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Evolution of Autonomous Vehicles and Advanced Automated Car Parking Development

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***Abstracts*—**The trend of autonomous vehicles is the future solution to road networks congestion in terms of their advanced ability to drive closer together and at higher speeds than humans can do safely. Infrastructure sector can drive the economic prosperity and provide a balance and inclusive growth of sustainable economy development. In this paper, the road infrastructure and the future development of electric car, self-driving of autonomous vehicles and the increasing demand of automated car parking system are critically revised and this paper aims to provide the insight and achieve better sustainable infrastructure and community in smart city.

***Keywords*—**Autonomous vehicles, sustainable infrastructure, real time parking, automated car parking.

I. Introduction

THIS paper is to discuss the development of road infrastructure in smart cities and the preparation for the evolution of full self-driving of electric cars and the trend of automated car parking. The road infrastructure and the future development of electric car, self-driving of autonomous vehicles are revised. Study of the increasing demand of automated car parking system to achieve better sustainable infrastructure and community in smart city is critically reviewed in this paper. Recommendation of improvement of existing road and associated facilities and planning of future road infrastructure will be discussed for future research.

Quality Infrastructure

According to G20 Principles for Quality Infrastructure Investment [16], infrastructure sector is the energy charger of economic prosperity and support a balance and inclusive growth of sustainable economy development. High quality and sustainable development of infrastructure also maximize the positive economic, environmental and community and contributed toward the future development of smart city. Advanced technologies in infrastructure development in smart cities also help improve the development of sustainable infrastructure development and unlock job opportunities and encourage further local technology innovation.

Prospects of Autonomous Vehicles Industry

Autonomous vehicles (AVs) will be the future trend to resolve the congested road network in terms of their ability to provide a safe, higher speed and closer driving conditions as compared with human driving characters. [11] Apart from US, most of the Asia countries like China, Japan and Singapore are well advanced in preparing for AVs entering the road system while several European countries like Sweden and UK have allowed for the testing and use of AVs on public roads. In terms of the type of AVs, there are different vehicles that may have quite different levels of autonomy, mainly, (i) Autonomous Only Vehicles (AOVs) which find their way using on-board sensors; and (ii) Connected & Autonomous Vehicles (CAVs) which communicate with other vehicles, road users and road infrastructure. [1] Tesla, for example, already has fully automated functions within their vehicles.

Future Trend of Electric Vehicle Industry

In view of the rapid innovations in automated vehicles and artificial intelligence technology, the great transition of conventional vehicle to electric vehicles will happen in next 5 years. The clear global trend and popularity of transition of conventional fossil fuel vehicle to electric vehicles to meet the target to reduce carbon emission in coming future is crucial to the future planning and development of sustainable infrastructure across the world. Autonomous Vehicles can significantly improve the traffic safety, alleviate the traffic congestion problem and eventually reduce the carbon emission [10].

Growth of Electric Vehicles from 2016 to 2020

According to a survey carried out in 2020 [15], about 22% of respondents in Asia has the concern of sustainability which eventually affects their interests to purchase electric vehicle while there is 12% of the respondents considering electric vehicle (EV) because of the benefit of air quality improvement.

With the trend of globally government regulatory action and concern of carbon emission, a growing number of automakers are intending to tap into market for EVs. In 2020, China EVs fleet reach around 4.5 million units while United States had approximately 1.8 million battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) in use in 2020 [15].

Development of Technology of Full Self Driving (Level 4 or above)

With the rapid development of the technology including personal self-driving vehicles, shared robotaxis, and connected vehicle platoons, the dramatic mass production of fully self-driving commercial vehicles in the consumer market will be foreseen in near future.

The level of full self-driving is developed rapidly in recent years and they can be categorized in six levels according to a system developed by the Society of Automotive Engineers (SAE) [13].

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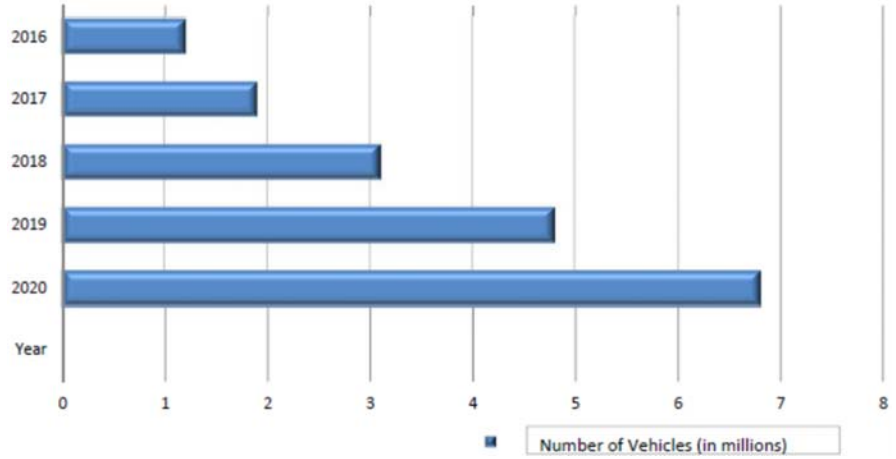

Fig. 1 Worldwide number of BEVs in use from 2016 to 2020 [15]

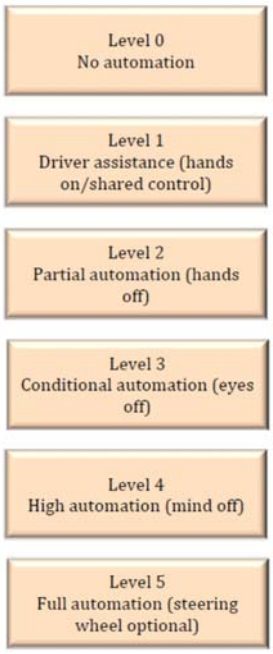

Fig. 2 Level of Full Self-driving [12]

II. Trend of Automated Car Parking Development in Sustainable Infrastructure

A. Future Trend of Automated Car Parking

Automated car parking is one of the ancillary infrastructures which are well developed to meet the growth of AVs as it has the benefit of reduction of the labor resource, cost effectiveness in minimization of parking and circulation space required when compared with conventional vehicle parking.

Underground automated parking provides alternative parking choices to tackle the insufficient parking space in congested and dense city. The benefit of underground automated parking will be more prominent in infrastructure development as it can alleviate shortage of ground floor space and tackle the congestion problem in urban cites. The final outcome of the development of underground automated parking can enhance of living environment in smart cities [6].

B. Automated Car Parking Facilities

In principle, automated car parking can reduce average passenger waiting times, improve accessibility and mobility, improve the quality of life and livability, increase service provision equity, cause less congestion and, increase the efficiency and capacity of car parking facilities [5].

Automated multilevel car parking systems with the use of "Automatic car parking system" particularly for stadiums or shopping malls which are crowded during weekends or public holidays has the advantage of taking less space for parking, reducing the manpower and traffic congestion and, offering a safe and secure parking slots within limited area. [3], [4]

C. Deficiencies of Conventional Road Infrastructure

With the increasing and wide adoption of automated vehicles in different smart cities, government authorities and stakeholders are now facing the problems of non-standard of infrastructure including road sign, carriageway width, etc. Currently, the roadworks standard is varied across different countries and cities for conventional vehicles and the lane width, pavement, speed limits, lighting, traffic sign, size and color of road marking, roads and highways structures may also be varied within the country and city. The variation of standard also found incompatible with full self-driving AVs. AVs heavily relied on high standard of internet connection. However, current data network system including WiFi and 4G/5G mobile network may not be well planned and designed to meet the requirement of automated driving and autopilot navigation and therefore upgrading of internet connection and infrastructure is considered necessary [2], [7], [13].

III. Recommendation of Improvement of Existing Roadwork and Future Development of Sustainable Road Infrastructure in Smart City

The development of sustainable road infrastructure in smart city required improvement and upgrading of existing roadwork as well as careful planning of new roadwork network and ancillary facilities standard. There are 5 key factors which are considered crucial to the sustainable road infrastructure including the following:

- Improvement of existing roadwork
- Future development of sustainable road infrastructure
- Underground automated car parking
- Real time parking system and
- Installation of EV charging facilities network

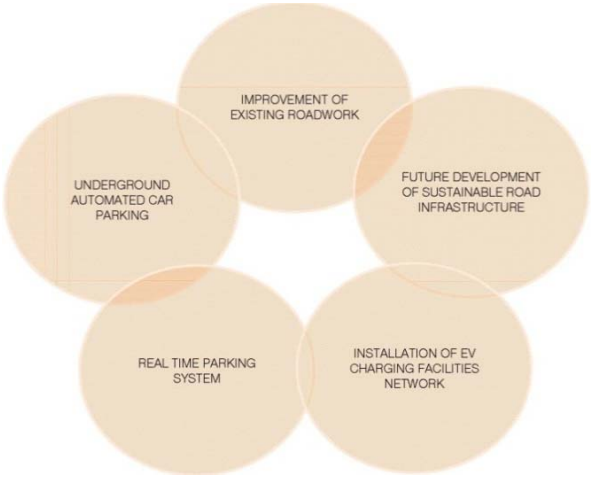

Fig. 3 Five key factors which considered crucial to the sustainable road infrastructure

A. Improvement of Existing Roadwork

Strategic planning and consideration during improvements of existing roadworks of future AVs capacity is crucial to ensure flexibility for smooth transition of conventional vehicles to AVs. It is also to ensure the sustainability of long-term sustainable infrastructure improvement program. The key issues related to sustainable infrastructure improvement program to be addressed include physical infrastructure, digital infrastructure and road operations [7].

B. Future Development of Sustainable Road Infrastructure

In the near future, fully AVs are expected to begin appearing on public roads and therefore planning ahead to meet the evolution of fully self-driving and autopilot is urgently needed. Since road infrastructure has a long renewal cycle, consideration of improvements of existing road infrastructure and further sustainable infrastructure development should be catered for the rapid automated vehicle development in the next 10-15 years. However, the durability and maintenance of the road infrastructure should be a challenge for traffic management in order to ensure a safe road condition for full self-driving AVs. Government should therefore take lead to consult with AVs industry partners and other stakeholders to develop a strategic planning, design rules and technical specifications for compatibility with the adoption of AVs. Regular review and adjustment of regulations and standards are crucial and necessary to maintain the harmony between technology development and infrastructure improvement.

Local government should allow future flexibility of the full adoption of AVs. Further improvement of internet connectivity under IT aspects includes

- standardization of new infrastructure elements,
- design of AVs parking slots,

Step 1: Follow instructions to stop inside the transfer cabin.

Step 2: All personnel vacate the transfer cabin and confirm parking request to start storage process.

Step 3: The lift transfers the vehicle to a parking level. The dolly transfers the vehicle on to a sliding shuttle dedicated for each parking level.

Step 4: The shuttle travels to a vacant space and the conveyor transfers the vehicle to the parking space.

Step 5: The conveyor returns to the shuttle to complete the storage procedure.

Fig. 4 Illustration of underground automated parking system arrangement

- pavement design,
- visible curves,

- lane width, road signage,
- lighting,
- bridges and highways structures
- traffic management strategies

C. Underground Automated Car Parking

Ground floor space is valuable in smart cities. In order to maximize the valuable space in urban areas for improvement of the city environment, the development of underground automated car parking became the trend with the advancement of fully automated car parking system and full self-driving AVs [8].

D. Real Time Parking System

Real time parking system can resolve idle vehicles, reduce the average passenger waiting times and distribute the passenger waiting times with service provision equity across the city. In Hong Kong, the government had already launched the scheme to invite carpark operators in certain urban and rural districts to open their real-time parking vacancy data and basic carpark information so that the drivers can access the real time information through mobile app using smart phones or AV navigation system [14], [6].

With the advancement of the innovative technology of self-driving, autopilot in automated vehicle and automated carpking system, the potential and development of real time parking will be a key element for future sustainable road and infrastructure development. [9]

The Automated Parking System (APS) is a smart solution for a smart city that promises to remedy the frustration and environmentally damaging traffic jams of much conventional parking. The APS Drivers can book parking spaces online using smooth and efficient of smart infrastructure. Moreover, high speed of parking and retrieval can shorten the queuing time.

E. EV Charging Facilities Networks

According to the survey [15], the major consideration factor of purchasers for purchasing EVs in Asian countries was the lack of EV charging infrastructure. To enable the promotion and wide adoption of vehicles, a careful planning of EV charging facilities within the cities is necessary in terms of the increasing needs for the enabling facilities to meet the limitation of car battery development. Government authorities play an important role to implement the construction of the enabling facilities within the cities and other stakeholders shall promote the provision of EV charging facilities within building including residential and commercial building and, retail mall car park. In Hong Kong, for example, the government had provided incentive in term of gross floor area exemption to promote and regulate the provision of electric charging facilities infrastructure in new private and public building developments. Meanwhile, the Government also officially launched a $2 billion "EV-charging at Home Subsidy Scheme (EHSS)" and it aims to subsidize the installation of EV charging-enabling infrastructure in carparks of existing private residential buildings and also facilitate the owners to install EV chargers at car parks of their residences to meet their own needs [14].

IV. Conclusion

In this paper, the global trend of EVs is reviewed. The new advancement of AI technology like real time parking system, AV, and automated carparking which is prominent for improvement of existing road infrastructure and future development of road infrastructure in smart cities is discussed. The rapid evolution of full self-driving of AVs and the impact to sustainable infrastructure to achieve better sustainable infrastructure and community is reviewed with recommendation of improvement of existing road and associated facilities and planning of future road infrastructure presented for future research.

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