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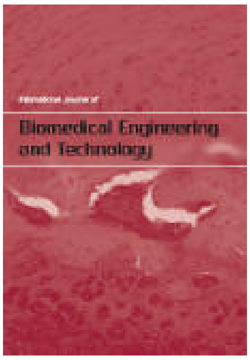

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A review on wheelchair and add-in devices design for the disabled

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Abstract: Owing to rapidly aging populations and rising road accidents, the daily use of wheelchairs, which has become necessary to aid mobility for the disabled, is growing globally. The patients with spinal cord injuries, cerebral palsy, and those inflicted with seizures need a wheelchair. The authors expect that the information gathered within this research will enhance the understanding of modern-day wheelchair requirements. This article presents the global research campaign, starting with a debut to the wheelchair and the communities they serve. Technological inventions focus on probably the most researched regions, creating one of the most interesting future research and development. This article reviews the role of wheelchairs for different disabilities by examining its respective merits and demerits. It highlights the gap between the associated technological features and capabilities, including the navigation and motion control methods, pros and cons of indoor-outdoor navigation on different surfaces such as standard, sandy, muddy and hilly terrain when using a wheelchair. Concerns related to the improvement the living conditions of the disabled have been concluded.

Keywords: assistive device; ergonomic design aspects; indoor-outdoor navigation; rehabilitation; wheelchair technologies.

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1 Introduction

The disabled are increasing daily worldwide because of a rise in the number of road accidents, old age (above 60 years) people, and owing to lifestyle-induced injuries. According to the World Health Organization (WHO) (2011), out of the total population, 15% handicapped. According to India's Census in 2001 (Chandramouli and General, 2011), the disabled are 2.13% of the total population. In 2011, recorded as 2.22% with 0.09% growth. In 2001, 4.8% older of the total population. In 2011, it recorded as 8% with 3.2% growth annually. Depending on the Ministry of Road Transport and Highways Government of India (Shantajit et al., 2018), an accident occurs per minute, per day in the country. The problems associated with the daily activities of the disabled, as shown below.

- housing
- social support and fairness inconvenience during the use of public transportation (Avutu et al., 2016).

They demand unique clusters like toilets, parks, playgrounds, and shopping complexes with step-free paths tailored to their housing issue needs. Unavailability of these amenities amounts to a violation of their fundamental rights. Social support and fairness toward the disabled may change from country to country, depending on government policies. It influences participation in various cultural activities. Significant modifications like low height footboard step and gap between the seats have mandatory for public transportation system efficient usage. To the following people, the wheelchair is essential to their daily activities:

- amputee
- spinal cord injury paralysis
- those unable to long walks aged people having gait issues

Simpson (2005) illustrated the major development work on the smart wheelchair since 1989. Leaman and La (2017) provided a comprehensive analysis of navigation algorithms, route tracking, and sensor fusion techniques. In 2005, Ding and Cooper briefed the fundamental working principle of a motorised wheelchair in an article, 'electric-powered wheelchair'. Flemmer and Flemmer (2016), in the review, explained the central evaluation done on the manual wheelchair for the period from 2000 to 2015. The authors tried to list out the opportunities and challenges in the wheelchair manufacturing industry around the globe. In this article, Initiation took to comprehensive, revise comparison of different innovative design(s) of the hand-operated, powered wheelchairs, and add-on devices developed globally so far. The current review presents the empirical study of technologies used for wheelchair and add-on systems. The present review deals with how the researchers use modern technological tools to create a new era for disabled people to enhance their quality of life.

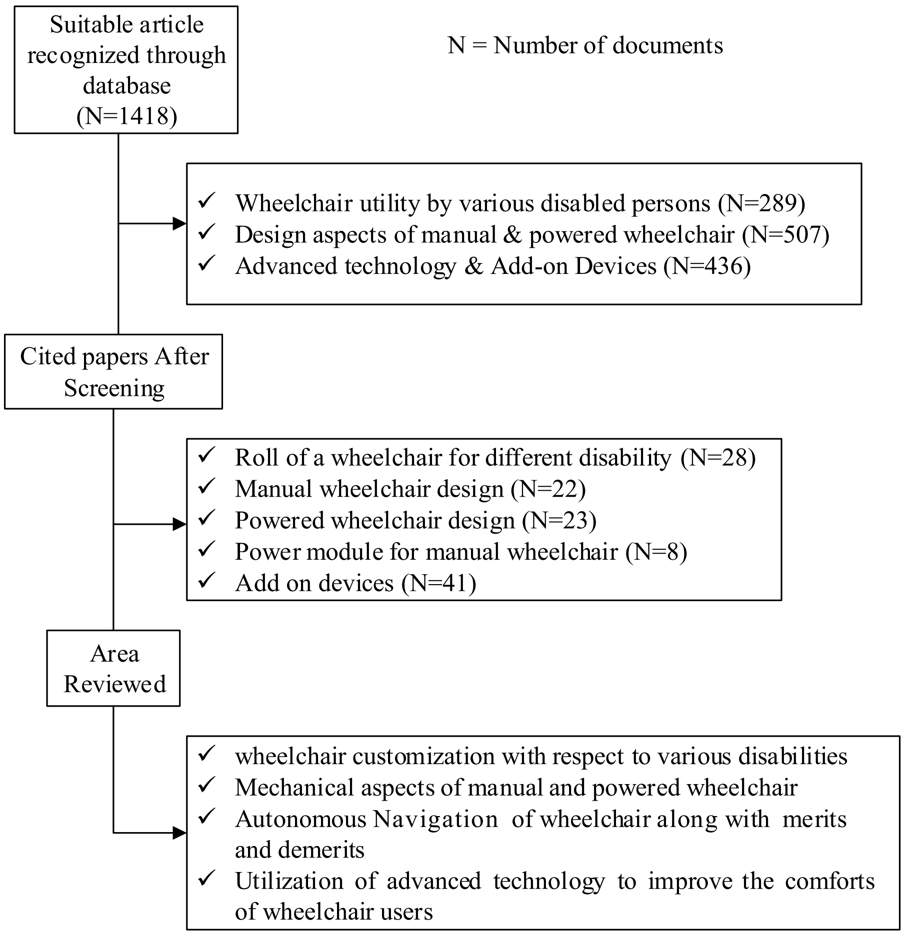
This analysis focuses on wheelchair function. The issues involved in the usage of equipment and alternative solutions for various disabilities are in Section 2. Section 3 explains the design aspects of manual and powered wheelchairs from both electrical and mechanical perspectives. Motion control methods of manual and powered wheelchairs on different surfaces and recent technology advances, add-on devices are in Section 4. As a concluding remark, Section 5 has illustrated along with potentials how wheelchair changed from traditional to smart.

2 Role of the wheelchair as an assistive device

2.1 Review method

The author has done a literature review between the years 2005 to 2019 as inclusion criteria. The journal publications cross-checked with the conference duplication found discarded as exclusion criteria. The authors examined the wheelchair from both the medical and engineering perspectives to estimate the performance. Physiotherapy, recovery, neuro-rehabilitation, navigation used as keywords. Figure 1 shows the number of publications used as a guide for various groups since applying the literature study's exclusion and inclusion requirements. PubMed contains evidence of required changes to reconfigure a wheelchair for different disabled. Standard repositories like Scopus, IEEE Xplore digital libraries, and articles indexed in a web of science used to gather the information in electrical and mechanical viewpoints regarding navigation algorithms architecture modifications and add-in devices.

Figure 1 Review methodology



2.2 Wheelchair option for various disabled people

The wheelchair helps disabled people to do their regular activities such as work, education, and entertainment without other help – however, irrespective of their disability, personal activities every day for each. The wheelchair's role varies based on disability nature, age, gender, living area, working areas, work nature, living style, and economic conditions from person to person. This paper explains a wheelchair's role to enhance their quality of life for different disabilities shown in Table 1.

Table 1 Role of a wheelchair for different disabilities

Nature of the disability	*Requirement/demands*
Lower-extremity amputation	With unilateral or bilateral amputees at the clinical stage, they need a wheelchair to cover short distances (Coffey et al., 2012). After the clinical setting, the subject should have either a wheelchair or prosthetic limb to fulfil the mobility requirement (Paul et al., 2012). Compared to a wheelchair use of a Prosthetic leg complicated. A professionally designed prosthetic leg and gait training are mandatory for the patients (Mathur et al., 2016) and socket interfacing a significant problem (Ferreira et al., 2017). • They preferred an electric-powered wheelchair since difficult to travel many kilometres by manual wheelchairs. Priorities of users will change based on employment nature. • Office assistants need a lightweight, small wheelchair to move within the office. In the postal worker's case, they will prefer a tricycle or scooter based on the distance. • The unilateral amputees need a wheelchair at the primary stage of treatment. They choose adaptive devices such as crutches, walking sticks, or walkers to fulfil the mobility requirement based on their lifestyle and requirements.
Stroke	The stroke causes sudden death of brain cells because of the insufficient blood supply in the blood-brain-artery. It may cause ischemic, temporary, and hemorrhagic. Stroke victims usually lose their body movements depending on the hand or area caused by the stroke. During the initial process (from 0 to 1 month), they lose (Harvey et al., 2008) motor and sensory function. The patient cannot move independently on the bed. Under these circumstances, the challenging tasks are consulting the doctor, shifting the patient from one room to another, and performing daily activities. Unfortunately, the formula is not available in the literature for rehabilitation engineers to design the wheelchair (Winstein et al., 2016). • Stroke patients need a wheelchair with a proper seating arrangement.
Muscular dystrophy	Genetic troubles in males. Duchenne and Becker are dangerous muscle dystrophy types out of many (Hegde and Ankala, 2012). Each motor cell has a lifespan of 120 days. Still, the lifespan decreases rapidly, leading to pseudohypertrophy, muscle wasting, reduced joint motion range, poor muscle control, increases muscle tightness, decreases muscle strength, and ultimately leads to a bedridden condition. • A powered wheelchair with an add-on device has recommended reducing caregiver workload (Lin et al., 2012).
Spinal-cord injuries	Damage determines the spinal-cord injuries (SCI) type. If the damage occurs at the cervical lumber or thoracic stage, a quadriplegic form of paralysis progresses to a paralysis of the body, neck, legs, and spine, which may cause difficulty in breathing and speaking. • Ekiz et al. (2014) analysed the importance of the appropriateness of wheelchairs. • The standard wheelchair design will help engineering design add-on devices for SCI patients to improve their lives (Kim et al., 2011).

Table 1 Role of a wheelchair for different disabilities (continued)

Nature of the disability	*Requirement/demands*
Paralysis	The paralysis can be paraplegia and quadriplegia based on the SCI level. The individual will experience weakness on both legs because of motor-sensory nerves or spinal cord injury. The paraplegia was resulting in a lack of capacity to move, sit, and stand. The individual with quadriplegia or tetraplegia may experience weakness in both legs and hands. Here, they are bound to a bed or wheelchair. In recent years the researchers have developed a different wheelchair (Lukman et al., 2017) by considering design ergonomics (Gil-Agudo et al., 2013), which suits the paralysed, improving their quality of life. • Paraplegia patients can use the manual wheelchair based on their requirements. • The tetraplegia patient needs an appropriate wheelchair with a caretaker to do their routine activities.
Cerebral palsy	Cerebral palsy or cognitive disability in infants causes deterioration of sensory dysfunction related to damage to the brain. It occurs during the initial life-start phase (0–3 years) because of intrauterine trauma, hypoxic brain injury forceps transmission, glycemia, calcium, and breech presentation (Rosenbaum et al., 2007). As the child ages, its height and weight will increase. If the child is not getting proper rehabilitation, they will have to depend on others for fulfilling daily functions. Samantha Ross et al. (2016) explained the effect of strength training on an adult with cerebral palsy (Ross et al., 2016). • A wheelchair with add-on devices to hold the child mandatory for safe ambulation.
Motor neuron disease	Its categories include neurodegenerative (Ward et al., 2010), amyotrophic lateral sclerosis (ALS), hereditary spastic paraplegia (HSP), progressive bulbar palsy (PBP). Here, patients lose their muscle control because of low sensory nerve activity—the most complicated of these progressive muscle atrophy and hereditary spastic paraplegia. Wasting muscles and muscle weakness leads to poor joint control. Patients develop contracture and deformities such as flexion knee deformities, decreased muscle length, scoliosis, kyphosis, and claw-hand deformity, leading to bed-bound conditions during the progressive phase disorder. • The powered wheelchair with support devices will help the patients to do their daily activities.
Neurodegenerative disease	The progressive loss of neuronal structural and functional anatomy results in neural pathway malformation and malfunction (Kishore, 2013). Here, the patient has poor body control, coordination with the muscle motor, motor difficulty painting, and generalised muscle weakness. Examples of neurodegenerative diseases include Parkinson's, Guillain-Barre's syndrome, amyotrophic lateral sclerosis, Alzheimer's, and Huntington's.

3 Wheelchair design aspects

3.1 Design aspects of a manual wheelchair

Manual wheelchairs provide a sick, injured, and disabled person with limited mobility to move in confined environments from one place to another. It requires physical exertion of patients or helpers. The disabled have difficulty operating the manual wheelchair without others' support in hilly areas or uneven terrain. In the 19th century, the first manual wheelchair with spokes had designed. While using manual wheelchairs, the upper limbs, elbow, and shoulder joints were severely affected, causing pain and discomfort to the individual. The rear wheel axial position dominates the impact on the upper limb parts. (Bertolaccini et al., 2017.) Wheelchair users with spinal cord injury will develop pain in the neck, low-back, and thoracic (Kovacs et al., 2018). The authors found that developed countries offer design modifications in the standard wheelchair unsuitable for developing countries (Podobnik et al., 2017). During the initial stage of design, the designer should consider ergonomic features. Wheelchair design concerning disability has the following.

- it should fit the user's needs and environmental conditions.
- should be of the proper size to provide appropriate postural support
- safe design, long-lasting, and made in the country
- locally workable for maintenance and repair at an affordable cost (World Health Organization, 2011)

The propelling force for the manual wheelchair and the upper limb joints movement range depends on the physical parameters such as material type, size, and weight. The stability and mobility of wheelchairs rely on a change in the centre of gravity (C.G.) and weight distribution. The manual wheelchair's physical parameters and its significance in the design process that offers a suitable wheelchair for users have shown below:

- Frame types and material: rigid frame has more strength and durability. It will give the best-propelling experience to the user compared with the folding frame. Because of rigidity, the total weight will increase, which leads to difficulty in transportation. However, the material type will decide the total frame weight. However, aluminium and titanium give less weight to the strength ratio, where the cost is high (Chenier and Aissaoui, 2014).
- Frame rake or squeeze: it relates the rear seat's seat angle to the front seat in the horizontal direction. The rake position will affect stability (Calhoun et al., 2013), the center of gravity, posture, and pressure distribution. We recommend it for an adjustable frame rake since the requirement varies between one user and another.
- Front frame angle: it is an angle between seats and footplate hanger and inversely proportional to the wheelchair's length. The manoeuvrability will increase with raised front frame angles. However, the turning circle will decrease where the user may not see their feet (Liu, 2008).

- Camber shows the angle between the rear wheel position and axle, ranging between 0 and 12 degrees. It can achieve by either an axle plate or with a cambered bar. An increase of one degree in the camber angle increases the floor level (Tsai et al., 2012) by 2.5 cm. The chamber is directly proportional to wheelchair stability.
- Frame taper: It shows the frame width, narrowing down from the seat to the footplates. It aims to ensure that the user can easily use the wheelchair while going to the toilet (Oliveira et al., 2019).
- Wheel-type and tyres: two significant parts of the wheelchair are the caster and rear wheels. The driver wheel size is larger than the driven wheel. The standard driver and driven wheel sizes are 20, 22, 24, 26, 3, 5, 6, and 8 inches. The tyres with tubes perform well for outdoor navigation since it provides high-rolling resistance, stability, and durability. The tyres' low rolling resistance with soft rubber is suitable for indoor navigation (Mason et al., 2012).
- Push rims: lightweight circular rims attached to the driver wheel used for propelling (Mason et al., 2010).
- Wheel locks/brakes: used to arrest the driver wheel during patient transfers from a wheelchair to another, and vice versa. However, the size and its position may vary between the users. Medolla et al. (2014a) explained the effect of a wheelchair configuration on mobility. Table 2 explained innovative design by researchers and different organisations in the past decade.

3.2 Design aspects of a powered wheelchair

Instead of manually propelling, used electric energy to run a powered wheelchair. But no similarity in design. Globally categorised manual wheelchairs are standard, transport, folding, heavy-duty, light and ultra-lightweight, sports, pediatric, and Hemi-height based on the system. However, the powered wheelchairs are available as standard, folding, and heavy-duty. We found that significant research has not yet changed the standard powered wheelchair design from the literature survey. The challenge associated with the present powered wheelchair is stepping climbing. In this review, the authors concentrated only on design modifications from a mechanical perspective, since Ding and Cooper (2005) explained the basic design of the powered wheelchair and its working principle. Leaman and La (2017) discussed modern powered wheelchairs' outstanding features such as stair climbing iBot, Patrafour, tank chair, level on all terrain. Various researchers and organisations' Attempts have been reviewed rather than the models discussed by Leaman and La (2017). In Podobnik et al. (2017), all-terrain wheelchair have designed to help a 360° wheel-steering mechanism avoids architectural barriers. Tao et al. (2017) provided a wheelchair design that can adapt to different step sizes. Nakajima (2017a) has tested the proposed wheelchair design for rough terrain.

Ma and Qi (2017) designed a prototype with dual control access benefits for both rider and caregiver. Plos et al. (2012) introduced a design concept based on extended modularity, functional accessibility, and social integration strategy (EMFASIS). Udengaard and Iagnemma (2009) gave prescriptions regarding the design and control of an omnidirectional mobile robot using a caster drive mechanism system. Mathur et al.

(2016) designed the wheelchair-using redundant wheel drive system, which operated using embedded.

Table 2 Recent innovations of a manual and electric powered wheelchair

Keywords of design improvement	*Design modification*	*Conclusion*	*Limitations*
Ergonomic design aspects, biomechanics (Skendraoui et al., 2017)	A lever mounted on hub less-wheels has specialised in this propulsion mechanism with automatic folding and lifting. The aim of this fresh notion would be that manual wheelchair optimisation considers ergonomics things.	The idea matches the specific necessities of the lifting handbook. The bouncy seat allows end-users to accommodate their standing based on stable conditions; this operation provides Significant health advantages related-to vascularity and digestion aid.	It is mandatory to measure the muscle, ligamentous, and joint donations of their human anatomy at the Wheelchair's Seat. These outcomes may clarify the features of modular wheelchair layout
Physically assistive devices, design mechanism, automatic braking system (Hirata and Tanaka, 2017)	It proposed a replacement athletics chair for each indoor and outside use that has bicycle-like quality, a freewheel mechanism, a variable transmission, and braking management.	Combining the CVT and clutch comes through varied helpful functions, specifically pedalling forward or backward, braking victimisation of the clutch slip force, and compensating the pedalling force once turning left or right.	The current clutch-engagement torsion is too tiny to apply an associate in Nursing considerable braking force. Better to use a clutch with a bigger engagement torsion. Also, a dry clutch encompasses a comparatively tiny variant of torsion management.
Hand rims positioning, removable hand rims, computer-aided design, (Fairhurst et al., 2016).	Elegant prototype wheelchair that will aim independent/ergonomic placement of hands pliers guide coupling of this hands rim movement to push brakes. Detachable hand pliers to ease the lateral move.	The chain drive system enables proportional gear change. That can lower the back pain in users that have lower shoulder or arm function. Manipulation of the gear ratio can lower the pressure required for propulsion, thus supporting.	This prototype Is Appropriate for testing the wheelchair skills and also upper limb propulsion biomechanics. There is still room for improvement. Mandatory to lower the bulk ought.
Human-centred robotics (Sasaki and Suzuki, 2018)	They used a rotary-legs mechanism to get a stair-climbing up and down mobility. The developed mechanics comprises four-bar linkage mechanism.	The suggested method could produce compulsory torque for stair-climbing mobility.	The rotary-legs mechanism has armed using a one-sided clutch. Hence, it cannot execute up the climbing.

Table 2 Recent innovations of a manual and electric powered wheelchair (continued)

Keywords of design improvement	*Design modification*	*Conclusion*	*Limitations*
Mid-wheel drive, standing wheelchair (Nickel et al., 2016)	They suited a chain driveway system with some manual position cubicle, incorporating freedom at the status posture. The hand's rims are all reachable from seated and standing places.	The model revealed signs of equilibrium in the number of inactive learning evaluations – a panel of wheelchair users supplying invaluable responses to direct additional objectives for advancement in upcoming improvement.	Additional work is necessary to build up a manual status that incorporates the status of freedom work plus dynamic mechanical, more operational and respective field analysing.
Quality function deployment method, power-assisted wheelchair (Chien et al., 2014)	It uses an excellent function setup procedure of growing a wheelchair having a user-selectable manual/electric propulsion style along with an additional solar-powered energy distribution technique	The key attributes of this suggested Wheelchair Power distribution, hence raising the travelling scope. Mechanical clutch system to allow an individual to change the functioning style.	We carried out an in-depth analysis of these setup elements' effects on all parts of this automobile operation – further the burden of installing gear to the wheelchair.
Lever propelled wheelchair, mechanical efficiency, (Agarwal and Gautam, 2014)	Suggested an improved style and design of the present levered wheelchair right here. This layout would boost the achievement capacities and societal Bounds of handicapped that hinder this handicapped moment's lifestyles daily.	The lever proved to become improved at practically all screening parameters compared with this push rollercoaster. The brand-new suggested design depends on most of the parameters.	However, there was an opportunity to advance and formula the improved design, which intends to improve effectiveness and consumer comfort and ease.
Ergonomic design, power-saving, assistive technology (Cai, 2014).	This analysis intends to point out a leverage chair to the older. The sequential design process, theory structure, design, ergonomic design and style, and completed physical appearance design at the analysis to produce the newest item.	The energy transport mechanism comprises two gears plus some string. The more expensive gear is the ability gear acted from the person, and the smaller gear acted from the power gear. It permits the user to go to the wheelchair with small energy.	It comprises an intricate design. Tedious for practical implementation includes a high manufacturing cost.

Table 2 Recent Innovations of a manual and electric powered wheelchair (continued)

Keywords of design improvement	*Design modification*	*Conclusion*	*Limitations*
Leveraged freedom chair, biomechanical testing, design evolution (Winter et al., 2012)	The plan development of this LFC throughout East Africa, Guatemala, and India. They used comments to enhance the seat from test areas between trials. It measures survey data profiling raises in operation after consecutive iterations—Quantitative Bio Mechanical performance.	The data presented inside this paper reveals the efficacy of this LFC factor mechanical benefit drive-train. Even the LFC always and out-performed main-stream hospital-style wheelchairs in rate, efficacy, and propulsion in either Guatemala or India trials.	When making technological innovation for developing nations and emerging markets and engineers ought to comprehend stakeholders as collaborators and provide them with the chance to pronounce solutions and problems.
Self-help devices, Human engineering, rehabilitation (Medola et al., 2012).	Based on anthropometric options and ergonomic concepts, they designed a brand-new automobile push rim and a manufactured prototype in memory, using the rapid prototyping technique and sequential generation of elements from melding.	Analysed by a sample of wheelchair users, that ranked the perceived quality of the gadget. The Newest push Border provided a functional grip, as the wrist Joint remained in small extension.	The sample never chosen Randomly to examine the wheelchair push rims restricts the generalisation of these findings. The single aspect of the model can limit the expansion of this outcome to other people.
Wheelchair design, Assistive technology, ANSI/RESNA testing (Zipfel et al., 2007).	They were thought of five chief factors once coming up with the latest chair, person needs, usage and producing circumstance, and material limitations. ALIMCO's price tag mount has been likewise an essential element. This price bracket depends on the means of a subsidy awarded to users needing from the government.	The planning approach from original layout tips on ANSI-RESNA screening over the ultimate ALIMCO prototypes occurred approximately four decades. This procedure will probably be compact from the upcoming stages; disadvantages struck from the workforce need noted for different collaborators' sake.	Even though jeopardised transportability is going, the seat will likely fulfil a necessity because of exceptionally. Other apparatus for auto uses have to get manufactured, like a lineup of customisable cheap cushions.

Batteries: Iwami et al. (2017) explained a removable electric drive system for wheelchairs. Sundaram et al. (2017) well described the step climbing wheelchair. Pearlman et al. (2009) developed and tested a low-cost electric powered wheelchair for developing countries. Figure 2 shows the various innovative designs proposed by researchers. The advanced powered wheelchair designs and mid-wheel drive systems available in global markets are not suitable for indoor navigation in developing countries. To overcome the indoor navigation problem with powered wheelchair design, the researchers developed an electric-powered assistant module for manual wheelchairs.

Figure 2 Recent developments of powered wheelchair design, (a) all-terrain wheelchair (Podobnik et al., 2017) (b) stair-climbing electric-powered wheelchairs (Tao et al., 2017) (c) personal mobility vehicle for steps (Nakajima, 2017a) (d) human-centred design of an electric wheelchair (Ma and Qi) (e) wheelchair initiative new generation (Plos et al., 2012) (f) omnidirectional mobile wheelchair (Udengaard and Iagnemma, 2009) (g) redundant wheeled drive system (Mohamed et al., 2017) (h) electric drive system for wheelchairs (Iwami et al.) (see online version for colours)

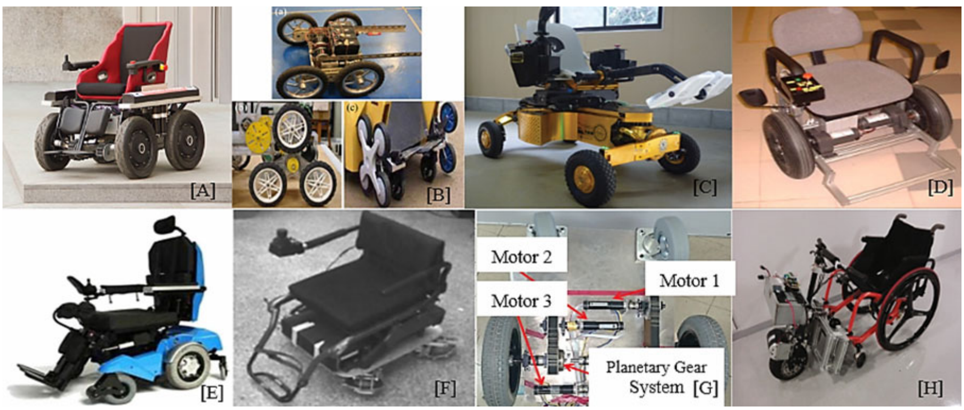


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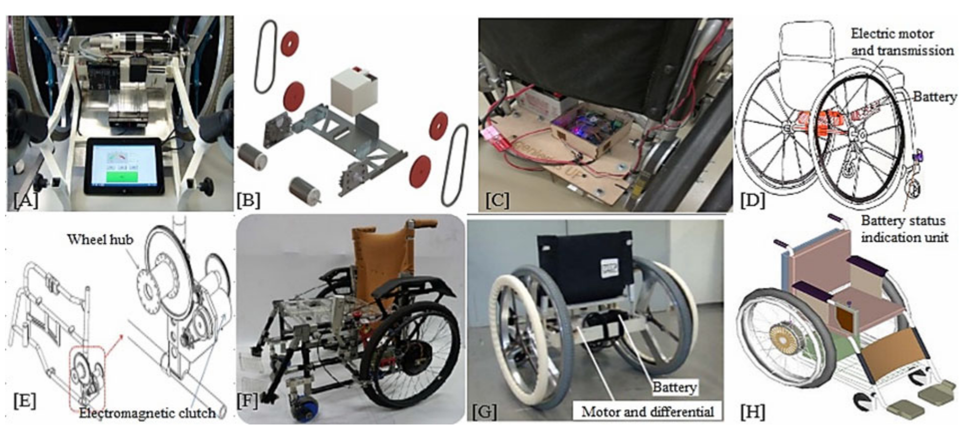
Figure 3 Recent developments of power module design for a manual wheelchair, (a) servo-controlled power-help systems (Medola et al., 2018) (b, c) electric wheelchair module (Galvan et al., 2017) (d) accessible power assistance for manual wheelchair (Ramirez and Holloway, 2017) (e) power-assisted wheelchair (Lee et al., 2016) (f) hybrid powered wheelchairs (Yoon et al., 2016) (g) servo-controlled power-assisted wheelchair (Medola et al., 2018) (h) gear less electrical motor for an ergonomic wheelchair (Tarimer et al., 2008) (see online version for colours)



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Medola et al. (2018) proposed a servo-controlled power-assistance system based on biomechanics for manual wheelchairs. The above designs' major limitation is wheelchair size (Medola et al., 2018). Galvan et al. invented a new device to convert a manual wheelchair into a powered wheelchair (Galvan et al., 2017). He invented an attachable power module for a manual wheelchair (Ramirez and Holloway, 2017). Lee et al. (2016) discussed the gravity compensated power-assisted wheelchair to save energy of the rider. Yoon et al. (2016) developed a hybrid-powered wheelchair with novel mechanical and control structures. Medola et al. (2012) explained the servo-controlled power-assisted system by modifying the manual wheelchair frame's standard design.

Tarimer et al. (2008) did a power-assisted module with a geared direct current (DC) motor and examined its efficiency for no-load and load conditions. The various prototype designed by researchers to represent the power-assisted modules, as depicted in Figure 3. Apart from the models mentioned in Figure 3, researchers developed the simulation model proof for their ideas. Avutu et al. noted the lever assisted power module (Avutu et al., 2016) and different drive systems in transferring the motor's rotational energy to the wheel (Avutu et al., 2017). Kwak et al. (2017) tested a one-wheel hybrid wheelchair's performance. Yang et al. (2012) explained the dual power wheels.

From the author's perspective, the powered wheelchair has to design, which is weightless and user-friendly. The manufacturing cost will come down if caster wheels of manual wheelchairs have replaced with powered wheels compared to traditional powered wheelchairs. This design allows the user to integrate the powered module system into any manual wheelchair. The standing-powered wheelchair much useful for disabled with diabetics since it reduces the risk from pressure sores – unfortunately, commercialisation is not done for the bulk of designs and prototypes.

4 Add-on devices

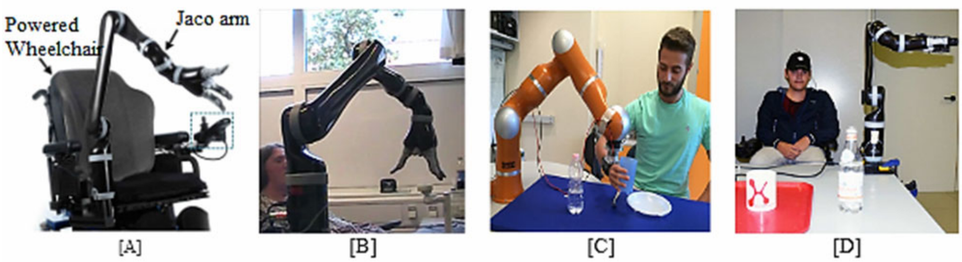
The add-on devices will facilitate the user to achieve their task efficiently. Sometimes, these devices can replace the need for a caregiver or ease the task. However, the add-on devices will consume power, and a wheelchair becomes more complex and bulkier. Therefore, detachable and lightweight add-on devices are desirable without compromising the essential functions of the wheelchair. The add-on devices categorised as

- robotic arms
- path planning device
- movement control devices.
- communication devices
- exoskeleton modules
- physiotherapy devices

4.1 Robotic arms

Robotic arms mounted on the wheelchair or table. Compared to wheelchair fitted components, table-mounted arms have more advantages. Mechanical arm performance depends upon the degree of freedom (DOF), weight, material, and control methods. More DOF allows more tasks to perform without caregivers. The wheelchair with two robotic arms helps users do tasks such as sit and stand, transfer between bed to a wheelchair, and vice versa. Fall et al. (2018) proposed a multimodal body-machine interface using custom-designed surface electromyography sensors. Struijk et al. (2017) found a tongue-controlled assistive robotic arm for tetraplegia people. Lauretti et al. (2017) introduced the motion planning system for a robotic arm.

Figure 4 Recent developments in different robotic arm designs, (a) the JACO robotic arm mounted on the wheelchair (Fall et al., 2018) (b) tongue-controlled assistive robotic arm (Struijk et al., 2017) (c) DMP computational models (Lauretti et al., 2017) (d) lightweight robotic arms (Baldi et al., 2017) (see online version for colours)



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Baldi et al. (2017) proposed a lightweight robotic arm to serve people with has limb mobility impairments. The recent developments in different computerised arm designs, as shown in Figure 4. Besides these, Graser et al. (2013) explained the assessment of the time taken for a robotic arm to design and different ways the user can use. Several researchers developed novel ideas using advanced technology and implemented it in the simulation atmosphere (Yu et al., 2017b). However, the prototype can help to check the device's feasibility in a real-time environment.

4.2 Path navigation module

Path search, obstacle identification, and device movement control are the crucial stages in navigation module design. The selection of path search algorithms (Avutu et al., 2017) has based on the path's nature, either a known or unknown path. To capture the image of the real-time surroundings used cameras. They compared the real-time images with an initially stored database using the image processing algorithm to control device movement. Observed a significant difference in algorithms used for autonomous navigation in different surroundings, such as indoor and outdoor. The outdoor navigation depends on surface types like sandy, muddy, and hilly terrains. High torque has required to create movement in the wheel on these surfaces compared with the typical body. To the best of our knowledge, for wheelchair movement control, significant research has been done on existing navigation algorithms. However, the cost of such modules is high and unaffordable for ordinary people. The obstacle in the path may be stationary or dynamic. To identify these obstacles used, various sensor fusion techniques. The signals from various sensors have fed to the processing unit to design an accurate obstacle detection module. It provides the device's control signal – the recent developments in the path search algorithms, including path mapping given in Table 3.

Table 3 The recent development in the path search algorithms and mapping

Novelty	*Reference*
Understanding indoor scenes' efficiency from a single image increased with no knowledge of the internal camera calibration.	Wei and Wang (2018)
An algorithm has developed to combine the functions of star trackers and navigation cameras.	Jiang et al. (2018)
Introduced the flicker-free line coding scheme to increase the accuracy of indoor navigation.	Fang et al. (2017)
The Neural networks and line-of-sight guidance algorithms merged to improve the identification of the path near the door.	Jung et al. (2018)
He introduced a histogram-based generic framework for the indoor position system.	Bateux and Marchand (2017)
Carried out the Bluetooth low energy method, together side a machine mastering procedure.	Miyamoto et al. (2018)
Light detection and ranging [LIDER] concept used for navigation	Grewal et al. (2017)
Created an algorithm depending around the intermediate concentrate on along with a fuzzy logic controller	Maatoug et al. (2017)
They discussed the angle's difference of arrival (ADOA) in the 3D coordinate system for the indoor position system.	Zhu et al. (2018)
Explained the deep learning techniques to increase the accuracy of the indoor positioning system.	Clement and Kelly (2018)
Elobirated neural network models have to estimate the corrections from ground-truth training data.	Peretroukhin and Kelly (2018)
They introduced an improved visible light positioning system algorithm.	Zhang et al. (2017)
Explained the theoretical framework methods are to optimise the performance of spectral compression.	Talvitie et al. (2018)
Analysis of a large synchronised-based camera system dataset has discussed.	Zhu et al. (2018)
An algorithm introduced to correct errors caused by the scale drift in the monocular simultaneous localisation and mapping (SLAM) algorithm.	Shiozaki and Dissanayake (2018)
This calibration procedure directly estimates the mounting parameters for laser scanners and cameras.	Ravi et al. (2018)
Mentioned the lively mapping program utilising stereovision for navigation	Faisal et al. (2018)
Discussed the edge-f algorithm to estimate the velocity and depth of the autonomous vehicle.	McGuire et al. (2017)
Discussed scan site navigation and SLAM based on a continuously updated point cloud map.	Kim et al. (2018)

Table 3 The recent development in the path search algorithms and mapping (continued)

Novelty	*Reference*
For navigation mapping algorithms and simultaneous calibration have been introduced.	Gualda et al. (2019)
Discussed the multimodal 3D-based sensor for the large-scale area mapping	Jeong et al. (2018)
They elaborated on the utility of the open-source hardware and radio network sources for path mapping.	Miah et al. (2018)
They discussed autonomous vehicle position identification.	Horst and Möller (2017)
Clarified that the topological map structure and spectacle recognition to car or truck localisation	Lin et al. (2018)
The future automotive localisation algorithms have discussed for autonomous vehicles	Karlsson and Gustafsson (2017)
A ceiling-feature map designed using the upward-looking monocular camera has discussed	Jung and Song (2017)
Wi-Fi-based localisation system has discussed for autonomous navigation	Wang et al. (2017)
Because of discretised maps, discussed indoor localisation and mapping pedestrian dead reckoning.	Wang and Shen (2017)
Cascaded Kalman filter framework has proposed for MAP/INS/integrated Wi-Fi system.	Yu et al. (2017a)
He proposed UAV integrated LIDAR with the Inertial Measurement system for path mapping and localisation.	Kumar et al. (2017)
The Q-learning concept has used for path mapping and localisation	Huang et al. (2016)
They discussed lexical-based topological mapping for path mapping and localisation.	Rangel et al. (2017)
Discussed the web-based indoor navigation technique	Zeinalipour-Yazti et al. (2017)
They discussed the ring compression analysis concept and least trimmed squares.	Hata and Wolf (2016)

The current research and the corresponding article on alert devices design shown in Table 4. The accuracy of the complete navigation system depends on the control unit, which processes the signal coming from various sensors with the processing unit's help. It will provide an output signal for device movement control based on the system's algorithm. The joystick is a standard device used to control the movement of the powered wheelchair. According to user needs, the brain-computer interface's recent developments provide ample scope to design more accurate and sophisticated control devices without compromising engineers' essential utility. The current research has continued utilising physiological signals like EMG, EEG, EOG, Touch screen, and Remote control to control a modern wheelchair's movement.

Table 4 Recent research related to alert devices

Novelty	*Reference*
They introduced the application of a laser pointer and Android smartphone for obstacle detection	Saffoury et al. (2016)
They elaborated on the concept of local feature extraction and scale-invariant feature transform algorithms	Jabnoun et al. (2015)
Downsampling random sample consensus concept used	Li et al. (2015)
The multi-scale Lucas-Kanade algorithm has introduced	Tapu et al. (2013)
The concept of stereo cameras and M.W. radar used to sense the environment	Song et al. (2018)
Stereovision-based method used for detecting obstacles. Deep stacked auto-encoders and K-nearest neighbour's used	Dairi et al. (2018)
The concept of colour-coded markers with micro-ultrasonic transducers used to detect the obstacles	Lee et al. (2018)
Reliability of a laser scanner used for obstacle detection	Garcia et al. (2017)
The concept of an in-depth learning approach with the use of multiple sources used	Nguyen et al. (2017)
The modal predictive control-based algorithm used	Liu et al. (2017)
Trajectory preparation and quickly exploring arbitrary shrub algorithm utilised	Pharpatara et al. (2017)
He used the concept of a Markov random field framework	Kristan et al. (2016)

4.3 Future wheelchair perception

As per the literature, several researchers are trying to integrate modern technology devices to help ordinary people enhance their quality of life. In the future, exoskeletons may replace a wheelchair. The recent development in exoskeleton devices by worldwide researchers has shown in Table 5.

Table 5 Recent developments for exoskeleton devices

Recent developments	*Reference*
The operator can get full control in real-time using 'powered alternately walking exoskeleton' with the wheeled foot	Ma et al. (2018)
the linear quadratic regulator used to control the sagittal-plane walking	Nataraj and van den Bogert (2017)
Powered ankle plantar flexion included to the normal Exoskeleton	Griffin et al. (2017)
They developed five degrees-of-freedom shoulder exoskeletons	Hunt et al. (2017)
Lower limb exoskeleton	Lajeunesse et al. (2016)
They elaborated exoskeletons suitable for lower-body paralysis	Leslie (2012)
Goodbye wheelchair	Strickland (2012)
Medical exoskeleton has introduced with experimental results	Strausser et al. (2010)

5 Conclusions

Wheelchairs provide mobility to the disabled person. Additional design changes address their needs and comfort levels. We are witnessing the significant design change from a manual to electrical and up to a smart wheelchair. It signifies a paradigm change, despite one that happened when power wheelchair grew to become accessible the mass scale,’’ which had been technological progress from the handbook. Over the past ten years, computers and detectors are becoming faster, more affordable, and more significant, while computer-vision applications have gotten more complicated and easily accessible than before. The study area has generated many prototypes, the most useful sections substituted for a modular, upgradeable technique to promote the enormous numbers of individuals who want a wheelchair. Electric auto manufacturers have a primary situation to generate a stand-alone smart wheelchair and capitalise on the countless growing older baby boomers globally.

The smart wheelchairs can allow for people who have disability types by utilising a multimodal user interface that unites personal computer vision, contact, voice, and brain controller. These will have the ability to construct third maps utilising cell scanners and browse by flowing and assessing sensory info into real-time through cloud computing software. The point is intended for robots and humans to successfully socialise with public places to supply persons with disabilities the optimal/optimally standard of living feasible the chance to make the most of their capacity.

One can add various sensors, vision, and voice-activated robotic arms to a wheelchair. However, modular systems have preferred, which enables the user to choose options as desired. The thrust is to use navigation tools provided by mobiles, real-time sensor data analysis via cloud computing so that disabled people can function normally despite their disabilities and limitations. A robotic-human interface has set for the next stage where it carries out all the owner’s activities as required, thus freeing from themselves. Exoskeleton interface is the other possibility that enables the disabled to do everyday activities with ease. In Japan, paralytic patients could usually walk with exoskeletons. With these technological advances, disabled persons need not feel that they have disadvantaged.

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