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Mechanical Design of an Integrated Car Swivel Seat with Special Wheelchair for Disabled Drivers and Passengers

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Abstract

The independence of wheelchair users is frequently compromised by the physical challenges and safety risks associated with vehicle ingress and egress. In Malaysia, the high cost and dimensional incompatibility of imported swivel seats with local compact vehicles further exacerbate this issue. This study presents the mechanical design and simulation of an integrated swivel seat system that functions seamlessly as a detachable wheelchair, thereby eliminating the need for strenuous lateral transfers. Adopting a systematic engineering design methodology, the mechanism was optimized for the spatial constraints of common Malaysian vehicles, specifically the Perodua Myvi and Honda Civic. The proposed design features a worm gear mechanism for precise rotational control and dual linear actuators for vertical lifting, ensuring stable and ergonomic operation. SolidWorks simulation and motion analysis were employed to validate the structural integrity of the assembly. Results indicate that the lifting mechanism successfully supports a maximum dynamic load of 110 kg while maintaining smooth, gear-based actuation. This integrated solution offers a cost-effective, localized alternative to existing assistive technologies, significantly enhancing transportation independence for the physically disabled community.

1. Introduction

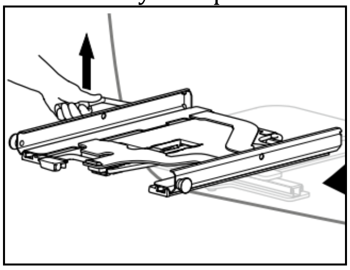
Transportation independence is a fundamental aspect of social inclusion, yet it remains a significant challenge for individuals with physical disabilities. Globally, over 1.3 billion people live with significant disabilities, and a substantial portion relies on wheelchairs for daily mobility [1]. In Malaysia, while official statistics indicate that 1.6% of the population is registered as disabled, the actual need for accessible transportation is likely higher due to an aging population and under-registration [2]. For wheelchair users, the process of entering and exiting a standard vehicle is physically demanding and hazardous. Research into the biomechanics of car transfers indicates that the "sit-to-stand" or "lateral transfer" motions required to enter a vehicle impose high shear forces on the lumbar spine and shoulder joints, leading to a high prevalence of musculoskeletal disorders (MSDs) among both disabled individuals and their caregivers [3, 4].

Standard vehicle seats are not designed to facilitate these transfers. They typically feature contoured bolsters and fixed orientations that create physical barriers, often necessitating caregiver assistance that compromises the user's independence. To address this, various assistive technologies have been introduced. Commercial swivel seat systems, such as the Turny and Carony series, utilize mechanical linkages to rotate and lower the seat out of the vehicle, significantly reducing the physical effort required for ingress [5]. Similarly, patent literature (e.g., US4170368) describes early mechanisms for rotating and sliding seats to bridge the gap between the wheelchair and the car interior [6].

However, a critical review of existing solutions reveals significant barriers to adoption in developing markets like Malaysia. Most commercial swivel seats are imported, resulting in prohibitively high costs that are inaccessible to the average B40 or M40 income groups. Furthermore, these systems are often engineered for larger Western vehicle chassis (SUVs/MPVs) and are frequently incompatible with compact Malaysian vehicles such as the Perodua Myvi or Honda Civic due to limited door frame clearance [7]. Recent local studies have highlighted the urgent need for "frugal innovation" in assistive technology—solutions that are low-cost, mechanically simple, and retrofittable to local car models [8].

Currently, there is a lack of fully integrated systems that combine a wheelchair and a swivel seat into a single, seamless mechanism suitable for compact cars. Most solutions still require the user to transfer from a wheelchair to a separate car seat, which does not eliminate the transfer gap entirely. Table 1 shows the available product in the market.

Table 1 *Available Product in the Market*

Product Name	Turny Manual	Turny Orbit 480	Carony 16
Manufacturer	Braun Ability Europe	Braun Ability Europe	Braun Ability Europe
Picture			
Type	Manual Swivel and sliding seat base	Motorized swivel seat with height adjustment	Seat that can be transferred from a wheelbase to swivel base
Swivel Range	0-97 degrees	0-97 degrees	Depends on what swivel base is used
Capacity	Up to 150 kg	Up to 170 kg	Up to 120 kg
Unit Weight	28 kg	60 kg	35.2 kg
Dimension	L: 47cm; W: 48.7cm; H: 8.1cm	L: 59cm; W: 47.5cm; H: 16.5cm	L: 71cm;W: 64cm; H: 430-570cm
Extension	16 cm	-	-
Vertical Travel	-	48 cm	-
Maintenance	Minimal, with occasional lubrication for moving parts	Minimal, with occasional checks on motor functionality and lubrication	Minimal, with occasional lubrication for moving parts

Therefore, this project aims to bridge this gap by developing a mechanical design for an integrated swivel seat system that functions as both a car seat and a wheelchair. By following George E. Dieter's engineering design methodology and using SolidWorks for kinematic simulation, this study focuses on optimizing the mechanism to meet the spatial constraints of Malaysian hatchbacks. The objective is to provide a safe, ergonomic, and cost-effective mobility solution that enhances independence for disabled individuals in Malaysia.

2. Methodology

This project adopts the engineering design process proposed by George E. Dieter, which provides a structured approach to systematically solving engineering problems. The design process is divided into three main phases: conceptual design, embodiment design, and detail design. In the first phase, conceptual design, four key stages were involved: defining the problem based on user challenges during vehicle entry and exit, gathering information through patent analysis and product benchmarking, generating multiple design concepts, and evaluating those concepts using decision matrices to select the most feasible solution.

The second phase, embodiment design, focused on refining the selected concept by developing the product architecture, configuring component arrangement and interactions, and assigning key parameters such as dimensions and tolerances. This ensured the design could be realistically implemented in vehicles such as hatchbacks and sedans. Finally, the third phase, detail design, involved using SolidWorks to create complete 3D models, exploded views, and technical drawings. Simulations and motion analysis were also conducted to visualize the functionality of the swivel seat and wheelchair integration. By following this systematic methodology, the project ensures that the final design is practical, ergonomic, and aligned with user needs. Fig. 1 shows the flow chart of the design process introduced by George E. Dieter.

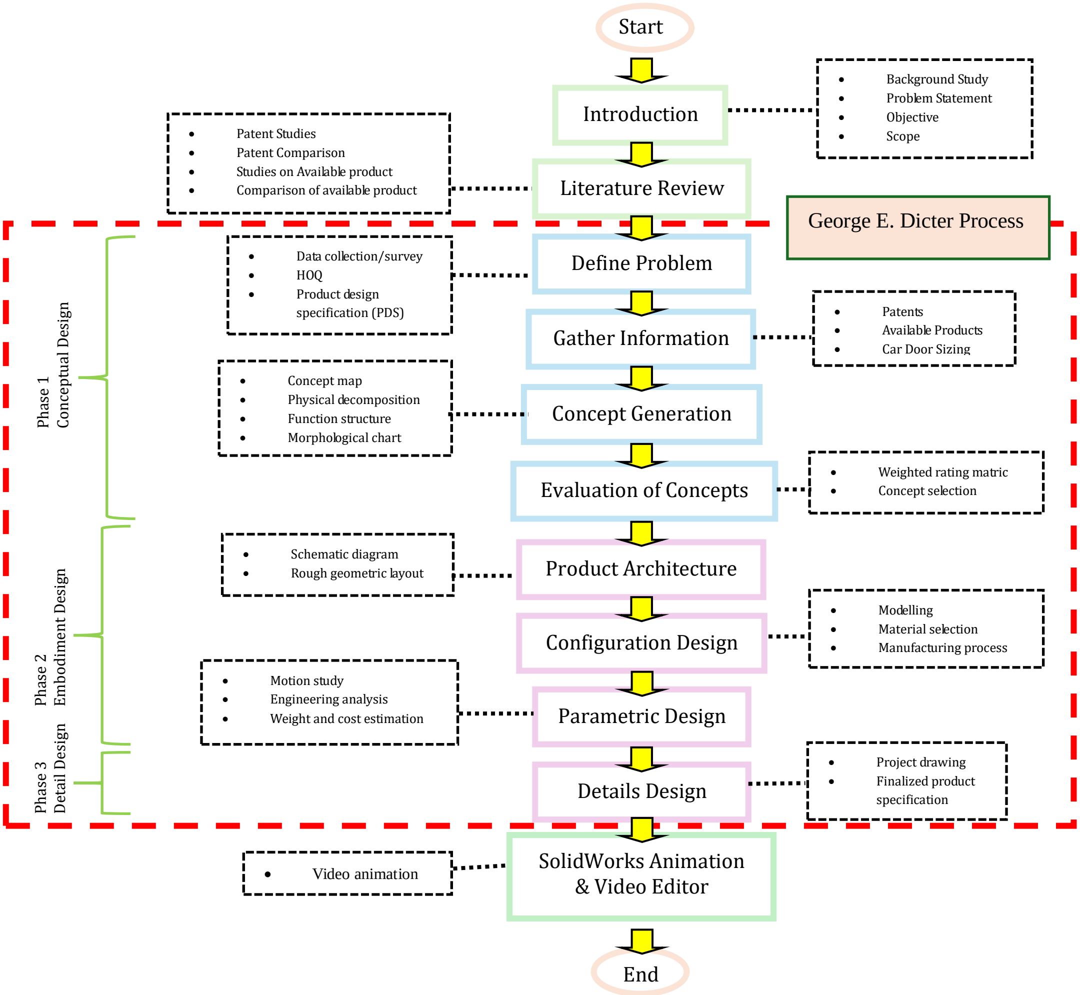


Fig. 1 *Flowchart of Design Process*

3. Design Process

The design process serves to guide students through a structured sequence of steps to develop an effective solution for real-world challenges. To understand user needs for an integrated car swivel seat with a special wheelchair, a Google Forms online survey was conducted under the title “Survey on Car Swivel Seat with Special Wheelchair Design”. The data collected from the survey was analyzed using an objective tree, which helped visualize and organize the design requirements. Additionally, relative weighting was applied to prioritize the user needs and establish the Product Design Specifications (PDS). The objective tree acts as a clear framework to outline the product’s functional requirements during the design phase. Finalizing this objective tree before proceeding ensures alignment between the user's expectations and the designer's direction. Fig. 2 illustrates the objective tree for the integrated car swivel seat with a special wheelchair, while Table 2 summarizes the corresponding product design specifications.

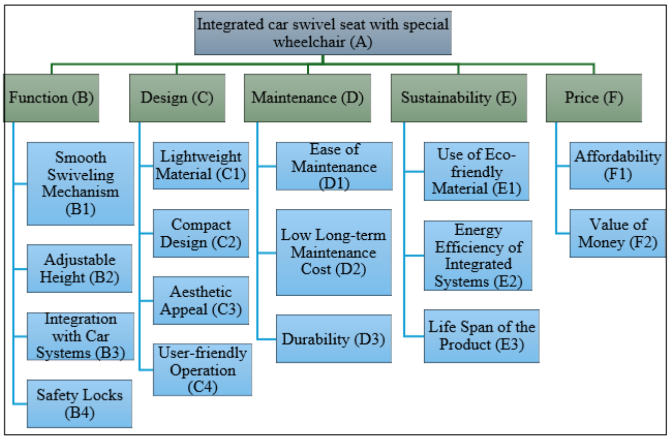


Fig. 2 *Objective tree for the Integrated Car Swivel Seat with Special Wheelchair*

Table 2 *Product Design Specification*

	INTRODUCTION
Title	Integrated Car Swivel Seat with a Special Wheelchair
Design Problem	Design a functional car swivel seat mechanism that can be integrated with special wheelchairs into vehicles for disabled drivers and passengers.
Intended Purpose	To transfer disabled drivers and passengers from wheelchairs into cars without lifting and without disassembling the seat from the wheelchair base
Target Customer	Disabled drivers and passengers
Special Features	The swivel seat mechanism could be control by remote control
	Customer Requirement
Functional	• Swivel Seat should be able to load above 115 kg • Swivel Seat base should weigh below 23 kg • Smooth Swiveling Mechanism during transferring disabled
Design	• Use lightweight material • Compact design
Maintenance	• 3 years maintenance interval • The parts should be easy to assemble and disassemble for maintenance • Low maintenance cost
Sustainability	• Longer life span • Use of Eco-friendly material • Energy efficiency of integrated system
Price	• The price must be less than RM4000

3.1 Concept Generation

During this stage, various methods such as morphological charts, physical and functional decomposition, and brainstorming were used to generate product concepts capable of fulfilling the intended functions. The functional structure of the Integrated Car Swivel Seat with Special Wheelchair is illustrated in Fig. 3.

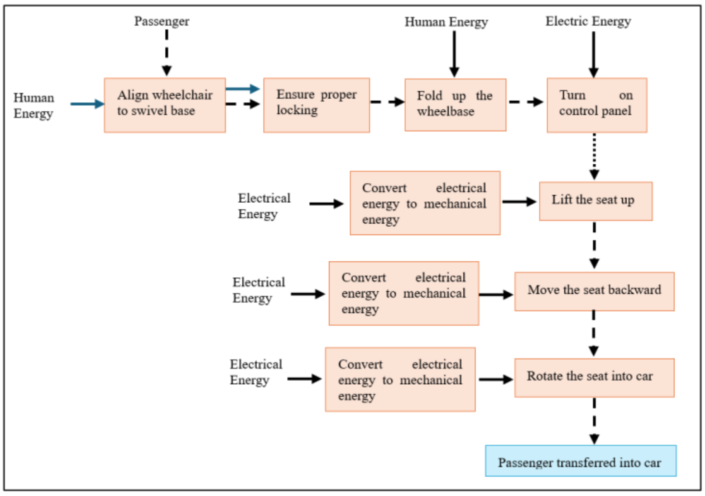


Fig. 3 *Function Structure for Integrated Car Swivel Seat with Special Wheelchair*

To evaluate the generated concepts, a weighted decision matrix was applied by combining priority values from the objective tree survey with the design requirements. This method enabled the comparison of three alternative concepts developed through the morphological chart. It helped identify the most suitable option that meets customer needs. The concept with the highest overall score was selected to proceed to the next stage of development. The selected concept combination is shown in Table 3.

Table 3 *Product Design Specification*

No.	Function	Selection Concept
1	Power Source	Car Electrical System
2	Wheelchair Alignment	Guided Track System
3	Folding Wheelbase	Semi-Automatic Folding
4	Lifting Mechanism	Electric Actuator
5	Seat Rotation	Motorized Rotation
6	Seat Extension	Sliding Rail Extension
7	Control System	Remote Control

3.2 Product Architecture

Product architecture plays a crucial role in the development process as it outlines the physical layout and key components responsible for performing the product's intended functions. It is developed based on the functional structure created during the concept generation phase. The main objective of product architecture is to organize these functional elements into logical groups or modules. A schematic diagram, as illustrated in Fig. 4, is used to represent how these physical components are arranged and how they interact within the system.

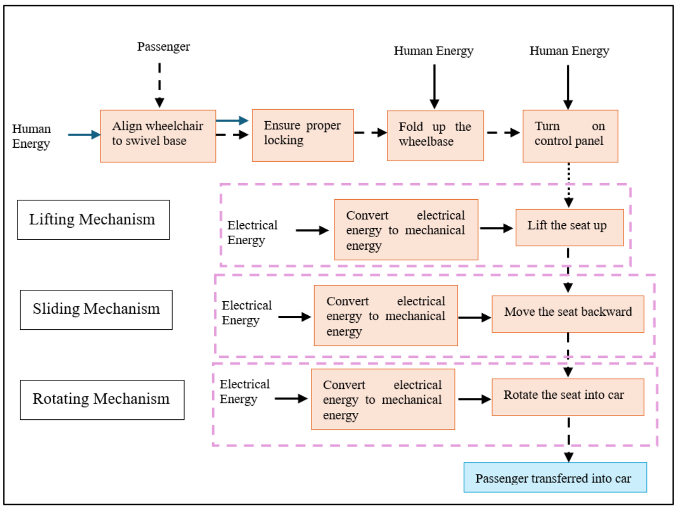


Fig. 4 *Schematic Diagram with Clustered Elements*

3.3 Modelling

The 3D models of the car swivel seat were created using SolidWorks software, a computer-aided design tool. The models were based on the concepts that were chosen in the previous stage of the project. These components were then integrated to form the final product, which is an Integrated Car Swivel Seat with a Special Wheelchair. Fig. 5 and Fig. 6 show the full assembly of the car swivel seat.

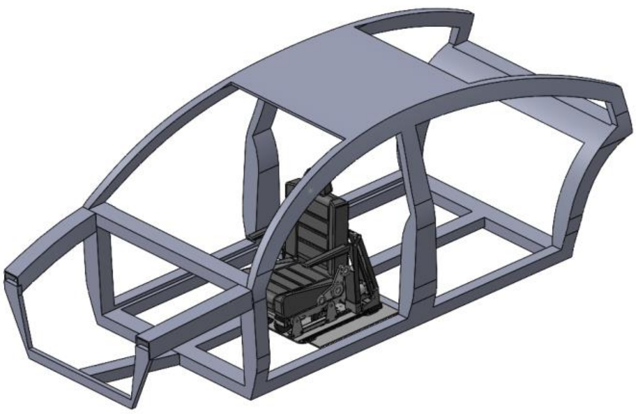


Fig. 5 *Full Assembly of Integrated Car Swivel Seat with Special Wheelchair*

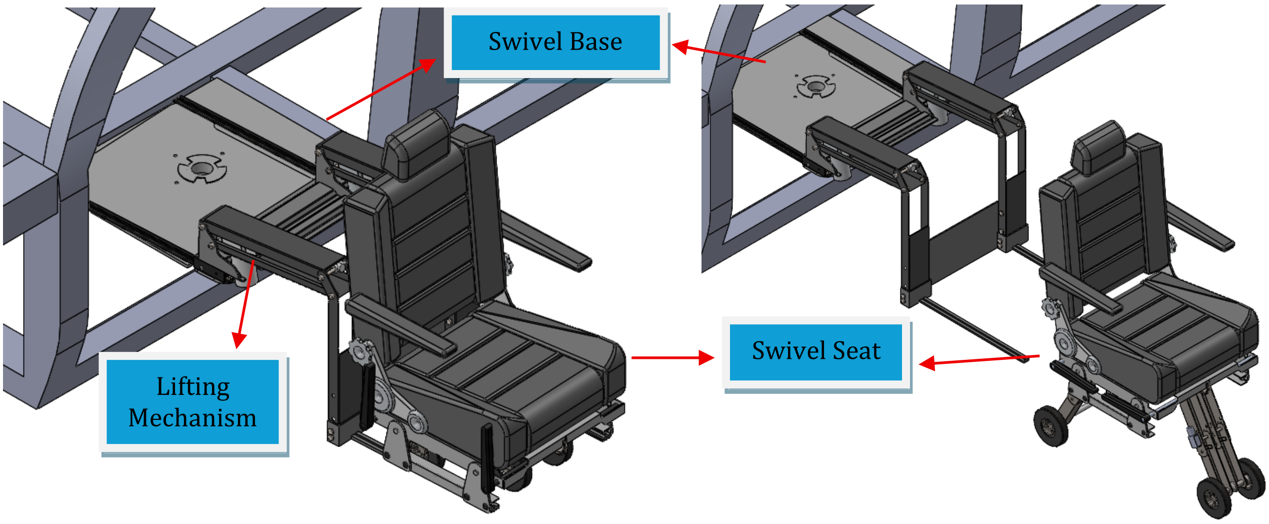


Fig. 6 Car Swivel Seat with label

3.4 Swivel Base

The swivel base uses a power window motor connected to a small gear that drives a larger semi-circular gear fixed under the upper base, as shown in Fig. 7. When activated, the motor turns the small gear, causing the upper base to rotate up to 90 degrees. This gear setup ensures smooth, controlled motion with mechanical advantage, allowing efficient rotation with minimal effort. The semi-circular gear also limits over-rotation, making the system simple, reliable, and ideal for controlled swivel applications.

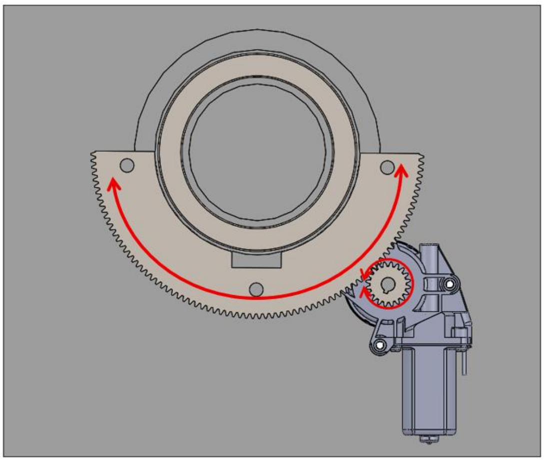


Fig. 7 *Power Transmission System of Swivel Base*

In swivel base mechanism, it is rotating a structure horizontally using a semi-circular gear driven by a small gear connected to a power window motor. The total weight of upper base, lifting mechanism, and swivel seat is 44.7 kg according to Fig. 8 while our target user's weight is 115 kg. Hence, the overall weight is around 160 kg.

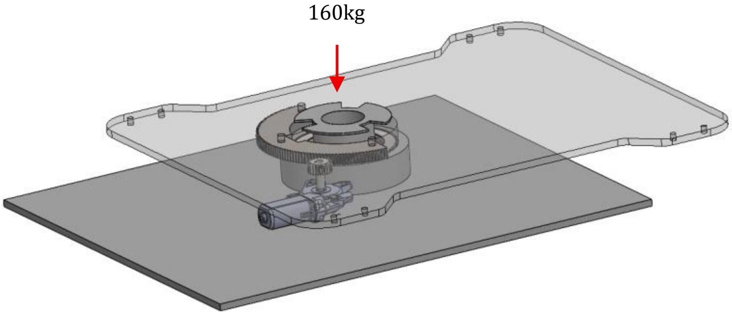


Fig. 8 Power transmission of swivel base

$$Torque, T = (I_{yy} \times \alpha) + (F_f \times r) \tag{1}$$

Where:
$I_{yy} = Moments\ of\ Inertia\ at\ y - axis = 15.7$
$\alpha = Angular\ Acceleration\alpha = \frac{2\theta}{t^2} = \frac{2\left(\frac{\pi}{2}\right)}{2.5^2} = 0.5027\ rad/s^2$
$F_f = Frictional\ Force = Force\ \times Friction\ Coefficient = 160 \times 9.81 \times 0.01 = 15.696\ N$
$r = radius\ of\ semicircular\ gear = 0.1215m$

$$T = (15.7 \times 0.5027) + (15.696 \times 0.1215)$$
$$T = 9.799\ Nm$$

The minimum gear ratio is calculated with:

$$Gear\ ratio = \frac{T_{required}}{T_{motor\ rated}} \tag{2}$$

$$Gear\ ratio = \frac{9.799}{2.9} = 3.379$$

Since the gear ratio required to rotate the semi-circular gear is 3.379. Therefore, the gear ratio of 8:1 used in the swivel base mechanism is good enough.

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The power required for the motor to rotate the gear is calculated with:

$$P_{required} = T_{required}\omega \tag{3}$$

Where:
$P_{required} = Power\ required\ to\ rotate$
$\omega = Angular\ velocity = \frac{\pi}{2(times)} = \frac{\pi}{2(5)} = 0.314\ rad/s$

$$P_{required} = 9.799(0.314)$$
$$P_{required} = 3.077\ Watt$$

Since the rated power of the motor is 18.2 W, which is higher than the power required to rotate the gear, the motor is able to rotate the gear.

For bearing selection, the equation below is used to select the suitable bearing:

$$C_{10} = a_f F_D \left(\frac{x_D}{x_o + (\theta - x_o)\left(\ln\left(\frac{1}{R_D}\right)\right)^{\frac{1}{b}}} \right)^{\frac{1}{a}} \tag{4}$$

$$x_D = \frac{60 L_D n_D}{10^6} \tag{5}$$

Where:
$C_{10} = Basic\ load\ rating\ (static)$
$a_f = Application\ Factor = 1.0\ (light\ load)$
$F_D = Desired\ radial\ load\ (kN) = 160 \times 9.81 = 1.57\ kN$
$x_D = Dimensional\ desired\ life$
$L_D = Total\ working\ hour\ (hr) = 5hr \times 365days \times 3years = 5475hr$
$n_D = Working\ speed\ (RPM) = 7.5\ rpm$
$R_D = Desired\ reliability\ = 0.9\ (assumed)$
$a = 3\ (ball\ bearing)$
$x_o = Rating\ life = 0.02$
$\theta\ (Weibull\ Parameter) = 4.459$
$b\ (Weibull\ Parameter) = 1.483$

$$x_D = \frac{60(5475)(7.5)}{10^6} = 2.464$$

$$C_{10} = (1)(1.57)\left(\frac{2.464}{0.02 + (4.459 - 0.02)\left(\ln\left(\frac{1}{0.9}\right)\right)^{\frac{1}{1.483}}} \right)^{\frac{1}{3}} = 2.147\ kN$$

Since the basic static load required is 2.147 kN which is lower than the basic static load rating of the bearing selected which is 285 kN, so the thrust ball bearing can support the load.

3.5 Lifting Mechanism

The lifting mechanism, as illustrated in Fig. 9, uses an electric actuator to raise and lower the seat platform via a multi-linkage system, providing smooth and stable vertical motion. As the actuator extends or retracts, it adjusts the seat height precisely based on user needs.

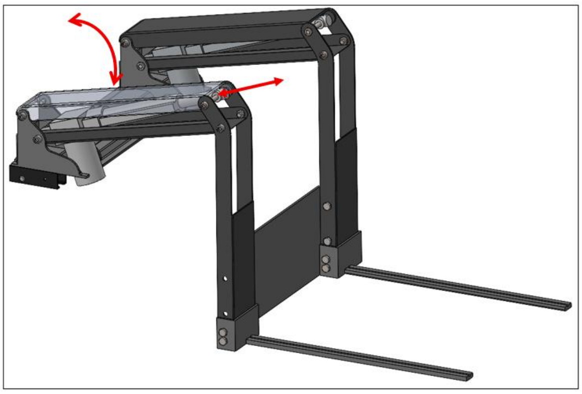

Fig. 9 *Power Transmission System of Lifting Mechanism*

Below it arm and at the base of the structure, as shown in Fig. 10, a horizontal movement system powered by a worm gear motor drives a pinion that meshes with a gear rack, converting rotation into linear motion. This allows the seat to slide horizontally with accurate positioning and reliable operation.

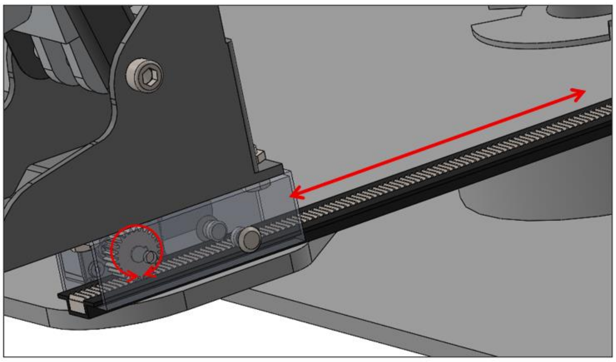

Fig. 10 *Power Transmission System of Sliding Mechanism*

The lifting mechanism involves an extension mechanism that can bring the wheelchair to move forward and backward using a gear rack driven by a gear connected with a worm gear box. The total weight of the lifting mechanism and swivel seat is 149 kg. The coefficient of friction of the gear is 0.1. Fig. 11 illustrates the load and parameters used for the power required calculation.

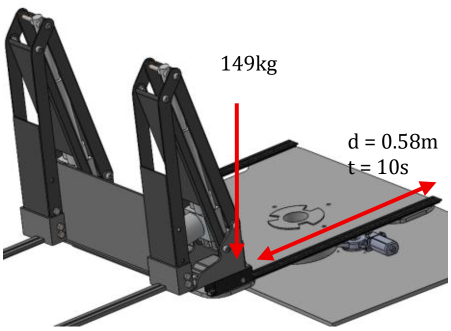

Fig. 11 Power transmission of sliding mechanism

The velocity of sliding is calculated with:

$$v = velocity = \frac{d}{t} \tag{6}$$

Where:
d = Displacement = 0.58 m
t = Times = 10 s

$$v = \frac{0.58}{10} = 0.058 \text{ m/s}$$

$F_f = Frictional\ Force = (149)(9.81)(0.1) = 146.169$ N

The power required to rotate the gear is calculated with:

$$P_{required} = F_f v \tag{7}$$

$$P_{required} = 146.169(0.058) = 8.478 \text{ Watt}$$

Since the power of geared motor is 45W which is higher than the power required to rotate the gear which is 8.478W, so the geared motor is able to rotate the gear. The torque required to rotate the gear is calculated with:

$$T_{required} = F_f r \tag{8}$$

$$T_{required} = 146.169(0.0125) = 1.827 \text{ Nm}$$

Since the torque of geared motor is 9.549 Nm which is higher than the torque required to rotate the gear which is 1.827 Nm, so the geared motor had enough power to rotate the gear.

In lifting mechanism, the electrical actuator is required to extend or shorten to lift or lower down the car seat. The total weight swivel seat with weight of people is 133 kg. The total force toward y-axis is 1305 N. SolidWorks motion analysis showed that the initial force required by both actuators to lift the seat and passenger was 12,265 N as shown in Fig. 12, exceeding the actuators' combined capacity of 12 kN. After reducing the Y-axis load to 1,256 N, the required force dropped to 11,828 N as shown in Fig. 13, which is within the safe limit. As a result, the swivel seat's load capacity was adjusted to 110 kg.

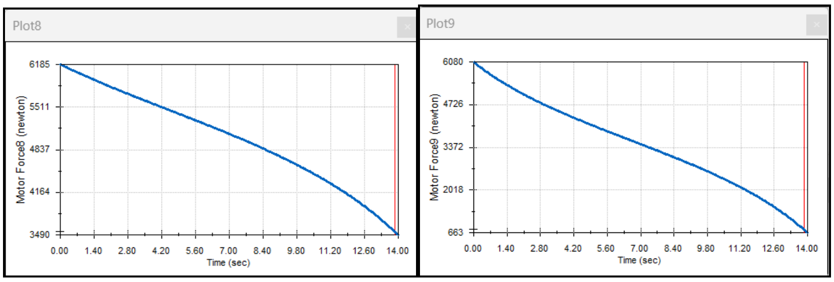

Fig. 12 Graph of force required for both linear actuator

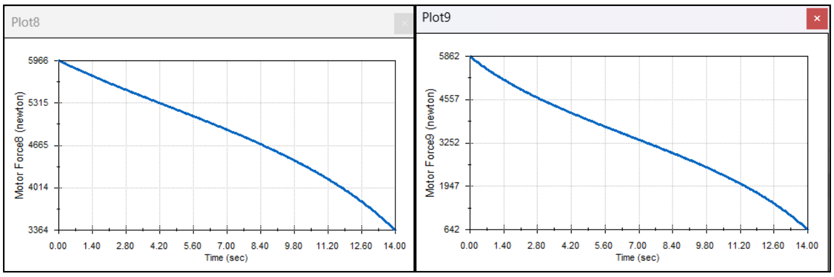

Fig. 13 Graph of force required after load modified

3.6 Swivel Seat

The swivel base features a manual propulsion system with foldable front and rear wheels. A user-operated crank, as shown in Fig. 14, turns a driver's sprocket, which drives a rear axle via a roller chain, propelling the wheelchair forward. For front-wheel movement, rotating the crank in the opposite direction engages a similar sprocket setup. This design allows efficient, arm-powered motion with minimal effort.

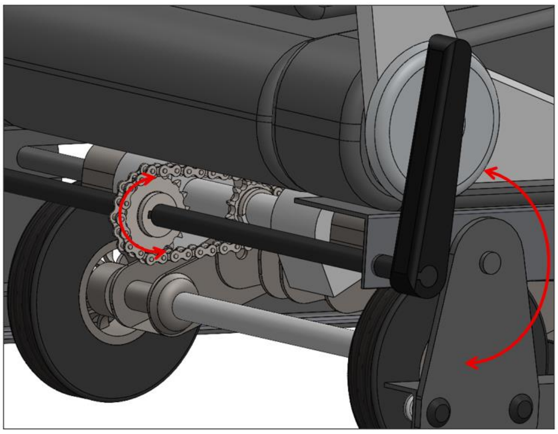

Fig. 14 *Power Transmission System of Swivel Seat's Wheel*

In the swivel seat, there is a foldable wheel for front and rear wheels, which is powered by a user-operated crank handle that directly links to a driver's sprocket as shown in Fig. 15.

The gear ratio of the chain is calculated with:

$$Gear\ Ratio = \frac{Driven\ Teeth}{Driver\ Teeth} \tag{9}$$

Driven Teeth = 13 teeth, Driver Teeth = 18 teeth

$$Gear\ Ratio = \frac{13}{18} = 0.722$$

The force toward the y-axis is calculated with:

$$F_y = mg \tag{10}$$

Where:
$F_y = Force\ toward\ y - axis$
m = Mass of wheel

$$F_y = 5.73(9.81) = 56.21\ \mathrm{N}$$

The torque required for the driven sprocket to fold up the wheel is calculated with:

$$T_1 = F_y r \tag{11}$$

Where:
r = Distance between gear and load

$$T_1 = 56.21(0.225) = 12.64\ \mathrm{Nm}$$

The torque required to rotate driver sprocket is calculated with:

$$T_2 = \frac{T_1}{Gear\ Ratio} \tag{12}$$

Where:
$T_1 = Torque\ for\ driven\ sprocket$
$T_2 = Torque\ for\ driver\ sprocket$

$$T_2 = \frac{12.64}{0.722} = 17.5\ \mathrm{Nm}$$

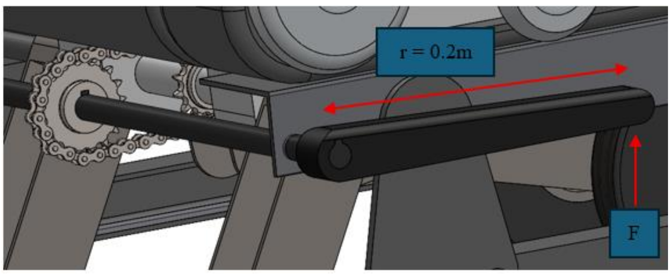

Fig. 15 Driver sprocket connected with the crank and handle

Since the sprocket is directly connected with the crank and the handle, the force required for user to rotate the crank handle is calculated with equation 11:

$$F = \frac{T}{r} = \frac{17.5}{0.2} = 87.5 \text{ N}$$

Therefore, the force required for the user to rotate the crank handle is 87.5 N.

3.7 Product Specification

Product Specification works as a guide, defining all the specific requirements and details that must be fulfilled by a product to direct its development and guarantee that it satisfies quality standards and consumer needs. Table 4 below shows the product specification of the Integrated Car Swivel Seat with a Special Wheelchair.

Table 4 *Product Specification of Swivel Seat*

Detail	Product Specification
Load Capacity	110.00kg
Weight of Swivel Base	41.58kg
Weight of Swivel Seat	18.14kg
Swivel Range	90 degrees
Dimension of Swivel Base (W*L*H)	584mm*906mm*702mm
Dimension of Swivel Seat (W*L*H)	620mm*864mm*1296mm
Power	500 W
Price	RM5379.73
Rotating Speed	3 rpm
Extending Speed	0.058 m/s
Rotating Time	5 s
Extending Time	10 s
Lifting Time	14 s

4. Conclusion

The project successfully developed an integrated car swivel seat with a special wheelchair, aimed at improving mobility and independence for disabled individuals. Designed using George E. Dieter's engineering design process and evaluated through SolidWorks simulation, the system features a rotating and sliding seat with a detachable wheelchair base. While the final design supports up to 110 kg and is constructed using Aluminium Alloy 6061-T6, some areas require improvement. It is recommended to upgrade the linear actuators to 7000 N models to meet the 115 kg load requirement and to optimize the swivel base geometry to reduce its weight from 41.58 kg to meet the 23 kg target. Further refinement of components, integration of foldable wheelchair features, and user testing are essential for advancing the design toward practical implementation and commercialization. To ensure safety and reliability, improvements in geometry and material selection are necessary for future development.

Acknowledgement

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References

[1] World Health Organization, Global Report on Health Equity for Persons with Disabilities. Geneva: WHO, 2023.

[2] N. A. Azmi et al., "Provision of key accessibility issues for people with disabilities in public transportation," in Proc. Int. Conf. on Architecture and Civil Eng., 2022, pp. 120–128.

[3] J. Karunagaran et al., "A biomechanical analysis of caregiver assisted wheelchair to car transfers," Med. & Health, vol. 21, no. 1, pp. 503–520, 2026.

[4] M. Hess, L. Kincl, and D. Mandeville, "Comparison of three single-person manual patient techniques for bed-to-wheelchair transfers," Home Healthcare Nurse, vol. 25, no. 9, pp. 577–579, 2007.

[5] B. Braun, "Method and apparatus for a vehicle swivel seat," U.S. Patent 10 518 670 B1, Dec. 31, 2019.

[6] L. B. Southward et al., "Transportation of disabled or invalided persons," U.S. Patent 4 170 368, Oct. 9, 1979.

[7] W. U. Nazarudin et al., "Car seat swivel for enhanced accessibility for disabled individuals," Multidisciplinary Applied Research and Innovation, vol. 6, no. 3, pp. 18–24, 2025.

[8] N. A. M. Nasir and E. Shukaib, "Industry 4.0 adoption and diffusion in manufacturing SMEs in Malaysia," in Proc. WCSE, 2022, pp. 200–205