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HUMAN CAPITAL IN THE LOGISTICS AND SUPPLY CHAIN INDUSTRY

LEGAL CHALLENGES AND POLICY SUGGESTIONS SUPPORTING THE ADOPTION OF AUTONOMOUS VEHICLES IN THAILAND

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HUMAN CAPITAL IN THE LOGISTICS AND SUPPLY CHAIN INDUSTRY*

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1. BACKGROUND

The development of logistics infrastructure is an important part of Thailand's development strategies which are revealed in several development plans: (a) Thailand's 20-Year National Strategy (2018-2037); (b) Twelfth National Economic and Social Development Plan (2017-2021); (c) Second Thailand Logistics Development Plan (2013-2017); (d) "Thailand 4.0" development scheme; and (e) Eastern Economic Corridor (EEC) Development Plan. As a result of implementation of these plans, the demand for workers in the logistics and supply chain industry may change according to the various directions of development over time.

In this regard, such directions will be focused on five areas of Thailand's logistics system, which, according to the Twelfth National Economic and Social Development Plan, are as follows:

1. Developing the country's railroad system as a primary mode of transportation and shipment;
2. Improving road systems to support increasing use of roads;

* *This article is based on the research project entitled Human capital in the logistics and supply chain industry, according to the new statistical development of Thailand, 2020.*

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3. Improving the public transportation system in central cities to increase the usage of public transport;
4. Improving the air transportation system for the efficiency of aviation and management;
5. Improving the maritime transportation system to reach its maximum capacity, and advancing Laem Chabang Port to serve as a center of the logistics hub in this region.

Thus, the key areas of the development plan as it relates to the logistics infrastructure can be categorized under four modes of transportation: (a) railroad transportation; (b) road transportation; (c) air transportation; and (d) maritime transportation. As Thailand's development plans are focused on complementing these modes of transport, policies related to logistics infrastructure can be treated as an "internal factor" that could affect development. For example, policies that increase the distance of roads and create new routes, develop railroad routes, including the Skytrain and Metro systems, increase the capacity of airports, expand seaports, especially in the EEC area, and support special economic zones, are likely to fuel the demand for jobs in each of the related modes of the transportation system.

Internal factors (direction of infrastructure development according to the government's plans) may be summarized by the modes of the transportation system as follows:

1. Railway infrastructure is expanding. First, the government plans to introduce double tracks where single tracks are currently used, which will raise the capacity of the railway system. However, the performance and number of locomotives and bogies might be factors that limit the use of rail transport. Second, several new routes of the Skytrain and the Metro in Bangkok and its vicinity are under construction; many of these will be completed in 2022. Third, the government project to develop a high-speed railroad is scheduled for completion in 2023.
2. Road infrastructure also has a tendency to increase. First, the government is focusing on expanding the expressway and the motorway, which will boost activity as long-distance travel on these roads is promoted. Second, according to statistics from the Department of Land Transport, vehicle registration seems to be increasing consistently despite the lack of a major development plan for primary and secondary routes.
3. The aviation infrastructure is being enlarged, as current airports are operating beyond their designed capacity. The government is focusing on the improvement of aviation infrastructure by expanding the capacity of airports, including building new airports, to support the number of passengers that had been increasing prior to the outbreak of the ongoing pandemic.
4. There is no major development program for maritime infrastructure, except for the expansion of seaports in the EEC to raise the capacity of shipping and economic activities in the area. In contrast, according to statistics from the Marine Department, local ports and their usage in Bangkok and its vicinity seem to be decreasing.

However, there also are "external factors" that could affect development apart from the modes of the transportation system. First, the impact of globalization, such as China's "Belt and Road Initiative," should lead to connecting various transportation routes

in the region and shaping new transport methods between countries. Second, the rise of electronic commerce (e-Commerce) will alter the practice of supply chain management and shipment structure due to changes in consumer buying behavior. Third, the advancement of technology that increases efficiency in the logistics and supply chain industry might replace human workers, for example, through the use of: 3D printing, self-driving vehicles, drones, artificial intelligence (AI), blockchain technology, Big Data, automation, augmented reality (AR) technology, Internet of Things (IoT), fifth-generation cellular communication (5G), and sensor systems.

In considering that technological adoption is crucial for development in the private sector, the potential effects of adoption of the above-mentioned factors may be summarized as follows:

1. Demand will rise for new jobs to support the use of new technology. For example, there will be a need for drone controllers, software developers, AI engineers, blockchain experts, IoT engineers, and data analysts.
2. The demand for some jobs will decrease, as technology can replace human workers, for example, replacing human drivers with self-driving vehicles, and replacing clerks with AI.
3. Human workers will have to learn new skills for using and adopting new technologies.
4. Some of the advanced technologies, however, might not affect employment due to cost-effective factors, limitations on their use according to government regulations, or it may not be possible to apply a technology in certain industries, e.g. exoskeleton technology is currently too expensive to implement and is not worth the cost of upgrading.

Moreover, tourism is another important factor that could affect logistics systems, considering that it is one of the sectors contributing the most to Thailand's economy. According to Tourism Authority of Thailand statistics, the number of tourists in the first half of 2018 increased by 12.46 percent compared with the same period in 2017. As a result, logistics systems will have to expand in order to support the number of tourists, which have been increasing over time due to the government's tourism policy, which is aimed at attracting more international tourists every year.

Given that the development of the logistics infrastructure in Thailand is changing in line with internal and external factors, the demand for employees in logistics and laborforce development in the logistics and supply chain industry is rising along with those changes. However, there is a gap in current studies on that demand and workforce development, as such studies are focused on specific sectors or areas. Moreover, the lack of knowledge from a holistic point of view and macroeconomic perspective might lead to the problem of employment mismatch as the workforce and the educational sector cannot grasp the factors that could affect the actual demand of industries.

This article is aimed at forecasting the demand for employees in logistics and workforce development in the logistics and supply chain industry over the next 20 years, by considering the changes related to the development of logistics infrastructure in Thailand, as well as macroeconomic perspectives and externally related factors, which will lead to policy recommendations on the appropriate development of human capital according to Thailand's development directions for each related sector.

2. METHODS

The methods used in this study consisted of quantitative and qualitative methods. The quantitative method used statistical data on logistics and supply

chain-related workers recorded in the Labor Force Survey undertaken by the National Statistical Office in 2019. Then, the authors calculated and forecast changes in the number of persons in the workforce. The qualitative aspect used information gathered through an in-depth interview and a foresight meeting with experts and stakeholders in the related industries.

Quantitative Methodology

Several methods have been used to estimate the demand for logistics workers, according to research on the demand for such workers. These include (a) the PmanP system,[1] a survey-based technique that implements survey data obtained from stakeholders in the calculation; (b) the Department of Skill Development's model that uses the Cobb–Douglas production function as a model for estimation; (c) the top-down model that analyzes a change in demand for workers in each group of sectors; (d) implementation of the Leontief production function for replacement of workers with technology; and (e) in-depth interviews with industry experts for an estimation based on the experts' assumptions. Each of the methods has its own limitation that cannot be used to gain a holistic point of view of the industry, as those methods were designed for a study in specific sectors or areas. Thus, a new model for estimation that is focused on the macro-perspective needs to be created in order to fill this gap.

For the quantitative part, this study uses statistical data from the Labor Force Survey for forecasting. Hence, to calculate the demand for logistics workers in terms of the number of workers, which could produce a holistic point of view in the industry, a mathematical model that combines internal and external factors as part of the calculation was developed for this study. The factors taken for calculation are as follows:

1. Projection of the demand for workers, according to the projected future economic growth rate.
2. The extra demand for the workers needed in specific jobs and sectors, which changes according to the government's development directions, or the economic growth rate. For example, a massive investment in the railroad system will cause an extraordinary increase in the demand for workers related to railroads.
3. The extra demand on workers according to changes in technological adoption. Some sectors may demand fewer workers as technologies will replace human workers, while some sectors may demand more workers with skills related to that technology, including newly emerging jobs. For example, advancement of AI will increase the demand for workers related to AI.
4. Projection of the demand for workers needed to replace retired workers. As a number of people will retire from their jobs every year, there will be a need for replacing them according to the number who retired.

Qualitative Methodology

For the qualitative part, this study collected opinions about the logistics landscape and employment situation from experts and stakeholders in the industries concerned, namely representatives from government agencies, the private sector, and academics, through interviews and a foresight meeting in the Northern, Southern, Eastern, and Northeastern regions of Thailand, as well as Bangkok and its vicinity. The process was separated into three phases.

The first phase involved an in-depth interview

[1] *PmanP system (Potential Manpower Project) by the Ministry of Labour is a database of demands and supplies for numbers of workers. The system calculated the demand and supply of workers by allowing employers and educational sectors to participate in the survey system on the needs of labor and the production capacity.*

about the employment situation – jobs in high and low demand, important skills that the industry preferred, and the impacts from internal and external factors that could affect business – including possible new jobs that emerge from the factors and jobs that might be terminated due to the changes. Then, the research calibrated the quantitative calculation with those factors to create pilot results of the demand.

The second phase was a foresight meeting used to present the pilot results, in which attendees gave their opinions on the results; the research would adjust the calculation according to those opinions, especially on the top three important jobs, the significance of a logistics degree for the job, and the possibility that the job might be replaced by technology.

Consequently, in the final phase, the adjusted results were sent to experts and stakeholders for final confirmation.

3. RESULTS

Given that the demand for the logistics workforce is affected by the development of logistics infrastructure by the government (internal factors), the estimation of the demand for logistics workers uses an assumption that the government has succeeded in developing the infrastructure according to the country's various development plans.[2]

The results are presented by quantitative and qualitative demands for logistics workers. It should also be noted that, as the ongoing coronavirus pandemic will likely have an adverse effect on the economy and infrastructure development, scenarios that could affect the estimation will be presented as well.

[2] *It should be emphasized that the real demand for the logistics workforce will also depend on many relevant factors, including economics factors, foreign investments, completion of logistics infrastructure, and technology adoption. In this case, if the government cannot complete the infrastructure projects according to the development plans, the demand for workers in logistics and supply chain-related industries will be reduced in line with the number of unsuccessful development projects.*

Quantitative demands for logistics workers

According to the Labor Force Survey by the National Statistical Office between 2013 and 2017, the workforce in the logistics and related industries has increased significantly.[3] The number of workers, 309,362, has increased by 15.3 percent, and the level of education among them has also risen. Most of the growth comes from workers in logistics transportation and warehousing, which saw an increase of 124,950 workers (39.7 percent). While the increases in the number of workers in other sectors are from road transportation (37,952 workers), supportive services (26,433 workers), and from parcel-post offices (23,937 workers). Logistics workers in other related industries also increased substantially by 136,328 workers (11.9 percent); in wholesale and retail sectors, by 125,707 workers; in the tourism industry, by 13,848 workers; and in the food and beverage industry, by 11,121 workers.

The authors' calculations find that the estimated demand for the overall logistics workforce could be as follows:

1. By 2025, there will be demand for 366,139 workers (73,228 workers per year between 2021 and 2025);
2. By 2030, there will be demand for 309,151 workers (61,830 workers per year between 2026 and 2030);
3. By 2035, there will be demand for 465,134 workers (93,027 workers per year between 2031 and 2035);
4. By 2040, there will be demand for 363,927 workers (72,785 workers per year between 2036 and 2040).

The Table below shows the quantitative demands for the logistics workforce could be distributed by various jobs.

[3] *The number of workers in the logistics and related industries was 2,022,209 in 2013, which increased to 2,331,571 in 2017.*

Table: Demand for logistics workers, by job and 5-year period

Job	2021-2025	2026-2030	2031-2035	2036-2040
Total demand (numbers within 5-year framework)	**366,139**	**309,151**	**465,134**	**363,927**
Drivers (cars, taxis, vans, heavy trucks)	167,899	161,870	215,682	170,998
Freight handlers	30,107	24,474	34,436	25,076
Stock clerks	26,777	18,638	39,955	25,156
Motorcycle drivers	26,053	22,989	29,381	25,008
Motor vehicle mechanics and repairers	18,922	11,923	27,345	21,109
Supply, distribution and related managers	14,497	9,276	17,521	15,908
Shelf fillers	7,696	5,228	10,112	6,524
Transport clerks	7,276	6,760	6,529	6,981
Procurement officer	6,846	3,442	9,370	8,221
Land moving and related operators	4,941	4,025	7,340	5,740
Transport conductors	4,522	2,948	3,741	4,380
Travel attendants and travel stewards	4,049	3,426	3,942	3,211
Civil engineering laborers	4,031	2,790	4,219	2,336
Retail and wholesale trade managers	3,521	2,806	6,912	5,650
Clearing and forwarding agents	3,404	2,849	4,343	3,944
Mobile farm and forestry plant operators	3,137	1,377	2,553	2,309
Travel guides	2,347	1,984	1,564	1,148
Door-to-door salespersons	2,346	1,730	4,269	3,101
Aircraft pilots and related associate professionals	2,344	1,734	2,569	3,834
Railway brake, signal and switch operators	2,269	2,112	2,188	1,966
Production clerks	2,114	862	3,137	1,713
Lifting truck operators	2,085	3,020	2,878	2,825
Travel consultants and clerks	1,964	1,548	2,151	1,574
Vehicle cleaners	1,948	920	3,040	1,136
Locomotive engine drivers	1,865	1,563	1,560	1,049
Commercial sales representatives	1,559	867	2,486	1,850
Ships' deck crews and related workers	1,286	447	2,800	814
Crane, hoist and related plant operators	1,149	1,156	2,372	978
Ships' engineers	1,057	183	671	82
Hand and pedal vehicle drivers	942	439	1,321	651
Aircraft engine mechanics and repairers	691	690	601	1,709
Meter readers and vending-machine collectors	664	362	1,448	-216
Air traffic controllers	493	377	433	270
Ships' deck officers and pilots	411	252	576	722
Air traffic safety electronics technicians	187	84	134	893
Town and traffic planners	154	30	90	458
Customs and border inspectors	125	30	76	-58
Trade brokers	59	37	108	117
Drivers of animal-drawn vehicles and machinery	38	8	23	111

Source: Authors' calculations

Qualitative demands for logistics workers

Regarding the qualitative demands for the logistics workforce, experts and stakeholders prefer the following general qualities in logistics workers:

1. Language proficiency
2. Morality and ethical values
3. Technology literacy and IT competency
4. Understanding of logistics-related laws and regulations
5. Excellence in services
6. Communication and team-work abilities
7. Problem-solving skills
8. Fundamental understanding of the logistics business
9. Specific logistics-related skills, e.g. machine/equipment maintenance, or safe driving

Effect of COVID-19 pandemic

In 2020, the coronavirus pandemic (causing COVID-19 disease) has crippled the global economy. Because of this, logistics and supply chain development in Thailand has slowed down. The effect of COVID-19 on the demand for workers in logistics and supply chain-related industries could be summarized under three possible scenarios:

Scenario 1: COVID-19 slowed down investments and infrastructure development for 2-3 years

Under this scenario, the demand for workers in logistics and supply chain-related industries will be the same as the estimation, but the demand will be delayed until the COVID-19 pandemic has settled down, taking approximately 2-3 years for economic activities to return to normal.

Scenario 2: COVID-19 becomes a chronic disease

Under this scenario, COVID-19 becomes a chronic disease that keeps interrupting the development of Thailand's logistics infrastructure. The demand for workers in logistics and supply chain-related industries will be reduced in line with the number of unsuccessful development projects.

Scenario 3: Globalization is weakened

Under this scenario, globalization is weakened by the COVID-19 pandemic: international investments in Thailand will be reduced and the number of international tourists will decline. The demand for workers in logistics and supply chain-related industries will weaken in line with the changes in global investments and tourism.

Despite the pandemic, which has slowed down the demand for workers, the demand for workers who are related to advanced technology, such as AI, Big Data, and IT, will barely be affected. The pandemic might be a factor that even accelerates the demand for this type of workforce, as technology is less affected by the pandemic and there is a tendency for industries to adopt technology faster.

4. CONCLUSION AND POLICY RECOMMENDATIONS

Employment mismatch is an important issue in logistics and supply chain-related industries, according to experts and stakeholders. Currently, education related to workforce development cannot fulfill employers' preferences as the curricula do not correspond to real working situations. Furthermore, the number of graduates is also not correlated to industries' demand due to the limitation of knowledge on the demand by specific jobs.

To promote the appropriate development of human capital for logistics and supply chain-related industries that correspond to Thailand's development strategies, a number of recommendations have been formulated for policy purposes, as follows:

Recommendations on education

For vocational certificate and diploma:

- Improve the curricula on logistics and

supply chains for obtaining vocational certificates and diplomas by implementing core competencies on logistics-related activities determined by the Thailand Professional Qualification Institute. Improved curricula need to be taught by lecturers who are specialized in logistics, or by logistics professionals. Furthermore, students in such courses should have to participate in the dual vocational education (DVE) system with a logistics-related company for two semesters in order for the students to gain experience in real working environments.

- The Thailand Professional Qualification Institute should enter into a memorandum of understanding (MOU) with the Office of the Vocational Education Commission to give support on competency testing for students. Students who pass the competency tests should be granted a co-certificate as validation of their competency.

For academic degrees (undergraduate degrees and graduate degrees related to logistics and supply chains):

- Create a competency/occupational standard test by implementing core competencies on logistics-related activities as determined by the Thailand Professional Qualification Institute as a solution to the problem of employment mismatch. Owing to the fact that the demand for logistics professionals with an academic degree is low at a time when there are many academic degrees on logistics and supply chains, including logistics and supply chain-related degrees, such as economics, engineering, or accountancy, there is a need for competency and occupational standards that match the academic skills and employer's requirements while filtering out those who are mismatched. The standard test would serve as a mechanism for validation of competencies.

For "Thailand 4.0" and "Logistics 4.0":

- Educational systems need to produce workers with high levels of language literacy. As Thailand's development strategies are focused on support for investment from overseas, there will be demand for a workforce that is fluent in non-native languages, such as English, Chinese, and Japanese.
- Educational systems need to produce workers with knowledge of technologies. Because advanced technologies in the future, such as Big Data, blockchain, robotics, automation, and IoT, will have a role to play in logistics development, labor without knowledge of advanced technologies or workers who cannot adapt to them may get replaced.
- An MOU needs to be established between the educational sector and the business sector for appropriate workforce development. The business sector should be involved in the production of workers by providing experts from its field of expertise to serve as teachers, including providing necessary equipment and designing the curricula.

Recommendations on skills development

- Employers can use skill development funds provided by the Department of Skill Development to support skills training for their employees. This fund would provide employers with financial support

for skills training programs, while the employees that complete the training program would be conferred a standard certificate that could be used to increase their wages.

- Employers may create an MOU with the Thailand Professional Qualification Institute to support their employees in terms of competency testing, especially support for covering the expenses of low-income professionals.
- Employers should support their employees to gain access to logistics skills training programs, which are available through several related organizations, such as the Transportation Institute of Chulalongkorn University, Department of Industrial Promotion's Division of Logistics, Thai Logistics and Production Society (TLAPS), Thai-Nichi Institute of Technology, and Thai-German Institute (TGI).

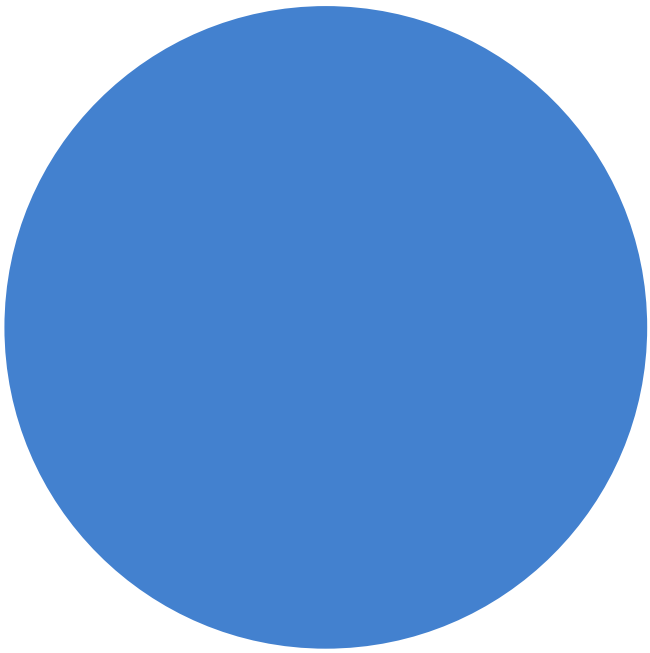
Recommendations on labor development by modes of transportation

For railroad transportation:

- The State Railway of Thailand (SRT) needs to improve the curriculum to support modern locomotive and signaling systems.
- Railway jobs should be promoted among unemployed persons, as railway jobs offer a good work environment, compensation, and welfare.
- Railway-related sectors, state-owned enterprises, and private companies should create MOUs with the educational sector, as a preparation process for real working environments, by supporting each other on teaching and equipment.

For road transportation:

- Employers and professional drivers need to improve their professionalism by respecting and strictly following the driving and traffic laws. For example, the time spent on driving, number of trips, or resting time need to be followed according to what is allowed by the law. Furthermore, employers need to give drivers proper compensation and welfare, as this type of job requires a high level of responsibility.
- Drivers need to improve their competency by taking a test of their competency as validation of their driving skills.
- A positive image of drivers needs to be promoted to attract more people to this profession. Because professional driving is a job with decent wages and career path, it could lead to a decent quality of life.
- The government should support professional driving as a career by supporting a vocational education system for professional drivers, including training for unemployed persons. Moreover, the government and business sectors should consider enlisting personnel as an alternative for the job.
- The government has to regulate competition in industries by enforcing requirements on equalizing the number of trucks and drivers, as driver shortages could lead to talent poaching.
- The government needs to consider allowing foreign workers to work as drivers as a solution to the driver shortage, especially foreign workers who could engage in cross-border driving.
- The Department of Land Transport needs to consider registering motorcycles as



freight vehicles, as using motorcycles for the platform economy has become more popular lately. Such registration would serve as a mechanism to support the business, including riders, and to regulate the use of motorcycles for this type of business.

- The government needs to recognize the use of motorcycles as freight vehicles and the platform economy as a form of employment to regulate the business. Currently, employment in this form of business is not protected by the law. For example, no professional standards, labor protection, and safety procedures exist for this type of work. Moreover, the government also should support professional standards and training systems for this type of job.
- The government should use the platform economy as a solution for unemployment problems, especially for marginal youth, such as the undereducated, addicts, and former convicts.

For air transportation:

- The airline business in Thailand needs to create incentives to prevent Thai pilots from working for foreign airlines.
- Aviation training institutes need to improve their courses to comply with International Civil Aviation Organization (ICAO) standards. Furthermore, aviation training institutes also need to include psychological training as part of their programs.
- The government should support the Civil Aviation Authority of Thailand (CAAT) to get certified by the European Union Aviation Safety Agency (EASA) as a validation of standards.
- Aviation maintenance technician training programs need to receive more support from the government and stakeholders, as there is a demand for this profession. The training programs need to comply with EASA standards, support modern aviation systems, and focus on improving students' language proficiency.
- Aviation maintenance technician training programs need to be taught by instructors who are certified according to EASA standards and, if possible, those instructors should be foreigners.
- Aviation maintenance technician training programs need to allow other types of technicians to apply to the programs in order to boost the creation of aviation maintenance technicians.
- Aviation maintenance technician training programs should create an MOU with international institutes following EASA standards in order to improve their

courses up to international standards and give students better training experiences through international collaboration and student exchanges.

For maritime transportation:

- Promote career paths in maritime transport and encourage application for positions suffering from shortages, such as naval officers, naval pilots, and ship technicians.
- Improve current curricula and training by supporting collaboration between the educational and business sectors.
- The Merchant Marine Training Center's training programs should include a 12-month internship onboard a cargo ship in order to give the students real working experience under certain circumstances and evaluation criteria.
- The Merchant Marine Training Center's training programs should include "soft" skills, such as moral and ethical principles, apart from the ordinary "hard" skills.
- The Merchant Marine Training Center's training programs should be focused on improving students' language proficiency, as communication in foreign languages is important for career development.

Recommendations for the government

- The government can prevent the problems associated with labor shortages by providing more employment opportunities, especially in important sectors, for labor groups that currently are left out of employment sectors, for example, foreign workers and dropout individuals with qualified skills.
- The government needs to support advanced training programs in the educational sector because skills training systems need to implement advanced technology as a part of their programs to make workers familiar with new technologies.
- The government needs to create long-term recruitment and development plans by supporting studying and training abroad in order to fulfill development needs, especially in advanced technology sectors. Such support will give direct opportunities for potential labor to study under international standards and environments.
- The government needs to create an incentive for logistics and supply chain-related careers. First, the government should promote a clear career path and benefits in this sector to enable people, especially the unemployed, understand what is involved in logistics and supply chain-related careers. Second, the government could give tax benefits for positions that are related to the country's development or positions that face problems with labor shortages.

LEGAL CHALLENGES AND POLICY SUGGESTIONS SUPPORTING THE ADOPTION OF AUTONOMOUS VEHICLES IN THAILAND

Saliltorn Thongmeensuk
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1. INTRODUCTION

Soon, driving and transport will become more autonomous and driverless. Autonomous technology is enabling vehicles to operate fully or partially without any input from drivers apart from setting the navigational prerequisites or destination. Moreover, the technology enables the vehicles to communicate and share some information with each other. As a result, autonomous technology can create substantial benefits, including easing traffic congestion, with an increase in vehicle speeds and upgraded traffic flow, transforming mobility for people with disabilities, and a reducing the costs and duration of travel. At the same time, autonomous vehicles can potentially save energy and decrease emissions through efficiency and promotion of electrification.

In addition, this technology can significantly enhance roadworthiness. According to an integrated database on road fatalities by the Department of Disease Control, the Ministry of Public Health, in 2020 the fatality rate from road accidents per 100,000 population in Thailand was 32.7 on average, or a total of 22,491 deaths. An average of three people per hour die as a result of traffic accidents in Thailand, which is twice the global average. Traffic accidents also cause enormous losses to the Thai economy: approximately 500 billion baht per year. Autonomous vehicle developers estimate that this technology could significantly lessen traffic fatalities.

Although this innovation's benefits are undeniable, the significant issues surrounding this new technology are focused on numerous legal challenges. One of the most significant implications is who should be liable if a vehicle causes injuries or damage, or violates traffic regulations. Liable parties may include the manufacturer of such an autonomous vehicle or its component parts, software developers, passengers, or owners. Thus, liability laws need to indicate where the liability resides in

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conflicts between these groups of people.

Moreover, even though autonomous vehicles can potentially decrease driver errors, they may still pose some risks to passengers and road users. In the period 2016-2018, about four fatalities were associated with autonomous vehicles around the world. Therefore, safety authorities need to consider whether existing laws are appropriate to regulate such technology, whether there is a need to establish specific regulations and provisions for testing and deploying this new technology on public roads, and whether the controllers of these vehicles need special driving licenses.

Many countries have permitted the testing of driverless cars on public roads and have issued regulations governing autonomous vehicles. For instance, Germany has amended its Road Traffic Act (*Straßenverkehrsgesetz*), which now encompasses "motor vehicles with highly or fully automated driving functions." Meanwhile, in the United States, as of 2018, 21 states and the District of Columbia had passed laws explicitly governing highly automated vehicles. Thailand, however, has not yet created specific laws to regulate any level of vehicle automation.

2. DEFINITION OF AUTONOMOUS VEHICLES

An autonomous vehicle refers to a vehicle that can maneuver itself without human interaction or instruction. In a technical context, the term "autonomous" infers that the vehicle can partly or totally perform without human input or command. The Society of Automotive Engineers (SAE International) provides a more specific definition of "autonomous vehicles" as it categorizes "automation" into six levels, ranging from no automation to full automation. The level of automation relies upon the roles of the driver or passenger in monitoring the driving environment and conducting "dynamic driving tasks." It is worth noting that the term "dynamic driving task" not only refers to the operational elements, such as steering, braking, and accelerating the vehicle, but it also includes tactical elements, such as changing lanes, turning, applying signals; however, this term does not involve strategic aspects, such as determination of the destination.[1]

The automation levels developed by SAE International have become the primary reference for all relevant partners involved with this groundbreaking technology.[2] The details of the automation levels are shown below in Figure 1.

3. AUTONOMOUS VEHICLE MARKET OVERVIEW

The use of autonomous vehicles can reduce emissions by up to 90 percent, and save 40 percent of travel time. Using fast fiber connections, 5G can create the hub of a database center for every autonomous vehicle, ensure the certainty of the automatic braking system and accelerate decision-making during the course of driving.[3] Furthermore, congestion in the future will be massively reduced as the autonomous vehicles lead to significantly lower demand for the use of private cars. According to simulations in Lisbon, an efficient public transport system with advanced technology can reduce by possibly 65 percent the

[1] *Adrian Ilka, "Legal Aspects of Autonomous Vehicles – An Overview," 21st International Conference on Process Control (2017).*

[2] *SAE International creates reports concerning levels of automation for defining driving automation in on-road motor vehicles (standard J3016). The report referred to here has been adopted as federal policy by the U.S. Department of Transportation for the purpose of safe testing and deployment of autonomous vehicles. SAE International also entered into agreement with the German Institute of Standardization, affirming the automation level developed by SAE International as the global norm.*

[3] *Nipaporn Limsiriwong et al., "Study of Autonomous Vehicles in Terms of Stages along with Technologies and Possibility of Implementation in Thailand," First International Conference on Smart Technology & Urban Development (STUD, 2019).*

Figure 1: Summary Table of Level of Automation

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Task	System Capability (Driving Modes)
***Human driver* monitors the driving environment**						
0	No Automation	the *full-time* performance by the *human driver* of *all aspects* of the dynamic driving task, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the driving mode-specific execution by a *driver assistance system* of either *steering* or *acceleration/deceleration* using information about the driving environment and with the expectation that the *human driver* perform *all remaining aspects* of the dynamic driving task	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the driving mode-specific execution by *one or more driver assistance systems* of both *steering* and *acceleration/deceleration* using information about the driving environment and with the expectation that the *human driver* perform *all remaining aspects* of the dynamic driving task	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the driving mode-specific performance by an *automated driving system* of *all aspects* of the dynamic driving task with the expectation that the *human driver* will *respond* appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene	System	System	**System**	Some driving modes
5	Full Automation	the *full-time performance* by an *automated driving system* of *all aspects* of the dynamic driving task under *all* roadway and environmental *conditions* that can be managed by a human driver	System	System	System	**All driving modes**

Source: SAE International, Standard J3016.

number of passenger cars on the road at peak hours.[4]

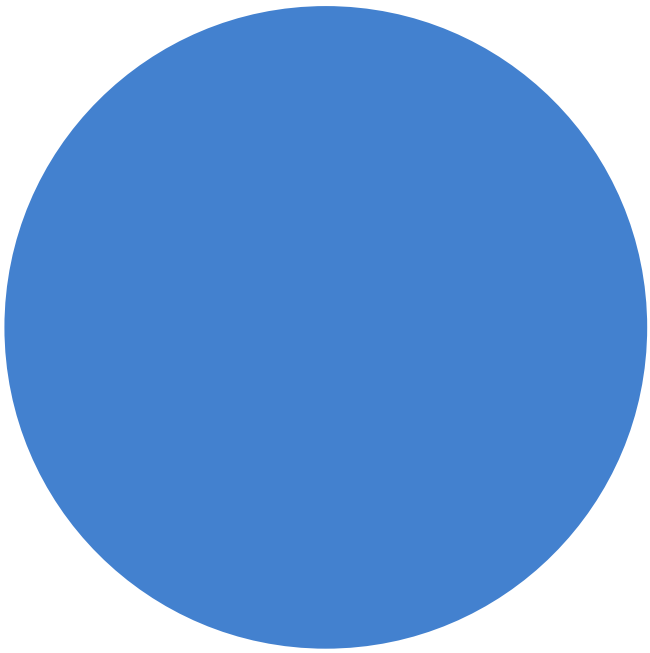
Additionally, the technology will reduce the cost of road accidents as it is expected to decrease injuries and fatalities by up to 33 percent.[5] Furthermore, according to the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA), overall driverless car premiums are forecast to decrease gradually as 94 percent of accidents will no longer be attributed to human error.[6]

Mordor Intelligence (2020) reported that autonomous cars globally reached a value of $19.46

[4] *Irum Sanaullah et al., "Autonomous Vehicles in Developing Countries: A Case Study on User's View Point in Pakistan," Advances in Intelligent Systems and Computing (2016): 561-569.*

[5] *Jun Wang et al., "Safety of Autonomous Vehicles," Journal of Advanced Transportation 2020 (2020): 1-13.*

[6] *"Driverless Cars Will Change Auto Insurance. Here's How Insurers Can Adapt," Harvard Business Review, March 7, 2018, https://hbr.org/2017/12/driverless-cars-will-change-auto-insurance-heres-how-insurers-can-adapt.*



billion in 2020.[7] The Research Department of Statista recently forecast, however, that the market value will decline in 2021 due to the COVID-19 pandemic. In order to prevent the further spread of the pandemic, governments across the globe have applied some containment policies, such as travel restrictions, leading to short-term supply chain disruptions. However, the global market is expected to recover and grow to approximately $37 billion in 2023.[8]

As for Thailand, the government has adopted the "Thailand 4.0" strategy to support economic growth based upon 10 S-curve industries, including the "next-generation automotive" industry, with research and development (R&D), innovations, and the digital economy at their foundation.[9] In 2020, the Thai government was testing self-driving "Tuk-Tuks" within restricted areas. The vehicles combine driving control technology with a six-seat electric golf cart equipped with an autonomous vehicle service application developed by Siri Ventures.[10] In addition, GenServ Co., Ltd. is bringing out "The First 5G Unmanned Shuttle Cart," a six-seat autonomous shuttle car controlled by the True 5G intelligent network. This shuttle car serves customers in the Lotus shopping center parking lot (Liab Duan Ram Intra branch).[11]

Autonomous vehicles are not yet on the market for commercial use. Nevertheless, Advanced

[7] *Mordor Intelligence, Autonomous/Driverless Car Market–Growth, Trends, Covid-19 Impact, and Forecast 2021–2026 (2020).*

[8] *Statista Research Department, Size of the Global Autonomous Car Market 2019-2023 (2021).*

[9] *Thailand Board of Investment, Thailand 4.0 Means Opportunity Thailand, 2017.*

[10] *Rahul Dutta Roy, "Built and Tested in Thailand – The Iconic Tuk-Tuk Goes Driverless in VC-Backed Bangkok Pilot," Auto Futures (2020).*

[11] *News Dir, "Shuttle Service The First Time in Thailand without a Driver - Siamphone.com," Newsdirectory3, March 5, 2021, https://www.newsdirectory3.com/shuttle-service-the-first-time-in-thailand-without-a-driver-siamphone-com/.*

Driver-Assistance Systems (ADAS), which attach electronic technology to assist drivers with driving and parking functions, are widely used. There are two automated systems with human interfaces in Thailand. The first system is the autopilot system. Tesla's autopilot system includes three automated modes: (1) "auto-steer" controls the vehicle in well-defined lanes and works together with traffic-aware cruise control; (2) "auto lane change" calculates automatic lane changes by pressing the turn signal; and (3) "auto park."[12]

The major players in the driverless car industry will be BMW, Mercedes-Benz, and Volvo, which held a substantial market share for the premium vehicle segment in 2019, such as the electric vehicle (EV) market (87% of the EV market) and plug-in hybrid electric vehicles (PHEVs) (92.8% of total market share).[13] In addition, Tesla is expected to be another prominent autonomous vehicle player because its autopilot system is the first commercialized technology accessible to both ordinary and wealthy people. At the same time, Honda and Toyota, the market leaders in terms of domestic passenger vehicle manufacturers in Thailand, may also become their major competitors because they are improving fuel efficiency along with the design of external car parts.[14]

The changes in technology can cause alteration in the Thai automotive supply chain because new parts and components, such as sensors, cameras, digital systems, and software, will become indispensable. Additionally, the increased demand for modules of parts could lead to the replacement of individual parts.

Thailand is a key supplier of core parts and components of autonomous vehicles, followed by other computer components, parts, and equipment (21.9% of exports in 2020), with the United States (27.6% of exports), Hong Kong (15.3%), the ASEAN zone (14.4%), the European Union (12.9%) and China (10.5%) having crucial export targets.[15] Therefore, the enhancement of production capacity and R&D is crucial for Thailand's parts suppliers to maintain export values.

4. ADMINISTRATIVE LAW ASPECTS

Legal challenges associated with the regulation of autonomous vehicles belong to the scope of administrative law, which covers, among other things, such legal challenges as the regulation of testing on public roads, the regulation of use on public roads, driving licenses, and technical controls. As illustrated in Table 1, this paper indicates that there will be rapid development of new laws and regulations to accommodate the introduction of driverless vehicles in some significant jurisdictions.

Thailand has not yet enacted specific laws regulating autonomous vehicle technologies. Consequently, the Notification of the Department of Transportation for Seeking Approval, the Approval and Duration of Using Road Vehicles and Markings Showing the Usage of Road Vehicles for Testing, B.E. 2560 (2017)[16] governs the testing of all types of vehicles also applies to the testing of autonomous vehicles. This notification requires the operator to obtain approval from the competent authority before undertaking testing and further sets forth that vehicles trialed on public roads must be controlled by a person with a driving license in accordance with the category of the vehicle being trialed. For instance, Section 11 of this act provides that "at the time when there is not enough illumination to view people, conveyances, or obstructions on the path clearly within the distance of

[12] *"Autopilot and Full Self-Driving Capability," Tesla, June 16, 2021, https://www.tesla.com/support/autopilot.*

[13] *Research and Markets, Thailand Automotive Outlook (2020).*

[14] *Krittin Tantisawetrat, "Driverless Car: Can the New Technology Find Its Way in Thailand," Sasin Management Consulting (SMC) (2020).*

[15] *Wanna Yongpisanphob, Industry Outlook 2020-2022: Auto Parts Industry (Krungsri, 2020).*

[16] *By virtue of Section 6/1 paragraph three of the Vehicle Act, B.E. 2522. (1979).*

Table 1: Laws and regulations accommodating the introduction of driverless vehicles

Issues		United States (California)	United Kingdom	Singapore
1. Specific laws and regulations related to autonomous vehicles (AV)		• California Vehicle Code • California Code of Regulations Title 13	• There are no specific laws for AV	• The Road Traffic (Autonomous Motor Vehicles) Rules 2017
2. Testing autonomous vehicles on public roads	Special license or permission	• Approval must be from the Department of Motor Vehicles prior to testing[1]	-	• Testing of autonomous vehicles is prohibited unless a permit is first obtained from the Land Transport Authority[2]
	Insurance requirements	• The manufacturer performing the testing shall obtain insurance or proof of self-insurance in the amount of $5,000,000[3]	• The Road Traffic Act 1988 requires insurance to cover the use of vehicles on public roads, but there is no specific insurance requirement for autonomous vehicles[4]	• Testing autonomous vehicles requires obtaining insurance[5] or providing the Land Transport Authority with a security deposit of not less than S$ 1.5 million[6]
	Requirement for test drivers	• Must be licensed for more than 3 years to drive a motor vehicle[7] • Must have completed compulsory training programs[8]	• The Code of Practice: Automated Vehicle Trialing 2019 • The drivers or controllers must hold driving licenses in accordance with the categories of the trial vehicles[9]	• Requires a qualified safety driver to be seated in autonomous vehicles [10] • Requires a qualified safety operator to monitor the operation of autonomous vehicles [11]
3. Using AV on public roads	License or permission	-	-	• The use of autonomous vehicle is prohibited on all roads unless a permit has first been obtained from the Land Transport Authority [12]
	Vehicle safety for personal use on public roads	-	• There are no specific laws for using AV. However, the user must comply with driver licensing and vehicle registration requirements [13]	• Must comply with the relevant driver licensing and vehicle registration requirements [14]
4. Reporting any incident involving AV		• A manufacturer shall report to the Department of Motor Vehicles the value of the damage to property or of bodily injury or death involved in AV accidents [15]	• The Code of Practice: Automated Vehicle Trialing 2019 • The trialing company should inform all relevant authorities about any incident or issue during the trial[16]	• A specified person must notify the Land Transport Authority of any incident involving the malfunction of the autonomous system or using AV[17]

[1] *Article 3.7 § 227.04 (d) of the California Code of Regulations.*
[2] *Article 4 (1) of the Road Traffic (Autonomous Motor Vehicles) Rules 2017.*
[3] *Article 3.7 § 227.04 (c) and Article 3.7 § 227.12 of the California Code of Regulations.*
[4] *Article 143 of the Road Traffic Act 1988.*
[5] *Article 14 of the Road Traffic (Autonomous Motor Vehicles) Rules 2017.*
[6] *Article 15 of the Road Traffic (Autonomous Motor Vehicles) Rules 2017.*
[7] *Article 3.7 § 227.34 (b) (1) of the California Code of Regulations.*
[8] *Article 3.7 § 227.34 (b) (2) of the California Code of Regulations.*
[9] *Article 87 of the Road Traffic Act 1988.*
[10] *Article 9 (b) of the Road Traffic (Autonomous Motor Vehicles) Rules 2017.*
[11] *Article 9 (c) of the Road Traffic (Autonomous Motor Vehicles) Rules 2017.*
[12] *Article 4 (2) of the Road Traffic (Autonomous Motor Vehicles) Rules 2017.*
[13] *Section 4.8 of the Code of Practice: Automated Vehicle Trialing 2019.*
[14] *Article 9 (a) and 9 (b) of the Road Traffic (Autonomous Motor Vehicles) Rules 2017.*
[15] *Article 3.7 § 227 (b) (1) of the California Code of Regulations.*
[16] *Section 3.11 of the Code of Practice: Automated Vehicle Trialing 2019.*
[17] *Article 19 of the Road Traffic (Autonomous Motor Vehicles) Rules 2017.*

not less than one hundred and fifty meters, the driver on the road must turn on the light or illumination of the category, character, and condition prescribed in the Ministerial Regulation." Therefore, partially automated vehicles can be trialed on public roads. On the other hand, this means that fully automated vehicles are not allowed to be tested on public roads.

In addition, the Vehicle Act B.E. 2522 (1979) requires all vehicles to be registered before being used on public roads.[17] Vehicles for which registration is sought must include all components and accessories prescribed in the Ministerial Regulation on Road Vehicle Components and Accessories, B.E. 2551 (2008). Moreover, the act requires safety inspection by the authority.[18] However, the regulation does not call for vehicles to be equipped with specific software, such as a data recorder for collisions.

Notably, there are no vehicle safety laws that directly forbid autonomous vehicles from operating on public roads. However, as the Road Traffic Act B.E 2522 (1979) obligates drivers to follow specific rules when using vehicles on public roads,[19] it implies that autonomous vehicles are banned from operating on public roads either for personal or commercial purposes.

The existing laws and regulations still are focused exclusively on conventional vehicles controlled by human drivers, while specific rules and regulations for monitoring activities related to autonomous vehicles are still absent. Therefore, to support technological progress, Thailand should begin developing specific requirements for testing and using of both partially and fully automated vehicles.

At the same time, identically to the practices of the United States and the United Kingdom, a driver or controller should be required to obtain special training on the controls of autonomous vehicles. This is so because, while the system itself maintains vehicle control, it is easier for a vehicle operator of an automated vehicle to lose his or her concentration on the driving task and become unable to regain situational awareness when the system takes over. However, the vehicle operators may still need to manually operate the vehicle if he or she encounters an automation programing failure.[20] Additionally, drivers may need to acquire new skills when driving different systems developed by different manufacturers.

Moreover, the relevant law, or laws, should oblige the company conducting the trial to obtain third-party insurance covering the individual or the company against any losses arising from accidents. Further, it should also require the testing company to notify the relevant authorities and the public immediately if an adverse incident occurs during the testing and use of autonomous vehicles. Finally, some relevant provisions under the Road Traffic Act B.E 2522 (1979) may need to be amended in order to allow fully automated vehicles to operate on Thai roads.

5. LIABILITY REGIMES AND THEIR APPLICATION TO AUTONOMOUS VEHICLES

Autonomous vehicle technologies are likely to weaken the notion that drivers are exclusively liable for their vehicles. By switching liability for the vehicles from the drivers to the manufacturer or software developer, these systems are likely to

[17] *Section 6 of the Vehicle Act, B.E. 2522 (1979).*

[18] *Section 7 of the Vehicle Act, B.E. 2522 (1979).*

[19] *Under the Road Traffic Act B.E 2522 (1979), the driver has the duty to comply with the law, such as the driver must turn on the vehicle's lights or illumination when there is not enough illumination (Section 11) or must give a light signal by blinking the front lights repeatedly, or give a right turn signal, or sound the horn to signal overtaking when passing another conveyance on the road (Section 44). Hence, it could be implied that driverless vehicles are prohibited from operating on public roads, whether for personal or commercial use.*

[20] *Wenshuo Wang, Junqiang Xi, and Huiyan Chen, "Modeling and Recognizing Driver Behavior Based on Driving Data: A Survey," Mathematical Problems in Engineering (2014): 1-20.*

undermine the traditional social apportionment of blame in car accidents.[21] Such error reduction may be roughly proportional to the extent to which the technology in question appears to control the car.

As illustrated in part 2, technology moves along a continuum between complete control of the vehicle by drivers and complete autonomous control. If the technology partially assists the drivers, it is less likely to frustrate the drivers' ultimate liability. On the contrary, if a vehicle with the "autopilot" feature crashes into another vehicle ahead, and the driver used the so-called autopilot correctly, the driver would not necessarily be at fault. In accidents involving drivers who reasonably rely on the car's ability to control itself, there may be no at-fault driver for the victim(s) to claim compensation.

There are three fundamental theories of tort liability that affect drivers: conventional negligence, i.e., traditional negligence; no-fault liability; and strict liability. First, according to the **traditional negligence principle,** an individual is held civilly responsible for harm that such an individual causes provided that the harm is considered a tort. The wrongdoer must remunerate the victim for any damage incurred. The essential features of traditional negligence are the existence of duty, breach of that duty, causation, and damage.In the case of motor vehicles, drivers must exercise reasonable care in their operation. Drivers are responsible for injuries they may cause in breach of the duty to exercise reasonable care. The basic idea of liability for negligence is that a person should be held liable for damage caused by his or her unreasonable failure to prevent the risk. The traditional negligence principles are set out in Section 420 of the Thai Civil Code and Commercial Code. However, in applying this section to autonomous vehicles, the driver of an autonomous vehicle is considered only a passenger, as he or she is not in control of the driving task. Because the injured party bears the burden of proof, it is difficult for that party to prove who is liable: the driver, passenger, vehicle manufacturer, software manufacturer, or the vehicle owner. In addition, technical knowledge and expertise are required to prove the claim.

Second, another liability theory relevant to autonomous vehicle technologies is **strict liability for abnormally dangerous activities**. This theory means that the person performing such an activity can be held responsible even though he or she is not at fault and took preventive measures to avert harm.[22] The reasoning behind this theory of liability is that the person engaging in ultrahazardous activities knows more about the dangers that such activities may cause and should therefore bear the related costs whether or not the person is at fault for the accident.[23] Under this system, victims of accidents involving autonomous vehicles can sue the owners or drivers, arguing that the operation of the technologies was considered an "abnormally dangerous activity;" therefore, the owners or the drivers should be strictly liable for any accident that occurs without proving if they were negligent.

Under Thai law, the principle of strict liability is adopted in Section 437 of the CCC. Thailand's Supreme Court Judgment No. 3437/2537 and No. 2659/2524 further interpret this section that the owner or operator of the vehicle under Section 437 of the CCC must be the person who was controlling the vehicle or operating the machine when the damage occurred. However, for autonomous vehicles, it is not the occupant of such a vehicle who can take

[21] *Jameson M. Wetmore, "Redefining Risks and Redistributing Responsibilities: Building Networks to Increase Automobile Safety," Science, Technology & Human Values, 29, no. 3 (2004): 391.*

[22] *Ken LaMance, "Ultrahazardous Activity Liability," LegalMatch Law Library (LegalMatch, June 25, 2018), https://www.legalmatch.com/law-library/article/ultrahazardous-activity-liability.html.*

[23] *Nidhi Kalra, James Anderson, and Martin Wachs, Liability of Regulation of Autonomous Vehicle Technologies (California PATH Research Report, 2009): 19.*

actual control at the moment of the accident, but the system or computer program that operates the machine or makes the decision.

Strict liability theory also applies under liability for defects in goods, according to the Product Liability Act B.E. 2551 (2008). According to this act, vehicle users do not have to prove that the operator intentionally or negligently caused harm within the meaning of traditional tort law. The manufacturer or software developer, on the other hand, has the burden of proving that the product did not cause the damage. Failure to prove this would result in product liability under this law. At the same time, users who have suffered damage as a result of autonomous vehicles still need to prove that the vehicles were used or maintained by their ordinary nature.[24] However, in the case of autonomous vehicles, new duties may arise for drivers or owners when using the vehicles beyond their current ordinary use, such as the duty to update software and the duty to install anti-malware systems. Therefore, in the event of an accident, the injured party or parties must additionally prove that the driver has complied with these obligations. In other words, the burden of proof will become more complicated. In case the injured party is not a user of the vehicle, not only must he or she prove that the defects of the product itself caused the accident, but must also prove that the driver of the autonomous vehicle used or stored it according to its ordinary nature.

Third, many jurisdictions currently apply **no-fault liability to automobile accident litigation and insurance.** According to this theory, the victims are not allowed to sue other drivers under the tort law unless the damage reaches a specific level of severity. Rather, victims must recover the value of the damage through their insurance policy, which remunerates them directly for the damage, regardless of whether anyone was legally at fault. As a consequence, this approach could eliminate the difficulty of determining who was at fault in a specific accident, thus leading to fewer lawsuits in court.

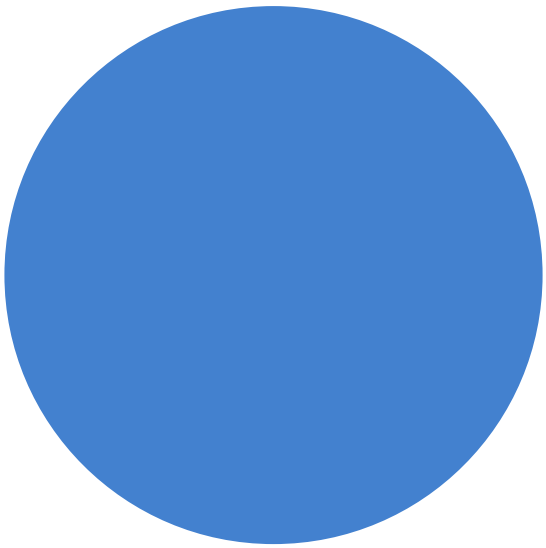
Thailand has also adopted the no-fault theory of liability for the insured under the Road Accident Victims Protection Act, B.E. 2535 (1992), which requires all owners and users of motor vehicles to purchase compulsory motor vehicle liability insurance. Given the preliminary coverage of the motor vehicle liability insurance, the insurer must indemnify medical expenses in cases where there are injuries, and funeral expenses in cases of death within seven days from the date the insurer receives the claim for indemnity regardless of whether anyone was legally at fault. Moreover, this act also established the "Victims Compensation Fund" with the objectives of indemnifying road accident victims for preliminary damage if the owner of a motor vehicle refuses to pay the victim(s) preliminary compensation or to pay compensation to the victims but not in the total amount.[25]

The switch of liability from drivers to manufacturers makes the no-fault liability regime for the insured more attractive.In such situations, although victims could sue the automobile manufacturers, product liability lawsuits are generally costlier and more time-consuming than the lawsuits concerning ordinary cars. No-fault liability regimes are created to swiftly compensate victims without the necessity to identify an at-fault party.

At the moment, it appears that no country has created particular legislation as to liability or insurance in the context of autonomous vehicles. The United States can serve as an example: the states of Michigan and Nevada have passed laws that assign liability when a driver modifies an autonomous driving system without the manufacturer's consent; thus, both drivers and manufacturers are subject to liability to

[24] *Section 6 of the Product Liability Act B.E. 2551 (2008).*

[25] *Section 23 (1) of the Road Accident Victims Protection Act, B.E. 2535 (1992).*



varying extents.[26] Hungary requires the developers of autonomous vehicles to take full responsibility for all damage incurred when deploying such a vehicle for development because, under the Civil Code of Hungary, the operation of an autonomous vehicle qualifies as a hazardous operation that entails strict liability. In contrast, Japan does not hold manufacturers entirely responsible for all damage as the liability associated with accidents is distributed based on the actual cause(s) proven.[27]

It should be noted that a strict liability system may give rise to unnecessary delays in manufacturers adopting autonomous vehicle technologies. Due to the gradual switch of liability from the driver to the manufacturer, the developers may be reluctant to adopt technologies that would lead to more liability. Moreover, they may have to price their innovation into their product to cover their foreseeable liability costs. This situation may result in higher prices for consumers and a slower introduction of this innovation in the market than would be socially optimal. Simply put, the costs of liability in this event may fall on the technology users because they are included in the product prices.

6. CONCLUSION AND POLICY SUGGESTIONS

In sum, the incumbent liability systems do not excessively create unusual or unexpected liability concerns for vehicle controllers. In contrast, the benefits of this technology, including the decline in the number of road accidents and the lower costs of insurance, will accelerate the adoption of autonomous vehicles by users. Meanwhile, the product liability of manufacturers may increase as manufacturers may be liable under a number of liability theories. This may lead to a significant delay in the adoption of the technology even though the technology itself dramatically benefits society.

In this case, the no-fault liability regime for the insured appears to be the most appropriate regime for recovering damages awarded in a judgment on autonomous vehicle accidents because it can swiftly compensate victims without the burden of identifying an at-fault party. As Thailand applies three theories of liability to the damage caused by autonomous vehicle accidents, the benefits and costs of each theory of liability should be further evaluated. The results of the analysis could clarify whether each of the existing liability regimes can effectively restore the value of items damaged due to accidents while neither discouraging R&D in the automotive industry nor delaying the pace of technology introduction.

Moreover, while this paper is just an initial attempt to plumb the potential liability and regulatory implications of autonomous vehicle technology, policymakers and automakers should consider the following suggestions to support the autonomous vehicle industry:

Transport Infrastructure Improvement. Thailand is facing three main challenges on infrastructure

[26] *Patrick Fair and Raffaele Giarda, Global Driverless Vehicle Survey, (Baker Mackenzie, 2018).*

[27] *bid.*

to support the adoption of the new technology, as follows:[28]

- 5G technology is the most vital component that has to be implemented before the level 3 or higher level of autonomous vehicles can actually be operated. Currently, the lack of consistent high-speed Internet is the main obstacle, making it difficult for automated vehicles to communicate with each other as the vehicles need to repeatedly gather information about driving conditions, such as traffic jams and potential obstacles blocking the road. This requires both the ability of the latter to respond to all circumstances and the reliability of the software. Highly detailed maps are required to navigate safely and use various sensors and methods without human input.[29]
- Autonomous vehicles generally work better on high-quality roads. On the contrary, Thailand's poor road quality can obviously become a barrier to the deployment of driverless cars. This problem is exacerbated by extreme variations and unique traffic signs in Thailand, which means that the problems of inconsistency, recognition inaccuracy, and detection failure are far from being solved.
- The density of electric vehicle charging stations is one specific index on readiness for KPMG autonomous vehicles calculated by the total number of EV charging stations divided by the length of paved roads. The results can reflect the willingness to update the road network for new technologies. Currently, the number of charging stations in Thailand has increased slightly to 817 stations in February 2021,[30] which reflects a very low density of charging stations compared with other countries.[31]

As a consequence, the government should actively take the first vital step to improve the transportation infrastructure to support autonomous driving and vehicle communication. In the initial stage, autonomous driving can be limited to certain areas, such as highway networks with a stable environment, to introduce autonomous driving. After that, the government should continue to expand the infrastructure to support this technology in other areas. Meanwhile, traffic lights and road signs should be improved to ensure that vehicles can "learn" the correct rules, as learning requires an unbiased, appropriately labeled, and high-quality training dataset on various driving scenarios. In addition, it is anticipated that Thailand should expect to have a 5G network fully covering its major cities by the end of 2021.[32] As AIS, True Move H, and DTAC are still expanding their service areas, the government should take advantage of 5G technology to support the communication between autonomous vehicles.

[28] *KPMG International, Autonomous Vehicles Readiness Index Assessing Countries' Openness and Preparedness for Autonomous Vehicles (2018).*

[29] *Nipaporn Limsiriwong et al., "Study of Autonomous Vehicles in Terms of Stages along with Technologies and Possibility of Implementation in Thailand," First International Conference on Smart Technology & Urban Development (STUD, 2019).*

[30] *Yuthana Praiwan, "EA Aims to Bump up EV Charging Outlets to 1,000," Bangkok Post, accessed July 6, 2021, https://www.bangkokpost.com/business/2067471/ea-aims-to-bump-up-ev-charging-outlets-to-1-000#:~:text=SET%2Dlisted%20renewable%20power%20developer,deputy%20chief%20executive%20Amorn%20Sapthaweekul.*

[31] *KPMG International, Autonomous Vehicles Readiness Index Assessing Countries' Openness and Preparedness for Autonomous Vehicles (2018).*

[32] *Nipaporn Limsiriwong et al., "Study of Autonomous Vehicles in Terms of Stages along with Technologies and Possibility of Implementation in Thailand," First International Conference on Smart Technology & Urban Development (STUD, 2019).*

Policy Development and Regulatory Promulgation. Another crucial step is to adjust the legal environment to support the upcoming technology. Many countries have started to adapt their legislation. Some of them have established specific regulatory systems for this technology, including systems for testing or using such vehicles on public roads. The Thai government should also start preparing relevant policies and adjusting the local legal environment. However, the novelty of this technology may bring about uncertainties in the application of laws and policies in practice; therefore, it should be emphasized that the promulgation of such laws will require extensive collaboration and a series of consultations among legislators, technical experts, and users to make the most feasible and appropriate decisions regarding the extent of regulation.

Standardization of Technologies. At the international level, the United Nations Economic Commission for Europe (UNECE) World Forum for the Harmonization of Vehicle Regulations (WP.29) has established the Working Party on Automated/Autonomous and Connected Vehicles. This working party is currently working on safety provisions which apply to all autonomous driving systems. In June 2021, it established new landmark vehicle regulations associated with autonomous vehicle technologies, i.e., UN Regulation No. 155 on Cyber Security and Cyber Security Management Systems; UN Regulation No. 156 on Software Updates and Software Updates Management Systems; and UN Regulation No. 157 on Automated Lane Keeping Systems (ALKS).[33] Thailand should, hence, consider adopting these UNECE regulations in supporting the introduction of autonomous vehicles on the country's public roads. Harmonization of automobile parts and the operation of autonomous technologies would enable the technology to function generally in an identical way irrespective of vehicle manufacturers, which would decrease the number of accidents caused by the confusion of consumers.

[33] *UNECE, "Three Landmark UN Vehicle Regulations Enter into Force," UNECE, February 5, 2021, https://unece.org/sustainable-development/press/three-landmark-un-vehicle-regulations-enter-force.*

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