WORKING PAPER 2018-15

Fuel-efficiency technology trend assessment for LDVs in China: Transmission technology

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Date: 17 September 2018
Keywords: transmission technology, fuel efficiency, passenger car

1 Background

Fuel-consumption standards drive down China's use of fuel by the on-road sector and encourage the uptake of advanced vehicle-efficiency technologies. Understanding the need for a policy roadmap and long-term strategies to provide certainty for long-term fuel consumption, technology advancement, and potential compliance costs for manufacturers, China is looking ahead to advance post-2020 standards for light-duty vehicles.

In its "Made in China 2025" strategic initiative (MIIT, 2015), China set a 2025 fleet efficiency target of 4 L/100 km for passenger cars, a 20% decrease from the 2020 target of 5 L/100 km. In the Technology Roadmap for Energy Saving and New Energy Vehicles published by the Society of Automotive Engineers of China (SAE China, 2016), a 2030 fleet efficiency target of 3.2 L/100 km was set. To evaluate whether and how these targets can be met, it is essential to understand what technologies will be available within the 2020-2030 timeframe and what the costs of applying those technologies in the Chinese market will be.

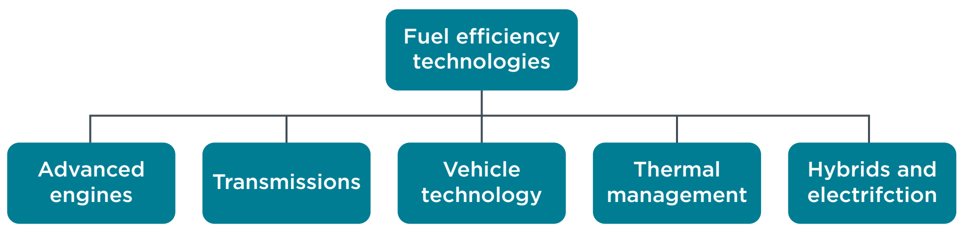

Figure 1 Categorization of fuel efficiency technologies in the working papers

This series of technical working papers aims to provide a comprehensive understanding of the current availability, effectiveness, and future market penetration of key fuel-efficiency technologies that manufacturers are likely to use in China by 2030. This information enables a more accurate, China-specific understanding of future technology pathways.

We group technologies into several categories: advanced engine, transmission, vehicle technologies, thermal management, and hybrids and electrification (Figure 1). The specific technologies we considered include those that are available today and others that are under development and expected to be in production in the next 5-10 years.

This research relies on information from publicly available sources, third-party databases, and information from the participating partners. Our approach includes:

- A detailed literature survey, including both Chinese and global regulatory documents, official announcements, and industry and academic reports.
- Analysis of databases from Polk and Segment Y.
- Conversations with manufacturers, tier one suppliers, research entities, and domestic and international experts.

For each key technology, we discuss how it reduces passenger-car fuel consumption, its effectiveness in

Acknowledgments: The authors thank the Energy Foundation China for sponsoring this series of studies. We greatly appreciate valuable comments from Hui He (the ICCT) and Ameya Joshi (Corning).

reducing fuel consumption, and its current level of application or potential application in the China market. Wherever applicable, we compare technology trends in China with those in the United States and the European Union to reflect potential technology pathways in the long term.

This working paper assesses technology progress and new developments in transmissions.

2 Introduction

Because of lower costs and fuel consumption, manual transmissions (MTs) have been the mainstream technology for decades in China. However, MTs' leading market share has eroded in recent years as demand for automatic transmissions grew in response to an expanding vehicle population and increasing city congestion. The market share of MTs has decreased from a peak of more than 70% in 2009 to 39% in 2017 (Figure 2). Today, automatic transmissions account for the majority of new vehicle sales.

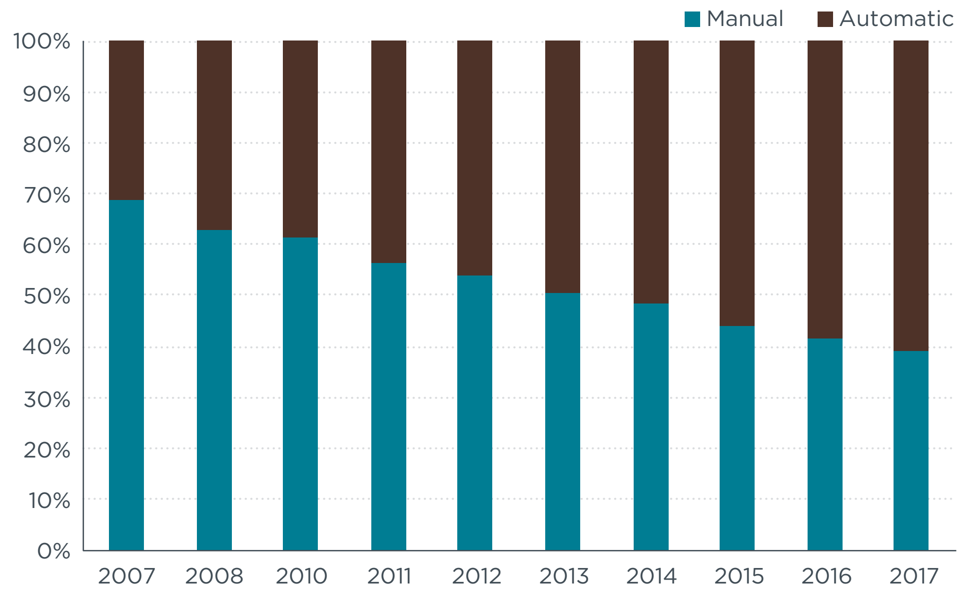

Figure 2 Market penetration of manual and automatic transmissions in China, 2007-2017

The automatic transmission (AT) market is split among several types in China:

- Conventional ATs traditionally use a torque converter and a set of planetary gear sets. Shifting gear ratios is accomplished through the hydraulic selection of a specific planetary gear set. Although the efficiency of an MT is generally higher than that of a hydraulic AT, advances in torque converter lockup and hydraulics have improved the efficiency of ATs. As the number of gear ratios increases to six or more, ATs allow an engine to operate closer to its most efficient speeds more of the time. This significantly reduces the efficiency gap.
- Dual-clutch transmissions (DCTs) consist of two separate manual transmissions with odd-numbered gears on one shaft and even-numbered gears on a second shaft. Each shaft has its own clutch, and the gear on one shaft is disengaged at the same time that the gear on the other shaft is engaged. This design approaches the efficiency of an MT and offers the potential for smooth and quick shifts without torque interruption. Because a vehicle with a DCT must start moving while engaging one clutch, manufacturers use either a wet hydraulic clutch (wet DCT) or an accumulator and high-pressure hydraulic (dry DCT) to improve launch performance.
- Continuously variable transmissions (CVTs) conventionally use a belt or a chain to connect two pairs of concentric cones, with infinite variability between the maximum and minimum gear ratios. The efficiency of the transmission is reduced by frictional losses related to clamping forces on the belt/chain as well as the need for high-pressure hydraulics. However, the system produces an infinite number of engine/wheel speed ratios, allowing the engine to always run at optimal speed/load points, thus maximizing engine efficiency.
- Automated Manual Transmissions (AMTs) are manual transmissions that employ an electro-mechanical clutch actuator to automatically complete the shift. AMTs combine the efficiency of MTs with the convenience of ATs as the gears shift automatically. AMTs have been widely used on commercial vehicles in Europe. Unlike DCTs, AMTs use a single gear shaft.

Table 1 shows fuel-consumption benefits and costs for different transmission technologies based on estimates by the U.S. National Highway Traffic Safety Administration (NHTSA), Environmental Protection Agency (EPA), and the China Automotive Technology and Research Center (CATARC). It includes estimations of different types of transmissions, aggressive shift logic, early torque converter lockup, and high-efficiency gearbox.

As Table 1 shows, DCTs tend to exhibit higher cost-effectiveness in both U.S. and Chinese estimates as they generate significant benefit while costing less than a conventional 4-speed AT (4AT). MTs consume less energy than automatics, but ATs select the optimum gear ratio at all times. So switching from a manual to an automatic with more gear ratios—particularly a DCT—can offset the advantage of a conventional MT and lead to greater fuel efficiency overall.

Table 1 Projected benefits and costs of considered transmission technologies

	Fuel-consumption reduction		Direct manufacturing cost (CNY*)		
	U.S. estimate[a]	China estimate[b]	U.S. estimate (2025)[a]	China estimate[b]	Relative to
6-speed MT	2.0%–2.5%	2.0%	1107	1800	5-speed MT
5-speed AT	1.1%-1.6%		448		4-speed AT
6-speed AT	1.7%-2.2%		-70		4-speed AT
8-speed AT	6.4%–7.8%	5.74%	231	5500	4-speed AT
6-speed DCT**	5.7%–8.1%	4%	-1126 (dry) -794 (wet)	1700	4-speed AT
8-speed DCT**	9.7%–12.6%		-154 (dry) -179 (wet)		4-speed AT
CVT	6.0%–8.7%	3.75%	—	1200	4-speed AT
Aggressive shift logic(ASL)	5.1%–7.0%		141		No ASL
Early torque converter lockup	0.4%–0.5%		128		No early torque converter lockup
High-efficiency gearbox	4.3%–5.7%		1043		No high-efficiency gerabox

* Exchange rate between USD and CNY is 1:6.4
** Fuel consumption reduction estimation includes impact of AMT
[a] U.S. EPA and NHTSA, 2012
[b] CATARC, 2017

3 Current status

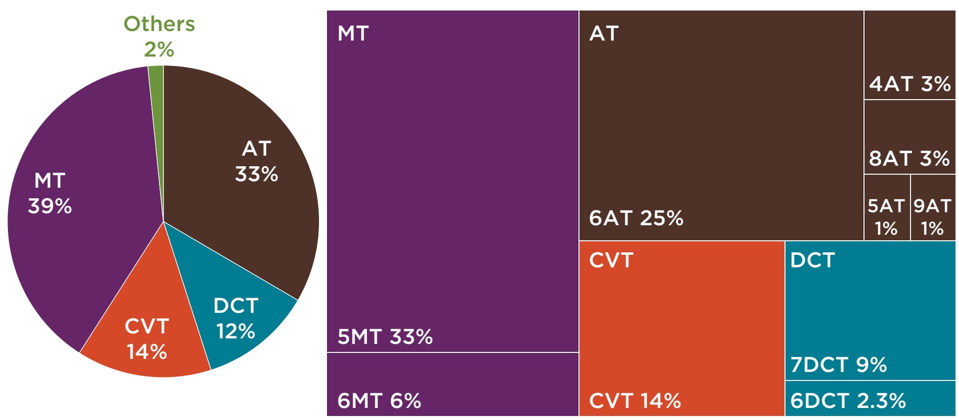

Figure 3 Market penetration of transmission by type among passenger cars in 2017

Most ATs and CVTs today have adopted torque converter lockup to reduce fuel consumption by lowering the loss of power transfer through the fluid inside the torque converter and from slippage during rapid acceleration. Despite different transmission control strategies, the lockup is usually triggered at higher speeds. At lower vehicle speeds, torsional energy is harder to dampen, and it can create shaking or shuddering as it passes through the vehicle. Thus, early torque converter lockup requires upgraded materials to withstand higher loads (Isenstadt, German, Burd, and Greif, 2016). Only a few models enable lockup at lower speeds. For example, the Mazda Atenza is mated with a 6-speed automatic transmission (6AT) with early torque converter lockup. This expands the lockup range from 64% on current 5ATs to 89% over the New European Drive Cycle (NEDC) (Mazda, 2018).

According to Table 1, ATs with aggressive shift logic (ASL) could also significantly improve fuel efficiency compared with conventional ATs without ASL. ASL increases efficiency through downspeeding, which enables earlier upshift—at lower rpm during acceleration—and shift optimization. This requires constant monitoring of all gear options and selecting the gear that puts the engine in the most efficient operating zone. This paper does not have information on shift control strategies of vehicles in China.

As shown in Figure 3, the conventional AT is the most popular non-MT technology in China, with a market share of 33% in 2017. Among these, 6AT is most prevalent, accounting for 25% of the market. CVTs account for 14% and DCTs, 12%.

Among independent automakers, adoption of ATs remains low relative to that of joint ventures. In 2017, MTs accounted for 72% of new sales by independents, as most of their products were designed for mid- to lower-end consumer groups (Figure 4). Of ATs sold by independent automakers, conventional ATs had the highest market share, followed by DCTs and CVTs.

Figure 4 also illustrates the market development of different transmission types in China. CVTs and DCTs have seen a huge increase in market share from 2010 to 2017, with penetration of CVTs expanding faster than that of DCTs from 2014 to 2017. The development of CVTs and DCTs has been much slower in the independent manufacturer fleet. DCTs were more widely deployed by independents, and the market share of CVTs decreased from 2014 to 2017.

Independent manufacturers that explored ATs chose different development strategies. In 2014, BYD adopted DCTs on 29% of its cars; Dongfeng and Chery had a growing share of CVTs, 15%-20%; and Chang'an, Great Wall, and Geely focused on developing ATs.

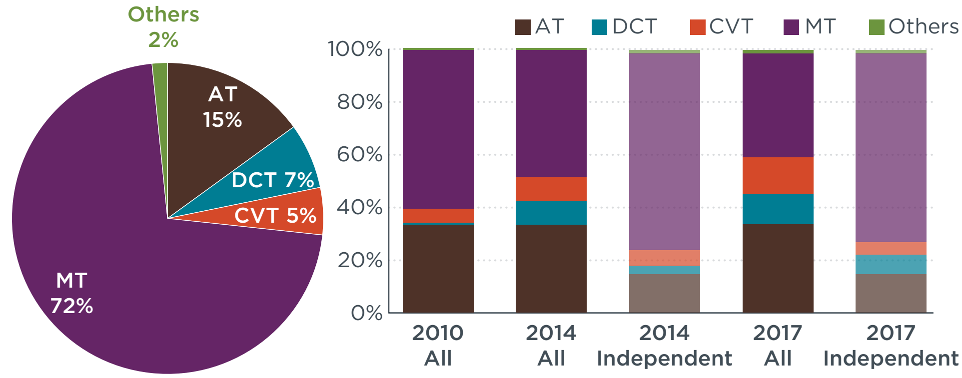

Figure 4 Transmission types among passenger cars from independent manufacturers in 2017 (left); transmission penetration trends of all manufacturers and independent manufacturers from 2010 to 2017 (right)

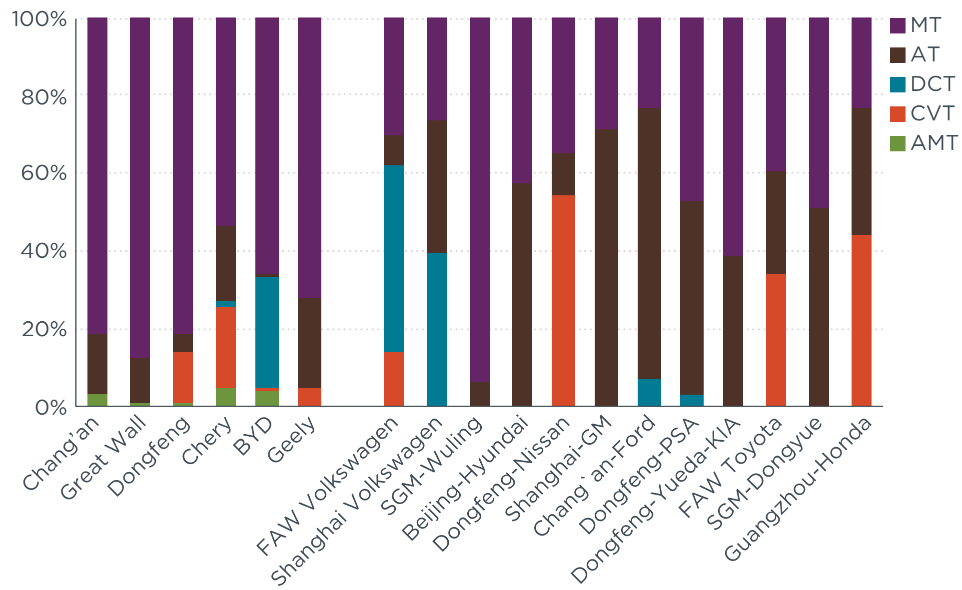

Figure 5 Transmission types by major manufacturers in 2014

Adoption rates for advanced transmissions are generally much higher among joint ventures. In 2014, deployment of DCTs by FAW-VW was 48%, and by Shanghai-VW, 39%. CVT penetration for Dongfeng-Nissan was 46%, for FAW-Toyota, 34%, and for Guangzhou-Honda, 41% (Figure 5). This shows that the advanced transmission strategies of joint ventures are likely to depend on the technology decisions of parent manufacturers, such as DCT from VW and CVT from Japanese manufacturers.

The design of MTs is simpler than that of ATs, and domestic suppliers lead the way in meeting MT demand from independent manufacturers. Because ATs are technically more complex, they are still mainly imported or supplied by foreign companies that produce in

China. In 2015, around 95% of ATs in China came from foreign companies (Chen, 2016). According to customs data, this percentage decreased to 75% in 2017.

As the localization of foreign transmission suppliers is slow, independent manufacturers and domestic suppliers have increased investment in research and development of transmission technologies. In recent years, independent manufacturers or domestic suppliers began to develop the capacity to mass produce ATs.

Table 2 lists applications of advanced transmission technologies by some of the main manufacturers in China. As highlighted by shading, a number of ATs, DCTs, CVTs, and AMTs have been developed by domestic suppliers or independent manufacturers. Among those, manufacturers have focused more on DCTs than CVTs. Chang'an, Geely, and JAC have developed DCTs for some models. Chery is the only one on this list that has put CVTs into production. There are some applications of AMTs on small vehicles, such as those by JAC and Haima.

There are many collaborations between domestic suppliers and foreign companies. These are listed in

Table 2 Transmission application by some main manufacturers in China.

	Type	Segment	Model example	
Geely	6MT	A/compact	Emgrand	Mass production (2013-) Small production (2016-)
	7DCT (W)	2.0T(B/SUV), 1.5T(A/B/SUV)	Lynk 01	800,000 units/year estimate (2017.12-)
	7DCT	Hybrid	–	Under development
	6AT	B/SUV	Boyue, Borui	300,000 units/year (2010-); 600,000 units/year (2018-)
SAIC	6MT	1.5T (compact SUV), 1.8L+ (G)/2.0L+ (D)	Maxus G10, MG5, Roewe 350	Mass production
	6DCT (W)	A/B/SUV	Roewe 550/950, MG6 etc.	600,000 units/year
	7DCT (D)	A0/A/SUV	MG6	600,000 units/year
	9AT	SUV	Chevrolet Equinox	Mass production
	EDU2AT	EV	Roewe e550/ei6 etc.	Mass production
GAC	7DCT	A	Viaggio, Trumpchi	Mass production
	7DCT (W)	–	–	Mass production estimate (2018.12-)
	9AT	Medium/large SUV	Avancer 370T	Mass production
Chang'an	6MT	A/compact/compact SUV	Yuexiang V7/Raeton etc.	Mass production
	5DCT (W)	A	Eado PHEV, XT etc.	Mass production
	7DCT	1.5T, 1.8T	–	Mass production bidding
	5AMT	Small	Yuexiang, Benben Mini etc.	Mass production
Chery	6MT	SUV	Riich, Tiggo etc.	Mass production
	CVT	1.6-2.0L	Chery A3、Chery E5, etc.	600,000 units/year
	8AT	SUV	Jaguar Landover	Mass production
BAIC	5MT	Compact/SUV	Senova, Foton etc.	Mass production
	6MT	Compact	Aumark S1, Ollin CTS, etc.	Mass production
JAC	6MT	Small/compact SUV	Ruifeng S3 etc.	Mass production
	6DCT (F)	Compact SUV	Ruifeng S7, S3 etc.	Mass production
	6DCT (R)	MPV	Ruifeng M6 etc.	Mass production
	5AMT	Small	Tongyue	Mass production
Great Wall	6MT	Compact	Haval H2, H5, H6	Mass production
	7DCT (W)	Flat engine	WEY VV5/WEY VV7	500,000 units
BYD	6DCT (W)	–	S7 etc.	Mass production
JMC	8AT	SUV	Landwind X5, X7	200,000+ units
Haima	5AMT	Small	Cupid	Mass production

Note: Shaded transmissions are developed and produced by domestic suppliers or independent manufacturers; others are developed in partnership with foreign companies.
(W)– Wet; (D) – Dry; (F) – Front; (R) – Rear

Table 2 without shading. For example, the 7DCT of Great Wall is the first 7-gear wet DCT in mass production in China. It is currently applied on the WEY VV5 and VV7 in 2017, two SUV models introduced by Great Wall. The transmission control unit, sensor cluster unit, and application software are supplied by Continental, and the dual clutch module, by BorgWarner. Besides the WEY models, Haval H2S, H6, and H7 will be equipped with this 7DCT. Application may further expand into other models as production capacity increases (Gasgoo, 2017). The 8ATs applied on JMC's Landwind X5 and X7 were developed by Shengrui Transmission Co. with support from Ricardo. This front 8AT is 3.16% more efficient than 6ATs on the NEDC. Shengrui Transmission has already achieved strategic cooperation with eight manufacturers on 18 models. These models will mate with Shengrui's second generation 8AT.

Table 3 shows the production capacity of major domestic transmission suppliers in China. The transmission technologies listed in the table were mainly developed by domestic suppliers. These companies usually have long-term strategic cooperation pacts with manufacturers and continue to expand their business as production capacity grows. Some suppliers mainly focus on certain market segments. For example, Chongqing Qingshan Industry provides transmissions for more than 60% of mini cars.

As Table 3 highlights, there is a big gap between domestic and leading global transmission technologies. Three main reasons explain this gap:

Table 3 Transmission types by major domestic suppliers

Supplier	Type	Application	Note
Harbin DongAn Automotive Engine Manufacturing	6-speed AT	1.2L (Turbo)-2.6L (Turbo)	
Zhejiang Wanli Transmission	5-speed MT		
	6-speed MT		
	CVT	1.6L-2.0L	
Punch Powertrain	CVT	Small to large cars, SUV	
Zhuzhou Gear	5-speed MT	Compact, MPV, SUV, minivan	
	6-speed MT	Compact SUV	
Chongqing Qingshan Industry	5-speed MT	mini, small, compact, MPV	
	6-speed MT	A/compact/compact SUV	
	5-speed DCT(Wet)	Compact	
	5-speed AMT	Mini, small	
Ningbo Shuanglin Auto Parts	6-speed AT	B/SUV	
	6-speed AT (Front)		In development
Shengrui Transmission	8-speed AT	SUV	
	13-speed AT	B+ SUV/MPV estimate	In development

a. **The lack of core transmission technology.** Many automatic gearbox patents are already monopolized by big international companies like Aisin (Japan), ZF Friedrichshafen AG (Germany), BorgWarner (USA), and Xtronic (Japan). This makes it challenging for domestic technologies to catch up. For example:

- The accuracy of gear teeth has a significant influence on vehicle noise, vibration, and harshness (NVH) and durability. The current automatic gear teeth are produced mostly by grinding or honing. The accuracy of teeth grinding by domestic suppliers is one class lower than that of the leading supplier. The internal gear honing technique, which is widely used by leading global suppliers, has just begun in China.
- The hydraulic torque converter is a key part of ATs and CVTs, but China's design and manufacturing capacity for hydraulic torque converters needs to be improved.
- Transmission control units of CVTs, ATs, and DCTs are still mainly supplied by foreign companies.
- The electromagnetic valve and sensor cluster unit of hydraulic pressure control systems are mainly supplied by foreign companies. Domestic suppliers are conducting research and pilot production.

- The steel belt and chain of CVTs are purchased from foreign companies. There is no manufacturing capacity for these parts domestically.
- The development of lubricants for automatic transmissions is lagging. Most lubricants used by manufacturers come from foreign companies.
- The transmission brake system, which influences gear change performance, consists of a number of stamped parts. Domestic suppliers do not have complete capacity to manufacture all the parts.

b. **High R&D cost and market risk.** Investment in transmission development may not be proportionally related to benefit. The development cycle of transmissions is relative long compared with the usage cycle. For example, adding one more gear to a transmission would require redevelopment of both hardware and software. The new product may then lose market competitiveness if the development cycle gets prolonged by unforeseen challenges. Especially for manufacturers that produce a number models with lower production volumes, investment in transmissions may influence a company's entire operation.

c. **A lack of basic experimental data.** The development and production of advanced transmission technology requires not only manufacturing capacity but also substantial testing data to calibrate the product, which domestic producers don't have.

4 Further development pathways

In response to consumer demand and regulatory requirements, transmissions for passenger cars in China are moving toward a wider spread of gear ratios, optimized shift logic, improved transmission efficiency, and lightweighting (Figure 6).

Based on the trend from 2007 to 2017, MTs are likely to be further replaced by ATs. However, MTs will still be the mainstream transmission technology among independent manufacturers. This is first because independent manufacturers started late in developing automatic transmissions and are thus constrained by automatic transmission supply. In addition, they have a large low-end consumer base with vehicle prices targeted between 50,000 yuan and 150,000 yuan, making sales sensitive to price fluctuation.

Comparing three major AT technologies, traditional ATs have been the major option. As price-related elements—vehicle price and fuel cost—largely influence consumers' purchase decisions, significantly more vehicles have been equipped with DCTs among independent automakers in recent years because of their lower cost. DCTs have higher transmission efficiency and a wide application range, such as from 1.0L to 3.0L turbo. The technology is applicable to most mainstream models. Future market uncertainty comes from the complexity of gear teeth and technical challenges faced by domestic suppliers. Comparatively, the structure of CVTs is simpler and more cost-effective, making them more applicable on vehicles with smaller engines and on models from independent manufacturers. Consequently, the uptake of CVTs is likely to be faster among small cars.

Based on announced production plans and existing domestic capacity, demand for ATs will exceed supply over the next five years.

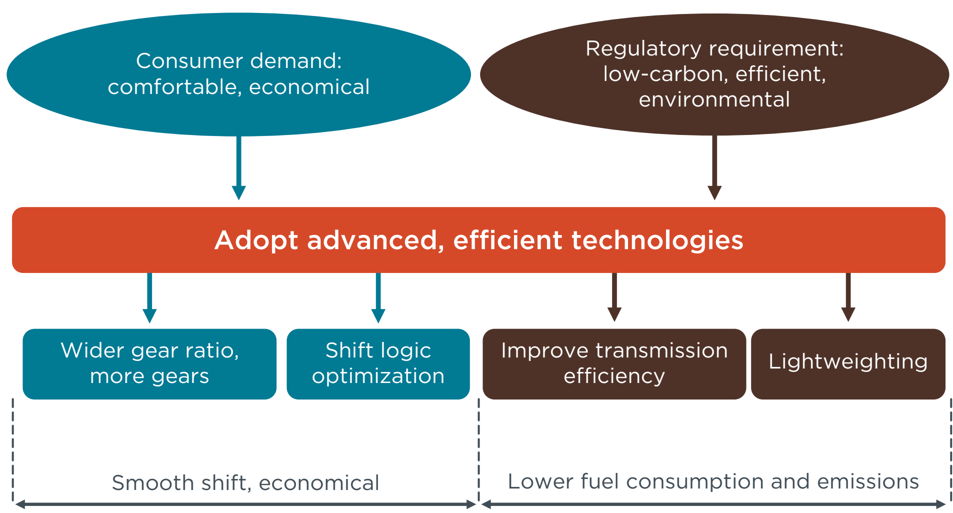

Figure 6 Demand for vehicle transmission development

The technology of 6-speed ATs are relatively mature, so ATs with more gears may gain market penetration on high-end models. Besides 9ATs which have already been applied on some models in China, 10ATs are planned for coming Lexus and Ford/GM models in the U.S., enabling both better performance and lower fuel consumption. As for DCTs, FEV has already estimated the cost of 8- and 10-speed DCTs, which implies their potential application in future models (Isenstadt et al., 2016). In the China vehicle market, AT penetration overall may not change significantly, while the share of CVTs and DCTs will increase as the technologies mature. The uptake of ATs among independent automakers will most likely focus more on DCTs while applying CVTs among the smaller vehicle segments. Figure 7 shows the projected transmission technology penetration among conventional vehicles by 2020.

Under China's electrification trend, a variety of transmission strategies have been adopted or are under development for hybrid and electric vehicles. Among transmission configurations for hybrids and plug-in hybrid electric vehicles (PHEVs), the most prevalent transmission configuration in China is parallel P2 mode. The emerging technologies are electric CVTs (eCVTs), electric DCTs (eDCTs), and dedicated hybrid transmissions (DHTs).

ECVTs do not use a belt or chain connected to a pair of variable pulleys as in conventional CVTs. Instead, eCVTs use an electric motor or generator to control the speeds of planetary gear set components. ECVTs have been used on the Toyota Prius for years.

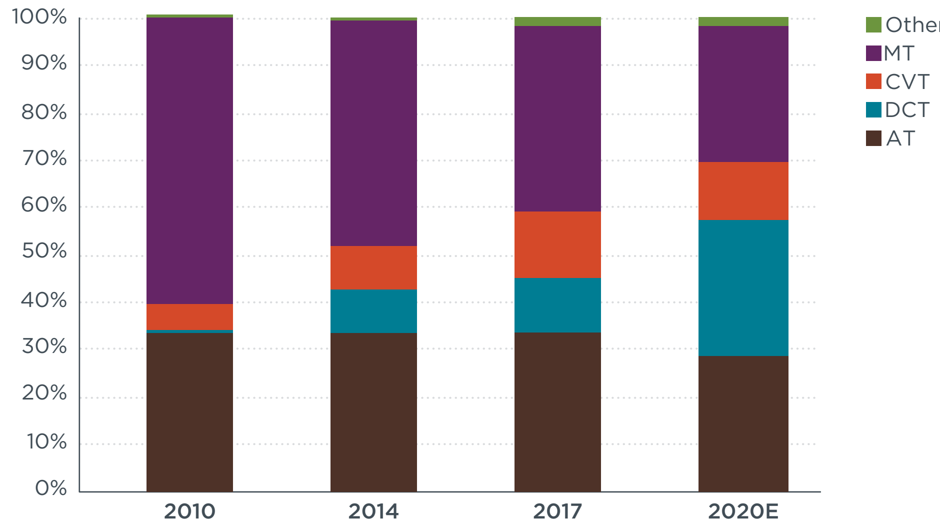

Figure 7 Projection of transmission technology penetration by 2020

Domestically, Shanxi Keliyuan Crane Equipment Co. has developed an eCVT that is similar Toyota's but with two planetary gear sets rather than just one.

EDCTs offer electro-hydraulic control with a dual pump system that consists of a mechanical pump and an electronic pump. DCTs in full hybrids are being used by many OEMs. Porsche has already used an eDCT in the 918 Spyder hybrid; Hyundai launched DCT-based full hybrids in 2016; and VW has used one in the concept model of the CrossBlue Coupé Group PHEV. In Europe, Getrag is offering OEMs a broader range of DCTs for hybrids. In China, Shanghai Automobile Gear Works introduced its eDCT hybrid transmission at the 2017 Shanghai International Automobile Industry Exhibition (SAGW, 2017). Volvo/Geely is known to be developing a DCT-based hybrid system.

DHTs use at least two sources of propulsion, an ICE and at least one electric motor. Without either of these sources, they are not fully functional. Because DHTs have the electric motor fully integrated into the transmission, they are different from parallel hybrids where the electric motor is an add-on component to the drive train. DHTs maintain a simple architecture and do not require an additional launch element to switch between modes.

Globally, the Aisin/Toyota DHTs are the most established in the market, but an increasing number of manufacturers are developing their own DHTs. Another mass-produced DHT is the Voltec II hybrid drive from GM used in the Chevrolet Volt and Malibu Hybrid. In China, SAIC developed an electric drive unit that uses two electric motors and a simple straight gear transmission. Because the transmission cannot operate without the electric motors, the system by definition is a DHT. SAIC is applying this system on the Roewe 550 and e950 PHEV.

Toyota, the first manufacturer to bring full hybrids to market, initially offered products mated with either CVTs or DHTs but quickly determined to use DHTs. In 2016, IHS estimated that DHTs accounted for 75% of hybrid vehicle transmissions (Guile, 2016). As more and more major transmission suppliers develop DHTs, their adoption will continue to increase. IHS predicts that DHTs will account for 50% of the hybrid fleet—and 5% of the entire fleet—by 2028 (Guile, 2016).

For battery electric vehicles, every electric car has a single-speed transmission, or reducer. Because electric motors have a much larger RPM range, makers of these vehicles usually pick a gear ratio that provides a good compromise between acceleration and top speed. Single-speed transmissions have limitations on:

- **Drivability:** One gear ratio cannot optimize vehicle performance under all circumstances, including acceleration at low speed, high-speed overtaking, and climbing. Acceleration is weak at high-speed driving, especially at speeds of 80 km/h or more, which influences drivability.
- **Efficiency:** With a single gear ratio, the electric motor cannot perform in its most efficient zone under different driving conditions. This may increase energy consumption at high speeds, reduce the benefit of brake energy recovery, and shorten electric driving range.
- **Safety:** If acceleration is limited at high speed, it may influence overtaking and thus reduce driving safety. Most reducers also do not have the parking gear function as on conventional vehicles.
- **Reliability:** Running the electric motor at high RPM is challenging for thermal management, NVH, and airtightness of the electric motor. To operate reducers at high speed, there are tough requirements on gear teeth processing technology, bearing life, and friction, wearing, and lubrication.

Because of these limitations, multi-gear transmissions are important to improve energy efficiency and performance of electric vehicles. Internationally and domestically, development of multi-gear transmissions has mainly focused on existing AMT, DCT, AT, and CVT technologies used on conventional vehicles.

Tesla tried to develop a 2-speed transmission but failed. Consequently, Tesla applies a single-speed gearbox on its Model S. The electric motor of the BMW i8 drives the front wheels via a 2-speed automatic gearbox. It always runs in first gear while in eDrive but switches to second gear in mixed modes (InsideEVs, 2015).

Controlled by software, an eDCT with two gears has all the benefits of a conventional DCT but with reduced weight, size, power loss, and cost. The performance, design, and efficiency improvements can translate into greater vehicle range or a smaller battery pack. Two-gear AMTs eliminate the clutch and directly connect to the electric motor output shaft. They use the speed change of the electric motor to switch gears. They are the preferred option by suppliers because of lower cost, higher efficiency, and greater stability. However, gear switching comfort, bump, and control present technical challenges. Because of load torque limitations of CVTs and low efficiency and smaller gear ratio ranges of ATs, CVT and AT transmission pathways are less popular than DCT and AMT pathways.

It is estimated that multi-gear transmissions for EVs will improve driving range by 8%-10% while improving performance. A two-gear transmission is the more feasible solution for light-duty vehicles.

5 Summary

Figure 8 summarizes the key technologies discussed in this working paper. The adoption status of each technology in China is indicated before the name of each technology. The pie chart is shown to reflect the latest market penetration of commercialized technologies in China, with 5MT, 6AT, and CVT having relatively higher shares. The start signs represent emerging technologies that appear on a couple of models, such as 6MT, 9AT, AMT, and DHT. The green flags represent underdeveloped technologies that have been applied or researched in other countries but are still under development in China.

The percentages following each technology summarizes its potential for reducing fuel consumption. In most cases, the reduction potential is compared with a designated baseline. The number represents an impact range considering the differences in baseline vehicles' segment, specifications, and other elements.

Based on the application status of transmission technologies in China, we group them into three categories:

Commercialized technologies. These are already adopted on at least several production models in China and could be applied widely through the fleet.

Emerging technologies. While available on passenger cars in the Chinese market, these have been adopted on only a couple of models, such as variants of flagship models or luxury vehicles that target at high-end users.

Underdeveloped technologies. Such technologies have been adopted in other markets but are not currently available on cars produced in China, or they have been announced by manufacturers or suppliers and are likely to be adopted on production cars in the near future.

Table 4 lists the transmission technologies under each category based on our definition. This information will be used to estimate fuel-saving potential of all efficiency technologies in the summary of this series of working papers.

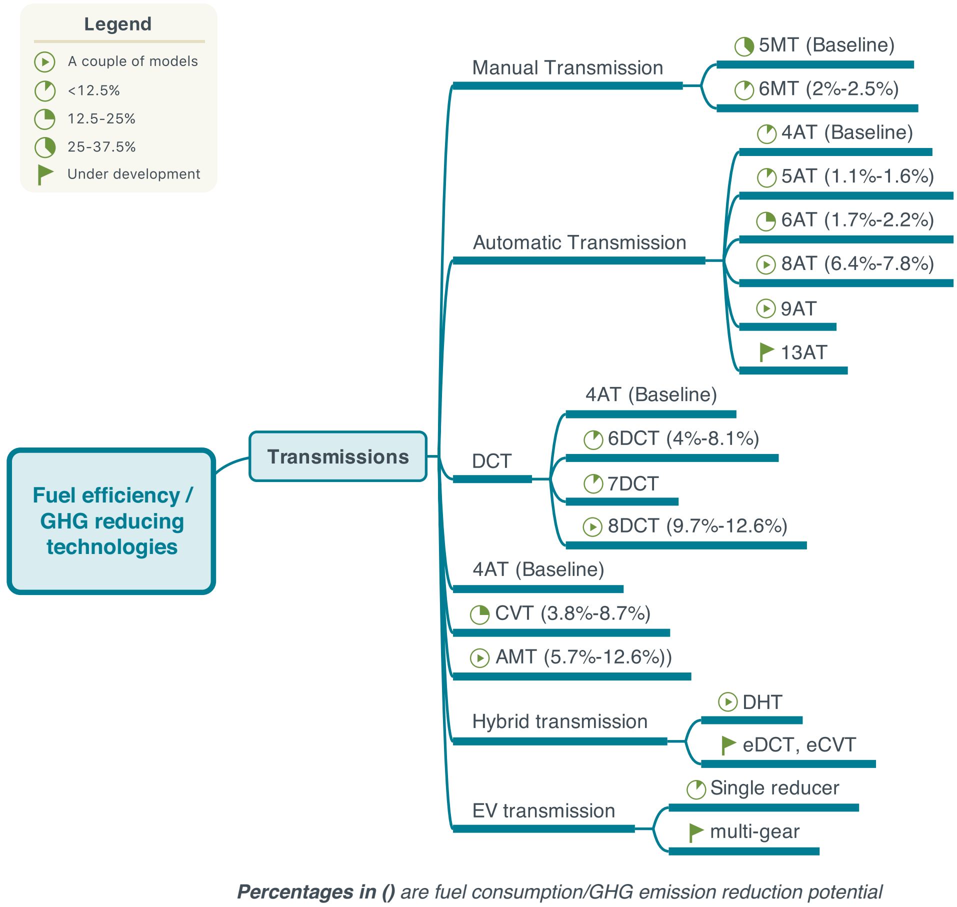

Figure 8 Advanced transmission technology map for passenger cars in China

Table 4 Transmission technologies at different development stages in China

Commercialized technologies	Emerging technologies	Underdeveloped technologies
• 5/6MT • 5/6AT • 6/7DCT • CVT • Single reducer (EV)	• 8/9AT • AMT • DHT	• 8DCT* • eDCT, eCVT • multi-gear transmission (EV)

*8DCT is categorized as underdeveloped because it has been applied on only one luxury version of the Honda Spirior.

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