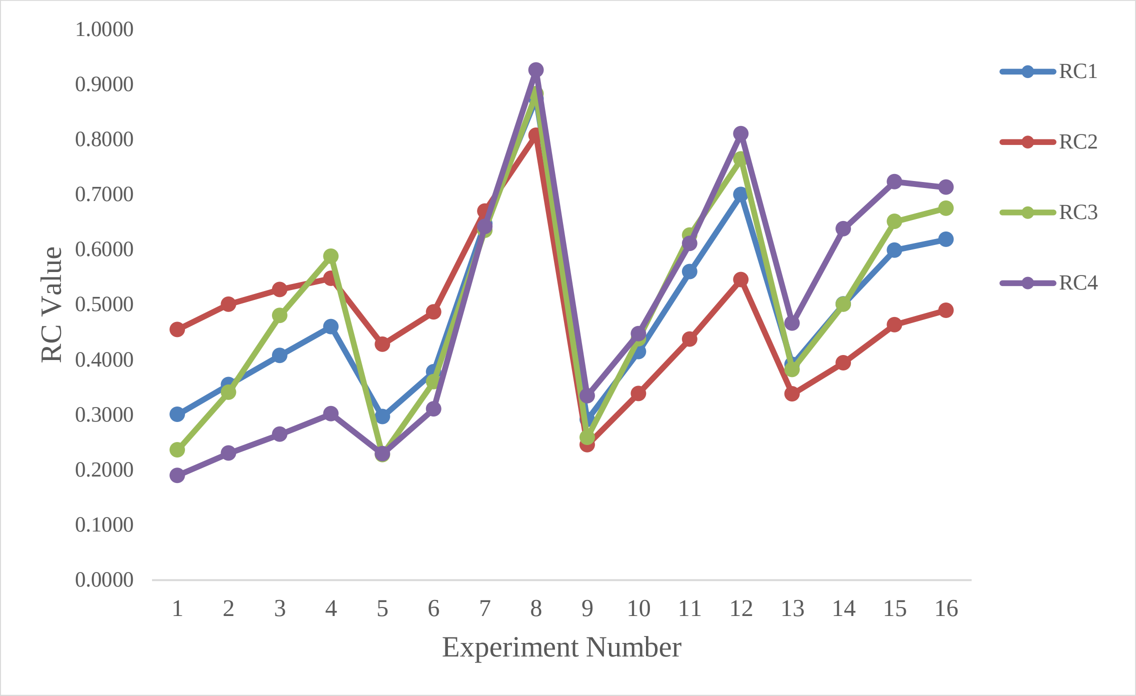
Table Number 7

Expriment Number	Performance Score
1	0.235856552
2	0.340927622
3	0.479991433
4	0.587805376
5	0.227302547
6	0.35956557
7	0.634680782
8	**0.882722125**
9	0.258464235
10	0.437628227
11	0.626070089
12	0.764143448
13	0.382162329
14	0.500201785
15	0.650842715
16	0.674866369

Based on the analysis of the table, Experiment Number 8 (15 mm thick with 3 supports) emerges as the optimal solution for this set of weightages in the TOPSI for this case. A similar procedure is conducted for the subsequent three criteria, and the outcomes are documented in Table Number 8

Table Number 8

Experiment Number	33-33-34	25-25-50	50-25-25	25-50-25
1	0.30	0.45	0.19	0.24
2	0.35	0.50	0.23	0.34
3	0.41	0.53	0.26	0.48
4	0.46	0.55	0.30	0.59
5	0.30	0.43	0.23	0.23
6	0.38	0.49	0.31	0.36
7	0.65	0.67	0.64	0.63
8	**0.87**	**0.81**	**0.93**	**0.88**
9	0.29	0.25	0.33	0.26
10	0.41	0.34	0.45	0.44
11	0.56	0.44	0.61	0.63
12	0.70	0.55	0.81	0.76
13	0.39	0.34	0.47	0.38
14	0.50	0.39	0.64	0.50
15	0.60	0.46	0.72	0.65
16	0.62	0.49	0.71	0.67



Conclusion:

To investigate the influence of controllable variable (thickness of material and number of central supports), CAD is used for modelling. DOE is formulated to find the number of experiments according to the number of controllable variables and its factors. Total 16 experiments has been designed and analyzed to find the response parameters. TOPSIS, one of the best tool of MCDM is used for optimization. The optimized parameters are explained through one in depth imperial case study.

The analysis from Table 8 and figure number 1 reveals that Experiment Number 8 (15 mm thick with 3 supports) emerges as the optimal solution for all cases. The conclusion draws toward Experiment Number 8, suggesting it as the superior solution overall. Experiment Number 8 (i.e. **15 mm thick with 3 supports**) is the best solution

References:

1. Arish Ibrahim , Masters in Industrial Engineering, Teacher in Mechanical Engineering, India 2017 Design and Fabrication of Ramp Attachment for Wheelchair International Journal of Engineering Research and Applications 07.
2. Barbara Tewksbury Hamilton College • Department of Geosciences PhD2019, on-ramps to more effective teaching: quick-start guides to strategies for actively engaging students in the classroom to improve learning, 2019

3. Phillip G Resor Wesleyan University • Department of Earth and Environmental Sciences PHD 2019 on-ramps to more effective teaching: quick-start guides to strategies for actively engaging students in the classroom to improve learning
4. Jennifer M. Wenner University of Wisconsin - Oshkosh | UWOSH • Department of Geology PhD on-ramps to more effective teaching: quick-start guides to strategies for actively engaging students in the classroom to improve learning 2019.