

# Comparative Analysis of Gearbox Technologies in Indian Passenger Cars

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## Abstract

The Indian car sector has grown rapidly, offering a wide range of vehicles with cutting-edge technology. Transmission technology transfers engine power to the wheels, making it crucial to vehicle engineering. Indian vehicle gearbox technology will be thoroughly examined in this research. The paper examines manual, automatic, continuously variable, dual-clutch, and automated manual gearboxes. It extensively evaluates these technologies' working principles, advantages, limitations, and applications across vehicle segments. The essay examines how gearbox technology affects vehicle performance, fuel economy, and driving pleasure. The findings of this research will help Indian automotive industry stakeholders choose and improve transmission systems in future cars.

**Keywords:** *Manual Transmission, Automatic Transmission, Continuous Variable Transmission (CVT), Dual-Clutch Transmission (DCT), Automated Manual Transmission (AMT), IMT (Intelligent Manual Transmission).*

## 1. INTRODUCTION

The Indian automotive market has experienced a notable transformation in recent years due to the increasing demand for automatic gearbox technology. Automatic gearboxes provide convenience, ease of use, and improved driving comfort when compared to manual transmissions. Car manufacturers have confidently introduced a range of automatic gearbox systems to meet the changing tastes of Indian consumers. This study paper aims to offer a thorough overview of the many types of automatic gearbox technology utilised in the Indian automotive market. This study tries to provide clarity on the options accessible to Indian car purchasers by examining the operational principles, benefits, drawbacks, applications, and market presence of each gearbox type. The study will mainly concentrate on four key types of automatic transmission systems: torque converter, dual-clutch, continuously variable transmission (CVT), and automated manual transmission (AMT).

These technologies have been prominent in the Indian automotive market because of their distinctive features and adaptability to various driving circumstances. In order to achieve a thorough comprehension, this research work employs a methodical methodology. We will do a thorough literature research, analyse industry reports, and examine market trends to acquire the necessary data and insights. In addition, we will take into account expert opinions and customer preferences to offer a comprehensive assessment of the present status and future potential of automatic gearbox technology in India. The conclusions of this research paper will undoubtedly assist automotive manufacturers, industry professionals, and consumers alike, providing them with vital insights to make well-informed judgements regarding the most suitable automatic gearbox system for their specific demands.

Moreover, the study will enhance the current knowledge base by providing a contemporary overview of the Indian vehicle market and its automatic gearbox technological landscape. The subsequent sections will thoroughly examine each form of automatic gearbox system, encompassing its operational concept, benefits, drawbacks, applications, and market presence in India. We will undertake a comparison analysis to evaluate the performance and efficiency of different technologies, as well as investigate consumer preferences and market trends. The study will finish by providing a comprehensive analysis of the industry forecast and future trends in automatic gearbox technology, taking into account the potential obstacles and possibilities that await.

## 2. OBJECTIVES

The objective of the paper are:

- (1) To identify and classify the different gearbox technology used in the passenger car segment
- (2) To examine the benefits and drawbacks of each gearbox type in terms of performance, fuel efficiency, and cost-effectiveness.
- (3) To examine the influence of various gearbox technologies on the overall driving experience, encompassing factors like comfort, smoothness, and responsiveness.
- (4) To enhance future research and development in the field of automotive engineering in India, I hope to make a valuable contribution to the existing body of knowledge on gearbox technology.

## 3. LITERATURE REVIEW

"A Comparative Study of Manual and Automatic Transmissions in Indian Passenger Cars": 2018, Singh, R., & Gupta, A. This study conducted a comparison between manual and automatic gearbox technologies in the Indian passenger car segment. The analysis considered criteria such as fuel efficiency, performance, and customer happiness in order to provide insights into current trends and consumer preferences. Reddy, S., & Kumar,

2019, "Environmental Impact Analysis of Various Gearbox Technologies in Indian Commercial Vehicles": Reddy, S., & Kumar, A. This study examined the environmental effects of different gearbox technology in commercial cars in India. The study examined emissions data and fuel use to evaluate the sustainability of several gearbox types. Another paper titled "Challenges and Opportunities in the Adoption of Advanced Transmission Systems by Indian Automobile Manufacturers": 2020 by Sharma, P., & Verma, N.

This article analysed the obstacles encountered by Indian vehicle manufacturers while implementing advanced transmission systems, such as CVT and DCT. The integration of these technologies was examined, highlighting the prospects and potential benefits. Notable paper titled "Government Regulations and their Impact on Transmission Technology Choices in India" 2021, Patel, V., & Desai, S.

This study examined how government policies and regulations influence the selection of transmission systems by Indian vehicle manufacturers. The analysis examined the influence of emission regulations and other regulatory actions on gearbox decisions.

Another paper titled "Consumer Perception and Acceptance of Automatic Transmission in Indian Passenger Cars": 2022 by Gupta, M., & Sharma, R. examined consumer perceptions and acceptance of automatic transmission technology in Indian passenger cars and this paper investigated the factors that influence consumer preferences and identified potential obstacles to widespread adoption.

"Technological Advancements in Transmission Systems: A Review of Recent Developments in the Indian Automotive Industry": 2023, Kumar, S., & Choudhary, A. This review paper provides a comprehensive overview of the recent advancements in transmission systems within the Indian automotive industry. It focuses on the notable innovations and enhancements made across different types of transmissions.

#### 4. RESEARCH GAP

Despite the global interest in gearbox technology research, there is a lack of studies that specifically examine the dynamics of the Indian market. Existing literature mainly focuses on developed markets, so there is a need for more research to understand the unique challenges and opportunities faced by the Indian automobile industry in adopting various gearbox technologies. Additionally, there is a limited number of studies that combine consumer perspectives and environmental impact.

#### 5. METHODOLOGY & INTERPRETATION

There are four types of gearbox technologies.

##### 1. Manual Transmission

A manual transmission, also known as a manual gearbox or standard transmission, is a transmission technology where the driver manually selects and engages gears using a gear stick and clutch pedal. The transmission system consists of key components, including the clutch, flywheel, gear selector mechanism, and gears. The working principle of a manual transmission involves the coordination between the engine, clutch, and gears to transfer power from the engine to the wheels. When the driver presses

##### Benefits

Manual gearboxes have gained popularity in the Indian vehicle industry due to their numerous advantages:

- a. **Control:** Manual transmissions offer drivers enhanced control over the vehicle's acceleration, deceleration, and gear selection. Drivers have the ability to manually shift gears based on their preferences and driving conditions, resulting in a more engaging and dynamic driving experience.
- b. **Cost and Maintenance:** Manual transmissions are typically more affordable to produce and upkeep in comparison to automatic transmissions. They possess fewer intricate parts, hence decreasing the expenses associated with repairs and replacements.
- c. **Fuel Efficiency:** Manual transmissions can provide superior fuel efficiency compared to some types of automatic gearboxes, particularly in specific driving conditions like interstate cruising or steady-speed driving.

- d. Performance: Manual transmissions frequently offer superior performance and responsiveness, especially in sports cars or high-performance vehicles. They enable drivers to accurately manage the engine's power output and gear ratios, leading to faster acceleration and improved overall performance.

#### Drawbacks

In addition to their advantages, manual gearboxes do have certain drawbacks:

- a. Learning Curve: Mastering a manual gearbox demands specific abilities, and novice drivers may have to dedicate time and energy to acquire the skills of shifting gears and engaging the clutch seamlessly. This can discourage persons who want a more straightforward driving experience.
- b. Traffic Congestion: When faced with heavy traffic or stop-and-go circumstances, the continuous use of the clutch and frequent gear shifting can be tiring and uncomfortable. It demands greater effort and concentration from the driver in comparison to automated transmissions.
- c. Fatigue and Physical Exertion: Extended utilisation of a manual gearbox, particularly in congested traffic or on lengthy journeys, can result in tiredness and physical strain caused by the frequent use of the clutch pedal and gear shifting.

### 5.1 Application within the Indian Automobile Industry

Manual transmissions have been widely used in the Indian automobile industry, especially in entry-level and mid-range vehicles. They are popular for compact cars, hatchbacks, sedans, and some SUVs. Manual transmissions are cost-effective, offer better fuel efficiency, and can handle different road conditions across the country. In India, many car buyers prefer manual transmissions because they are affordable and have lower maintenance costs. Additionally, having both manual and automatic transmission.

It is worth noting that the Indian automobile industry has experienced a transition towards automatic transmissions in recent years. This change has been motivated by evolving consumer preferences and advancements in automatic transmission technology. The shift reflects the changing needs and desires of Indian consumers who value convenience, user-friendliness, and improved driving comfort. However, manual transmissions still hold importance, especially in specific vehicle segments and price ranges.

### 5.2 Effortless Gear Shifting Principle of Operation

Automatic transmissions, also called automatic gearboxes, are a transmission technology that removes the need for manual gear shifting by the driver. Instead, the transmission system automatically chooses and engages the right gear ratios based on vehicle speed, engine load, and other factors. The working principle of an automatic transmission involves important components like a torque converter, planetary gearsets, hydraulic system, and electronic controls. The torque converter functions as a fluid.

Within the automatic gearbox, a number of planetary gearsets are in charge of producing different gear ratios. These gearsets are made up of various gears, such as sun gears, planet gears, and ring gears. By selectively engaging and disengaging these gears using a combination of clutches, brakes, and bands, the automatic gearbox is able to provide the necessary gear ratio to the wheels without the need for manual input.

The hydraulic system, operated by electronic solenoids and valves, manages the flow of hydraulic fluid to control the activation and deactivation of the gear components. The electronic control unit (ECU) oversees different input parameters, such as vehicle speed, throttle position, and engine load, to calculate the most suitable gear ratio and make necessary adjustments.

### 5.3 Automated Manual Transmission (AMT)

The working principle

Automated Manual Transmission (AMT) is a type of transmission technology that combines the convenience of an automatic transmission with the cost-effectiveness of a manual transmission. It uses an electronic control unit (ECU) to automate the clutch operation and gear shifts, eliminating the need for the driver to manually operate the clutch pedal. The working principle of an AMT involves a manual transmission with a hydraulic actuator or an electromechanical system that controls the clutch and gear selection. The ECU receives input signals from various sensors, including vehicle speed, engine speed, throttle position, and driver inputs. Based on these inputs, the ECU determines the optimal gear ratio and timing for gear shifts. During gear changes, the AMT momentarily disengages the clutch, shifts the gear using the gear selector mechanism, and then re-engages the clutch. The clutch engagement and disengagement are controlled by hydraulic actuators or electromechanical systems. The driver can select the desired driving mode, such as automatic or manual mode, allowing them to manually override the gear selection when desired.

Benefits

AMTs have numerous benefits that contribute to their popularity in the Indian automotive sector:

- a. **Cost-Effectiveness:** AMTs are more affordable to produce and install in comparison to conventional automatic gearboxes. They make use of existing manual transmission components and necessitate minimum alterations, making them a cost-effective choice for both automakers and consumers.
- b. **Enhanced Convenience:** AMTs offer the convenience of an automatic transmission by eliminating the requirement for clutch pedal operation and manual gear shifting. This renders them suitable for drivers who desire an automatic-like driving experience without the elevated cost linked to traditional automatic transmissions.
- c. **Enhanced Fuel Efficiency:** AMTs frequently provide superior fuel efficiency in comparison to conventional automatic gearboxes. They enable optimised gear shifts that are tailored to real-time driving conditions, hence contributing to enhanced fuel economy and decreased emissions.
- d. **Versatility in Handling Different Driving Conditions:** AMTs excel in adapting to diverse driving conditions, such as navigating through city traffic or cruising on highways. They deliver seamless gear shifts and effortless clutch operation, guaranteeing a hassle-free driving experience in congested traffic and enhanced control for overtaking and accelerating on highways.

## Drawbacks

However, AMTs do come with a few limits and disadvantages:

- a. **Shift Lag and Jerky Gear Changes:** AMTs may encounter a minor delay or shift lag while changing gears, leading to a slightly rough driving experience. This is especially obvious when accelerating or decelerating rapidly.
- b. **Decreased Smoothness:** The automated clutch function in AMTs may not be as smooth as that of classic automatic transmissions. The clutch engagement and disengagement can occasionally be noticeable, resulting in a less polished driving experience compared to fully automatic transmissions.
- c. **Manual Control Limitations:** Although AMTs do provide a manual mode for selecting gears, they may not give the same degree of control and precision as a conventional manual gearbox. The gear changes may still be partially automated, reducing the driver's direct involvement.

## 5.4 Implementation in the Indian Automobile Sector AMTs

Implementation in the Indian Automobile Sector AMTs have become extremely popular in the Indian automobile industry, especially in entry- level and mid-range vehicles. They are the preferred choice for consumers who want the convenience of automatic transmissions at a more affordable price.

In India, AMTs are widely used in compact cars, hatchbacks, sedans, and even some SUVs. They offer a cost-effective alternative to traditional automatic transmissions while providing better convenience compared to manual transmissions.

Several manufacturers in India, including as Maruti Suzuki, Hyundai, Tata Motors, and Renault, have successfully met the rising demand for automatic transmissions by introducing vehicles equipped with AMTs. The inclusion of AMTs has played a crucial role in driving the expansion of the automatic transmission category.

## 5.5 CVT, or Continuously Variable Transmission

CVT, or Continuously Variable Transmission is a type of transmission.

### Principle of Operation

CVT, or Continuously Variable Transmission, is a transmission technology that offers seamless and infinite gear ratios. Unlike traditional transmissions with a fixed number of gears, CVT uses pulleys and a belt or chain to provide a continuously variable range of gear ratios. The working principle of a CVT involves two primary components: a variable input pulley and a variable output pulley connected by a belt or chain. Each pulley consists of adjustable cones that can change the effective diameter.

### Benefits

CVTs have gained popularity in the Indian vehicle market because to their several advantages:

- a. **Achieving a Smooth and Effortless Power Delivery:** CVTs offer a driving experience that is both smooth and uninterrupted, ensuring a continuous flow of power. The infinite gear ratios enable the engine to function within its most efficient RPM range, leading to enhanced fuel efficiency and a pleasant driving experience.



- b. **Enhanced Fuel Efficiency:** CVTs excel at optimising engine performance by maintaining the engine RPM within the most fuel-efficient range. As a result, they offer superior fuel efficiency compared to conventional automatic or manual transmissions, particularly during consistent-speed driving or in heavy traffic situations.
- c. **Improved Performance:** CVTs offer superior acceleration performance in comparison to conventional transmissions. The continuous gear ratios facilitate a more efficient power transfer to the wheels, resulting in rapid and seamless acceleration without the necessity for manual gear changes.
- d. **Compact and Lightweight:** CVTs are often more compact and lighter than conventional gearboxes, making them ideal for smaller and more fuel-efficient vehicles. The decreased weight enhances fuel efficiency and overall vehicle performance.

#### Drawbacks

CVTs, while advantageous in many ways, can have several restrictions and disadvantages:

- a. **Limited Power Handling:** CVTs may have restrictions in managing high torque or power outputs. In certain instances, the belt or chain may have a limited torque capacity, which can restrict the use of CVTs in high-performance or heavy-duty cars.
- b. **Reduced Driving Engagement:** Certain drivers may see CVTs as less engaging in comparison to conventional transmissions. The lack of discernible gear shifts can lead to a sense of detachment or a less dynamic driving experience for enthusiasts who appreciate the involvement of manual gear changes.
- c. **Possibility of Belt or Chain Wear:** The belt or chain utilised in CVTs may experience wear and tear over time. The maintenance and replacement of the belt or chain might be more intricate and expensive in comparison to conventional gearboxes.
- d. **Noise and Vibration:** CVTs have the potential to generate greater noise and vibration than traditional gearboxes, especially during intense acceleration or at high RPMs. Nevertheless, developments in CVT technology have significantly reduced these problems in modern automobiles.

#### Application within the Indian Automobile Industry

CVTs have become popular in the Indian automotive industry, especially in compact cars, sedans, and SUVs. They are well-suited for urban driving conditions, where smooth and efficient power delivery is crucial. CVTs have been widely used in small and mid-sized cars, offering improved fuel efficiency and a comfortable driving experience. In recent years, several automakers in India have introduced vehicles equipped with CVTs to meet the growing demand for automatic transmissions. These include Hyundai, Maruti Suzuki (Nexa models), Nissan, Mahindra, Volkswagen, and Toyota, among others. The availability of CVTs has given customers more options, combining the convenience of automatic transmissions with better fuel efficiency. CVTs have been particularly successful in the mid-range segment, attracting buyers who seek a balance between performance and fuel economy.

### 5.6 Dual Clutch Transmission (DCT) Principle of Operation

Dual-Clutch Transmission (DCT), also known as a twin-clutch transmission or direct-shift gearbox (DSG), is a type of transmission technology that combines the efficiency of

manual transmissions with the convenience of automatic transmissions. It uses two separate clutches to enable quick and seamless gear shifts without interrupting power delivery.

#### The working principle of a DCT

It involves two sets of clutch packs and gears, one for odd-numbered gears (1st, 3rd, 5th, etc.) and another for even-numbered gears (2nd, 4th, 6th, etc.). While driving in a specific gear, the next gear is pre-selected and engaged on the inactive clutch pack. When a gear change is initiated, one clutch disengages the current gear, while the other clutch simultaneously engages the pre-selected gear. This allows for near-instantaneous gear changes without any interruption in power delivery. The gear changes in a DCT are controlled electronically, and the system anticipates the driver's gear selection based on various parameters, such as vehicle speed, engine load, and driver inputs. Some DCTs also offer a manual mode, allowing the driver to manually control gear shifts using paddle shifters or a gear lever.

#### Benefits

DCTs have gained popularity in the Indian vehicle industry because to their several advantages:

- a. **Rapid and Seamless Gear Shifts:** DCTs offer exceptionally quick gear changes without any significant loss of power. The dual-clutch technology enables advance selection of the next gear, ensuring smooth and accurate shifts, whether in automatic or manual mode.
- b. **Enhanced Fuel Efficiency:** DCTs provide superior fuel efficiency in comparison to conventional automatic gearboxes. The swift and effective gear shifts enable the engine to function at its ideal RPMs, hence maximising fuel efficiency while delivering improved performance.
- c. **Improved Performance:** DCTs offer exceptional acceleration performance thanks to their capability to deliver fast and accurate gear shifts. The direct power transfer and reduced power loss contribute to enhanced vehicle performance and a dynamic driving experience.
- d. **Manual Mode for Enthusiasts:** DCTs offer a manual mode alternative for enthusiasts who appreciate the control and involvement of manual gear shifting. The paddle shifters or gear lever enable the driver to manually override the automatic mode and choose the desired gear for a more immersive driving experience.

#### Drawbacks

Although DCTs offer numerous benefits, they do come with certain restrictions and drawbacks:

- a. **Cost and Complexity:** DCTs are typically pricier to produce and upkeep in comparison to conventional manual or automatic transmissions. They comprise intricate mechanical and electronic parts, such as dual clutches and control systems, which can elevate the overall cost and complexity of the transmission.
- b. **Possibility of Smooth Low-Speed Operation:** Certain DCTs may demonstrate a minor jerkiness while operating at low speeds or when initiating movement from a stationary position. This can be attributed to the inherent characteristics of the dual-clutch system and the necessity to rapidly engage and disengage clutches.



- c. **Heat and Durability Concerns:** DCTs produce a higher amount of heat in comparison to standard transmissions because of the friction that occurs during quick gear shifts. Proper heat control and the durability of the clutch system are crucial factors to take into account for DCTs in order to guarantee long-lasting dependability and optimal performance.
- d. **Repair and Maintenance:** In the event of a severe failure or the need for repair, a DCT can be more intricate and expensive than regular transmissions. Typically, specialised expertise and equipment are necessary to fix or replace components within the DCT.

#### Application within the Indian Automobile Industry

DCTs have garnered considerable popularity in the Indian automotive sector, especially in high-performance vehicles and premium models. They offer a blend of the fuel efficiency found in manual transmissions and the convenience of automatic transmissions, making them attractive to both car enthusiasts and everyday commuters.

Automakers in India have successfully introduced DCT-equipped vehicles in different segments, such as compact cars, sedans, and SUVs. These transmissions are ideal for drivers who desire a dynamic driving experience, rapid gear changes, and enhanced fuel efficiency. The wide range of models offering DCTs has increased customer options and played a significant role in the expansion of the automatic gearbox market in India. Tata Motors and Hyundai India Limited have specifically emphasized DCT.

Recent advancements in DCT technology have specifically targeted the issues of low-speed operation and durability, resulting in improved performance and reliability of these transmissions. With the growing demand for better driving experiences, DCTs are anticipated to be more widely used and refined in the Indian automobile industry.

#### 5.7 Smart Manual Transmission

"Intelligent Manual Transmission" is a technology Hyundai has introduced for select vehicles. It is a transmission that combines the control of a traditional manual gearbox with the convenience of an automatic transmission. The iMT system operates without a clutch pedal, setting it apart from conventional manual transmissions.

The working premise of Hyundai's iMT is as follows:

1. **Automated Clutch Operation:** In a traditional manual transmission, the driver relies on the clutch pedal to separate the engine from the gearbox during gear shifts. However, in the iMT, the clutch is handled electronically, eliminating the need for a clutch pedal.
2. **Clutch-by-Wire Technology:** The iMT system utilises a cutting-edge "clutch-by-wire" technology. Upon the driver's gear change command, the system intelligently detects the driver's intention through sensors and seamlessly manages the clutch operation.
3. **Driver Input Detection:** The iMT system effectively monitors many inputs, including accelerator pedal position, brake pedal status, gear lever position, and engine RPM.
4. **The iMT system employs advanced software algorithms to analyse driving conditions and the driver's behaviour, accurately predicting the optimal moments to engage and disengage the clutch for gear changes.**
5. **Engine RPM Synchronisation:** The iMT technology guarantees the proper synchronisation of engine RPM and gearbox input shaft speed, ensuring smoother gear shifts when engaging the clutch.

6. **Neutral Gear Detection:** The iMT system confidently detects the driver's intention to shift to neutral, for example, while coasting or idling, and autonomously disengages the clutch.
7. **Start-Stop Functionality:** Certain iMT systems can be integrated with the engine's start-stop feature, which automatically shuts off the engine when the vehicle comes to a stop, and then restarts it when the driver is prepared to resume movement.
8. **Manual Mode:** The iMT also offers the driver the ability to take control of gear changes manually using paddle shifters or a standard gear stick, allowing for a more engaging driving experience whenever desired.

The main objective of Hyundai's iMT system is to offer drivers a more convenient and comfortable driving experience while still preserving the enjoyment and involvement of driving a manual transmission. By automating the clutch operation, the iMT eliminates the need for drivers to concern themselves with clutch control, making it especially attractive to those who have less experience with manual transmissions.

#### Benefits

- a. **Cost and Maintenance:** It is somewhat more expensive than manual gearbox and has a lower maintenance cost.
- b. **Operations:** It functions similarly to a manual gearbox car, but without the need for a clutch pedal.

#### Drawbacks

**Limited availability:** This technology is exclusively offered in select Hyundai automobile models.

### 5.8 The influence of various gearbox technologies on vehicle performance

#### Velocity and Maximum Speed

The choice of transmission technology can have a significant impact on a vehicle's acceleration and top-speed capabilities. Different types of transmissions offer varying gear ratios and shift characteristics that directly influence how quickly a vehicle can accelerate and its maximum achievable speed. In terms of acceleration, automatic transmissions, including AMTs, CVTs, and DCTs, often provide smoother and quicker gear shifts compared to manual transmissions. This allows for faster and more consistent acceleration, especially in situations where rapid gear changes are required, such as overtaking or merging onto highways. However, it's worth noting that high-performance vehicles or sports cars often feature manual transmissions, as they offer precise control over gear selection and engagement. Skilled drivers can optimize gear shifts to extract maximum performance from the engine, resulting in impressive acceleration capabilities. When it comes to top speed, the choice of transmission technology plays a less significant role. The primary factors influencing top speed are the engine power and aerodynamics of the vehicle, rather than the specific transmission type. All types of transmissions can achieve similar top speeds if the engine power is sufficient and the vehicle design allows for minimal drag.

#### Effective Management and Mastery

Transmission technology has a notable impact on a vehicle's handling and control, especially during dynamic driving manoeuvres and cornering. The smoothness and speed of gear changes, as well as the ability to maintain the engine's optimal RPM, have a significant

influence on the vehicle's balance, stability, and overall handling characteristics. Manual transmissions offer a great deal of control over gear selection, enabling drivers to choose the most suitable gear for the driving conditions. However, automatic transmissions like CVTs, AMTs, and DCTs have the benefit of delivering seamless gear changes without the need for manual input. This can result in a smoother and more reliable driving experience, especially for daily commuting or navigating through heavy traffic. Certain sophisticated automatic transmissions, such as DCTs, provide the option of manual mode, enabling drivers to manually choose gears using paddle shifters or a gear lever. This feature combines the ease of automatic shifting with the capability to assume control in dynamic driving scenarios, thereby enhancing handling and control.

### Impressive Towing and Off-Road Capability

Transmission technology can also impact a vehicle's towing and off-road capability, as these activities often require specific gear ratios and torque delivery. Manual transmissions are generally preferred for towing heavy loads or navigating challenging off-road terrains. Their ability to provide precise control over gear selection allows drivers to choose lower gears for increased torque and pulling power. Manual transmissions also tend to have higher torque capacity, making them better suited for demanding tasks. In contrast, automatic transmissions, including AMTs, CVTs, and DCTs, can offer advantages in certain towing or off-road scenarios. Their ability to seamlessly adapt gear ratios based on driving conditions can provide smoother power delivery and improved traction control, especially when traversing variable terrains. Additionally, some automatic transmissions offer specific driving modes, such as "tow/haul" or "off-road," which optimize gear shifting patterns and torque distribution to enhance towing and off-road performance.

It should be emphasised that the towing and off-road capability of a vehicle is affected by multiple factors apart from the gearbox type. These factors include engine power, suspension system, drivetrain configuration, and vehicle weight distribution. A well-thought-out combination of these factors, along with the suitable gearbox technology, guarantees optimal performance in towing and off-road scenarios. Ultimately, it can be confidently stated that both Continuously Variable Transmissions (CVTs) and Dual-Clutch Transmissions (DCTs) have distinct benefits and factors to consider within the Indian automotive sector.

CVTs are highly effective at delivering power smoothly and efficiently, leading to enhanced fuel efficiency and a pleasant driving experience, especially in urban driving situations. They have become increasingly popular in compact cars, mid-sized sedans, and SUVs, providing a practical alternative to conventional automatic and manual transmissions. Nevertheless, CVTs could have difficulties when it comes to managing high torque and the perceived absence of driver engagement and dynamic driving experience. Noise and vibration levels could also be a matter of concern, and durability issues may arise owing to elevated operating temperatures. However, DCTs effortlessly merge the effectiveness of manual transmissions with the convenience of automatic transmissions. They provide swift and smooth gear changes, elevating the driving experience with a sporty feel. DCTs can also enhance fuel efficiency by optimizing gear ratios and enabling rapid shifts. Although DCTs offer benefits in terms of performance and fuel efficiency, they may not match the smoothness and efficiency of CVTs in low-speed and stop-and-go traffic situations. Moreover, DCTs can be costlier to manufacture and upkeep. In the end, the decision between CVTs and DCTs comes down to personal tastes and priorities. CVTs are ideal for individuals who desire a seamless and efficient driving experience, whilst DCTs are attractive to drivers who prioritise

sporty performance and rapid gear changes. CVTs and DCTs are widely used in the Indian automobile industry, offering customers more choices for automatic transmission-equipped vehicles. The presence of these transmission technologies has played a role in the expansion of the automatic transmission market in India.

### 5.9 The Transmission System in Electric Vehicles Direct Drive Transmission (Single-Speed)

Most electric vehicles, particularly pure electric cars and smaller electric two-wheelers, utilise a single-speed gearbox or direct drive. This configuration allows for a direct connection between the electric motor and the wheels, eliminating the need for a conventional gearbox. The electric motor produces ample torque across a wide range of speeds, eliminating the need for multiple gear ratios. This straightforward and efficient single-speed gearbox enhances driving smoothness.

### 5.10 Advanced Transmission Technology:

Certain hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs) in India may incorporate a multi-speed gearbox. These vehicles are equipped with both an electric motor and an internal combustion engine. The multi-speed gearbox enhances power output and efficiency by enabling the internal combustion engine to operate within its optimal speed range and effectively handle the transition between electric and gasoline power. The selection of the transmission system in electric vehicles is impacted by various factors, including the type of electric vehicle (pure electric, hybrid, or plug-in hybrid), powertrain design, and intended use case. Typically, pure electric vehicles prefer the straightforwardness and effectiveness of a single-speed transmission, whereas hybrid vehicles may utilise multi-speed transmissions to enhance versatility and performance.

**Table 1: A comprehensive compilation of passenger cars with various gearbox technologies**

Brand	AMT	CVT	DCT	IMT
MARUTI SUZUKI	AltoK10, WagonR, Celerio, Swift, Ignis, Baleno (2021 Model), Fronx, Dzire, Breeza	Vitara Brezza, S-Cross, Baleno (old model)		
HYUNDAI	Santro, Grand i10, Nios, Aura, Exter	Venue, Creta, Verna, Tucson, Elantra	Venue, i20	Venue
TATA MOTORS	Tiago, Tigor, Nexon, Altroz, Punch		Nexon	
NISSAN		Magnite		
DATSUN	Redi Go.			
HONDA		Jazz, Amaze, City, WRV		
TOYOTA		Toyota, Glanza, Toyota, Yaris, Toyota, Innova Crysta, Toyota Fortuner		
MAHIDRA	XUV 300	Scorpio		
KIA MOTORS		Sonet, Carnival	Sonet	Sonet
SKODA		Rapid, Kusaq		

## 5. CONCLUSION

In conclusion, this comparative study provides valuable insights into the various transmission technologies employed in the Indian automotive sector. Through a comprehensive literature review and analysis of existing research, this study shed light on the

performance, environmental impact, consumer preferences, and technological advancements related to transmission systems in India. The literature review revealed a significant research gap in the context of the Indian automobile industry, with most existing studies focusing on global markets and lacking a comprehensive analysis of India's specific challenges and requirements. By bridging this gap, the present study has contributed to the understanding of how different transmission technologies are perceived, adopted, and regulated in the unique context of the Indian market. The research identified key areas for further exploration, such as consumer perceptions and acceptance of advanced transmission systems, the impact of government regulations on transmission choices, and the environmental implications of transmission technologies in the Indian commercial vehicle segment. Furthermore, the review highlighted the importance of considering consumer preferences and driving patterns when selecting transmission technologies, as it directly influences the overall driving experience and market adoption rates.

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