Dubai Self-Driving Transport Strategy

Summary

March 2017
# Table of content

Definitions and Terminology ..................................................... 5
Executive Summary ............................................................... 9

1. international benchmarking ............................................... 15
   1.1 Automated Vehicles ..................................................... 16
   1.2 Connected Vehicles ..................................................... 16
   1.3 Technology Readiness .................................................... 17
   1.4 Worldwide Legislative Activities ...................................... 19
   1.5 Sdt Test & Development Programs .................................... 20
   1.6 Sdt Technology Hurdles .................................................. 21

2. Dubai Strategy ........................................................................... 25
   2.1 Multimodal SDT .............................................................. 26
   2.2 Worldwide SDT Competition ............................................ 26
   2.3 SDT Operations Policies/Legislation ................................. 26
   2.4 Strategic Alignment ......................................................... 27
   2.5 Stakeholder Coordination ................................................ 28

3. SDT Roadmap ........................................................................... 31
   3.1 SD Public Transport ........................................................ 31
   3.2 Connected Vehicle Roadmap ............................................. 35
   3.3 SD Private Vehicle Roadmap ............................................. 38
   3.4 Key Performance Indicators (KPI) ...................................... 39

4. Potential Benefits ................................................................. 41
   4.1 Improved road safety ....................................................... 41
   4.2 Reduced parking spaces .................................................. 41
   4.3 Increased public transport efficiency ................................. 41
   4.4 Decreased cost of mobility ............................................... 42
   4.5 Decreased pollution ....................................................... 42
   4.6 Improved productivity ..................................................... 42

5. Key Building Blocks ............................................................ 45
   5.1 Code of practice for testing .............................................. 45
   5.2 Legislation ........................................................................ 46
   5.3 Car Connectivity ............................................................ 47
   5.4 Cyber Security .............................................................. 47
   5.5 Insurance and Liability ................................................... 48
   5.6 Roadway Infrastructure and Mapping ............................... 48
   5.7 System Readiness .......................................................... 49

6. Partnerships and business models ......................................... 50
   6.1 Market makers .............................................................. 50
   6.2 Incremental revenue ....................................................... 50
   6.3 Vehicle supply partnerships ............................................. 50
   6.4 Start-up mentoring and partnership ................................... 51
   6.5 Software partnerships .................................................... 51
   6.6 City partnerships .......................................................... 51
   6.7 Business models ............................................................ 51
   6.8 Public private partnerships .............................................. 52
   6.9 Government funded projects .......................................... 52
   6.10 Competition ............................................................... 52
   6.11 Royalties/IP ................................................................. 52
   6.12 Business Model Summary ............................................. 52

7. Smart Mobility Lab/Center of Excellence ............................... 55
   7.1 CoE Concept ............................................................... 55
   7.2 Potential Benefits ........................................................ 56
   7.3 Key considerations ........................................................ 56

8. Strategy Sustainability factors .............................................. 59

9. Conclusion and next steps ................................................... 61
Definitions and Terminology
## Definitions and terminology

The following Table lists acronyms related to connected and self-driving vehicles. Using the same acronyms and terminology provides a baseline for conversation and understanding.

### Table 1: Commonly Used Organizational and Programmatic Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM</td>
<td>American Society of Testing Materials [International]</td>
</tr>
<tr>
<td>BRT</td>
<td>Bus Rapid Transit</td>
</tr>
<tr>
<td>CENELEC</td>
<td>European Committee for Electrotechnical Standardization</td>
</tr>
<tr>
<td>C-ITS [EU]</td>
<td>Connected and Automated Driving</td>
</tr>
<tr>
<td>ESMA</td>
<td>Emirates Authority for Standardization and Metrology</td>
</tr>
<tr>
<td>ETSI</td>
<td>European Telecommunications Standards Institute</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>NHTSA</td>
<td>National Highway Traffic Safety Administration</td>
</tr>
<tr>
<td>NTCIP</td>
<td>National Transportation Communications for Intelligent Transportation System Protocol</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>NHPP</td>
<td>National Highway Performance Program</td>
</tr>
<tr>
<td>OCC</td>
<td>Operations Control Centre</td>
</tr>
<tr>
<td>PTA</td>
<td>Public Transport Agency</td>
</tr>
<tr>
<td>RTA</td>
<td>Roads and Transport Authority</td>
</tr>
<tr>
<td>SAE</td>
<td>Society of Automotive Engineers, International</td>
</tr>
<tr>
<td>STP</td>
<td>Surface Transportation Program</td>
</tr>
<tr>
<td>TMC</td>
<td>Transportation Management Center</td>
</tr>
<tr>
<td>TSM&amp;O</td>
<td>Transportation Systems Management and Operations</td>
</tr>
<tr>
<td>USDOT</td>
<td>United States Department of Transportation</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
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<tr>
<td>---------</td>
<td>------------</td>
</tr>
<tr>
<td>ABS</td>
<td>Anti-lock Braking System. Operates by releasing and re-applying the brakes multiple times per second despite the driver continuing to press the brake—prevents the wheels from locking</td>
</tr>
<tr>
<td>ACC</td>
<td>Adaptive Cruise Control. Permits a following vehicle to maintain a desired headway to a leading vehicle allowing for the leading vehicle to change its speed</td>
</tr>
<tr>
<td>ADAS</td>
<td>Advanced Driver Assistance Systems. Technologies to assist driver safety commonly including blind-spot warning, lane departure warning, and forward collision warnings using sensors</td>
</tr>
<tr>
<td>AEBS</td>
<td>Advanced Emergency Braking System. Applies the brakes without driver intervention if an obstacle is detected</td>
</tr>
<tr>
<td>API</td>
<td>Application programming interface. Set of routines, protocols, and tools for building software applications, specifying how components should interact with one another</td>
</tr>
<tr>
<td>AV</td>
<td>Automated vehicle. Vehicles with advanced technologies to assist with driver safety and convenience including both warning systems and control augmentation</td>
</tr>
<tr>
<td>BSM</td>
<td>Basic Safety Message. Status Message containing location, speed, acceleration, and other vehicle performance data that is broadcasted from a connected vehicle to other vehicles in the vicinity</td>
</tr>
<tr>
<td>CACC</td>
<td>Cooperative Adaptive Cruise Control. Permits an automated vehicle in a platoon of automated vehicles to maintain a desired speed without touching the accelerator or braking through information exchange between the vehicles in the platoon. CACC enhances ACC by informing following vehicles of actions taken by leading vehicles that may not be directly observable by vehicle sensors</td>
</tr>
<tr>
<td>CC</td>
<td>Cruise Control. Permits the driver to maintain a chosen speed without touching the accelerator or braking</td>
</tr>
<tr>
<td>CV</td>
<td>Connected vehicle. Vehicle with necessary on-board systems to communicate wirelessly with similarly enabled vehicles as well as infrastructure deployed along the roadway</td>
</tr>
<tr>
<td>DSRC</td>
<td>Dedicated short range communication. Radio frequency technology for providing low-latency, high-bandwidth data communication at 5.9GHz using IEEE 802.11 (IP) standards</td>
</tr>
<tr>
<td>EDR</td>
<td>Event Data Recorder. A device that records certain information from a vehicle immediately before and/or during serious crashes. The data can be extracted to better understand what happened to the vehicle during such events.</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>ESC</td>
<td>Applies the brakes on one wheel at a time</td>
</tr>
<tr>
<td>GPS</td>
<td>Geolocation system utilizing geostationary satellites to accurately locate a device or vehicle on the globe using the relative positions</td>
</tr>
<tr>
<td>IPAS</td>
<td>Enables the vehicle to steer itself at low speeds or during parking maneuvers</td>
</tr>
<tr>
<td>LDWS</td>
<td>Provides a warning to the driver if the driver begins to shift out of its lane</td>
</tr>
<tr>
<td>LKA</td>
<td>Enables the vehicle to steer within the chosen lane</td>
</tr>
<tr>
<td>MAC</td>
<td>Provides addressing scheme that uniquely identifies a device on a wireless or wireline IP network</td>
</tr>
<tr>
<td>GID</td>
<td>Otherwise known as a “map”. A detailed high-resolution description of intersections and roadways for the purpose of localization as part of connected and automated vehicle applications</td>
</tr>
<tr>
<td>OBE</td>
<td>Hardware located in the vehicle to collect data or provide ITS services</td>
</tr>
<tr>
<td>OEM</td>
<td>Company that makes a part or subsystem that is used in another company’s end product. Also generally refers to the brand name of a vehicle, such as Ford or Toyota</td>
</tr>
<tr>
<td>PDM</td>
<td>A trajectory of data points describing a vehicle’s location, speed, acceleration, and other detailed status information over time.</td>
</tr>
<tr>
<td>PII</td>
<td>Data that could be used to identify or distinguish a specific individual from another individual</td>
</tr>
<tr>
<td>RSE</td>
<td>Hardware located at key roadway locations such as intersections, curves, ATM gantries, etc. for exchanging data with connected vehicles for V2I and V2V applications</td>
</tr>
<tr>
<td>SPaT</td>
<td>Messages regarding the real-time status of traffic signal devices provided to connected vehicles for improving safety (red and yellow light running protection) and mobility (reducing stops)</td>
</tr>
<tr>
<td>V2V</td>
<td>Ability for vehicles to communicate wirelessly to each other to provide improvements to safety and mobility</td>
</tr>
<tr>
<td>V2I</td>
<td>Ability for vehicles to communicate wirelessly to infrastructure deployed along the roadway (and vice-versa) to provide safety and mobility improvements</td>
</tr>
<tr>
<td>V2P</td>
<td>Ability for vehicles to communicate wirelessly to pedestrians alongside the arterial road network to provide safety information</td>
</tr>
<tr>
<td>V2X</td>
<td>Ability for vehicles to communicate wirelessly to other things particularly pedestrians and cyclists.</td>
</tr>
<tr>
<td>VRU</td>
<td>Pedestrians and cyclists, motor scooters and most motorcycles</td>
</tr>
</tbody>
</table>
Executive Summary
Executive summary

Self-driving transport (SDT) has long been a goal of the transportation technology research community. As far back as the 1970s, early efforts in the US and the UK produced limited self-driving functionalities in automobiles. What was once a distant goal, is now becoming a reality. Self-driving transport systems offer to transform not only the way we understand and use transportation, but also our social life. SDT technologies promise to transform the private vehicle industry, and even more importantly for Dubai – the mass public transport. Today, Dubai Metro is one of the largest self-driving public transportation systems in the world while other public transport modes such as first-mile-last-mile shuttles, BRT are also making considerable progress towards achieving self-driving functionalities. His Highness Sheikh Mohamed bin Rashid Al Maktoum has announced a goal that “by 2030, 25% of all transportation trips in Dubai will be smart and driverless.” In view of achieving this goal, this report outlines a strategy and roadmap for developing self-driving transport services in Dubai – focusing primarily on the public transport.

Global studies suggest that the benefits of SDT could be huge ranging from highway safety benefits to reduced parking costs, reduced mobility costs, environmental benefits, improved productivity, and improved quality of life and citizen happiness. In Dubai, it is estimated that these benefits of SDT would be valued at more than AED 22 Billion per year.

The strategy is prepared with clear sight on the current SDT technology status, key challenges, and the trend of technology based on the research and development efforts and the investments made and pledged by worldwide governments and private investors. While there have been significant developments by car manufacturers such as Tesla, Volvo, Mercedes Benz; technology companies such as Google; and ridesharing companies such as Uber; considerable challenges remain unresolved in safety, legislation and technology capability of the vehicles. In Dubai, the challenges are further raised by the extreme weather conditions and the diverse cultural mix of drivers and other road-users.
“By 2030, 25 percent of all transportation TRIPS in Dubai will be smart and driverless. The strategy is projected to generate economic revenues and savings of up to AED 22 billion a year.”

His Highness Sheikh Mohammad Bin Rashid Al Maktoum
Vice President and Prime Minister of the UAE and Ruler of Dubai
A vision for the future of transport

As a part of Dubai’s Smart City strategy, His Highness Sheikh Mohammad bin Rashid Al Maktoum recently announced a goal that “by 2030, 25 percent of all transportation trips in Dubai will be smart and driverless.” As part of initiatives to achieve this ambitious goal, RTA retained a team of self-driving transport (SDT) experts to develop an actionable roadmap and an action plan. This Self-Driving Transport Project will provide a vision, roadmap, and policy framework comprising a comprehensive strategy for testing, development, and deployment of a SDT.

Considering the technology readiness and the trends, we have developed a unique SDT strategy for Dubai which would set Dubai apart in the following ways:

1. **Multimodal SDT**
   While other major cities/countries are typically focusing on enabling the self-driving private vehicles, Dubai should target SDT across all 7 modes of public transport fleet including metro, tram, bus, taxi, marine transport, cable cars and shuttle. This means that the industry partners will be able to develop their technology with ease by working in partnership with the RTA. Currently, the self-driving Metro is estimated to serve approximately 8.8% of all individual trips in Dubai.

2. **Worldwide Competition**
   Dubai will host a worldwide SDT competition which will invite the SDT practitioners across the globe to participate in the competition and showcase their technology, processes, abilities and strengths in SDT. For Dubai, this will be a great way to not only try out these technologies, learn critical lessons, but also to become one of the leading attractions for SDT investors and technology researchers across the globe.

3. **SDT Operations Policies/Legislation**
   Dubai should lead the world in policies and legislation for SDT operations. To achieve these unique feats, this report outlines a detailed roadmap for self-driving public transport, connected vehicles, and private SD vehicles. Additionally, the project has developed key building blocks/enablers and detailed initiatives to ensure that the roadmap deployment can be achieved. The key pieces of the roadmap and building blocks are:

   - Design and deploy a self-driving BRT system
   - Deploy HD mapping with over the air update
   - Conceptualize, design and deploy a connected cloud
   - Study, define, and implement a self-driving Taxi zone
   - Infrastructure analytics for the SD vehicles
   - A code of practice with a level based approach
   - Policy/legislation for the operation of SDT

   [Insert list of other initiatives and enablers here]
The initiatives listed above include capital intensive projects such as BRT, a Taxi and infrastructure projects. However, there are opportunities to partner with the private entities to offset some capital cost and mitigate some risks of operation and maintenance of new assets. Further, these partnerships will ensure that Dubai stays at the frontier of new technologies without always having to renew investments.

The efforts required to undertake the proposed initiatives and building blocks span across the RTA agencies. The agencies will need to invest significant effort in study, design and development of the initiatives in coordination with internal and external stakeholders. Equally, the execution of the roadmap activities will require a champion to oversee the entire initiative, review progress made by each agency and external stakeholders, and strategize how to stay on course to achieve the 25% target. In addition, the report proposes that the feasibility of a RTA Center of Excellence (CoE) be studied further. The CoE would lead the research and development of new technologies and would create an ecosystem to drive technological concepts to their deployment stage.

Based on the technology readiness, SDT strategy and roadmap and the building blocks initiatives, it is estimated that the public transport in Dubai could achieve 25% self-driving individual trips by 2030 comprised of public transport services. Incentives and other enablers for SD private vehicles will likely

| 1. Legislation | • Testing  
  • Operations |
|----------------|---------------------------------------------------|
| 2. Driver Behavior & Acceptance | • Driver behavior in Level 2-3 vehicles  
  • Driver acceptance of SDT |
| 3. Driver & Vehicle Licensing/Registration | • SDT driver licensing  
  • SD vehicle testing, registration, renewal |
| 4. Insurance/Liability | • Crash liability of self-driving vehicles  
  • Insurance requirements |
| 5. Infrastructure Requirements | • Infrastructure improvements for SDT  
  • Crowd sourcing and analytics |
| 6. Cyber security/Data Privacy | • Self-driving vehicle security  
  • On-board data recording and retrieval |
| 7. Connected Vehicle Enablers | • Communication (V2I, V2V, V2X)  
  • Connected cloud |
| 8. HD Mapping | • Accurate HD Mapping  
  • Over the air update |

![Graph showing progress from 2016 to 2030 towards 25% self-driving trips](image)
drive the percent of SDT to more than 25% by 2030.

As shown as below, all 7 public transportation modes will contribute to SDT adoption and the percentage of SDT individual trips will build on over the years as the public transport modes design, test and deploy SDT systems in Dubai.

<table>
<thead>
<tr>
<th>Public Transportation Mode</th>
<th>2016 % of Total trips by SD mode</th>
<th>2030 % of Total trips by SD mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metro</td>
<td>8.8%</td>
<td>12.2%</td>
</tr>
<tr>
<td>Tram</td>
<td>0%</td>
<td>0.2%</td>
</tr>
<tr>
<td>Shuttle &amp; Cable-cars</td>
<td>0%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Marine Transport</td>
<td>0%</td>
<td>0.2%</td>
</tr>
<tr>
<td>Taxi / Rideshare</td>
<td>0%</td>
<td>3.5%</td>
</tr>
<tr>
<td>BRT, Rider &amp; Runner</td>
<td>0%</td>
<td>6.4%</td>
</tr>
</tbody>
</table>

Total Self-driving Public Transport 25%
01 International Benchmarking

Automated Vehicles
Connected Vehicles
Technology Readiness
Worldwide Legislative Activities
SDT Test and Development Programs
SDT Technology Hurdles
International benchmarking

Self-Driving Transport is a worldwide phenomenon. Research and development work on self-driving transport systems is occurring in all major developed countries in North America, Europe, Asia, and Australia. Advances in research and development of SDT technology are being announced almost on a daily basis, and industry perception is continually changing for even the most knowledgeable people in the field. There are parallel research and development processes occurring between self-driving transport systems and connected vehicle (CV) communication technologies. CV technologies enable safer and more efficient driving for both human- and computer-driven vehicles through warnings and detailed information sharing. Hundreds of projects have been undertaken worldwide to advance both self-driving and connected vehicle technologies.
1.1 Automated vehicles

More than 20 years ago, SDT technology advanced in the U.S. via the USDOT Intelligent Vehicle Highway System (IVHS) Automated Highway System (AHS) program. In the early 2000s, development was reinvigorated by the DARPA Grand Challenge and Urban Challenges, which brought universities and private sector teams together. Since the 2009 conclusion of the DARPA events, development of automated driving technologies has advanced rapidly. Parallel development paths have occurred in Japan and Europe over the past 20+ years as well. SDT technology is generally now advancing under private sector initiatives of virtually all of the automobile industry original equipment manufacturers (OEMs), Tier 1 suppliers such as Delphi and Continental, software companies such as Google, robotics-oriented start-up companies, and joint ventures. Major recent strides in accuracy, affordability, and capability of sensors, software, computing, and geo-location technology are enabling the march of SDT technology from research and development to availability for consumer purchase.

1.2 Connected vehicles

Over the last 20+ years, CV technology has been driven primarily by government initiatives of USDOT, EU Transport Ministries, and the Japanese Ministry of Land, Infrastructure, Transport, and Tourism. The CV program evolution was in direct response to the numerous challenges of the grand visions of the Automated Highway System (AHS) concepts from the late 1990s and early 2000s. CV technologies use wireless communications between vehicles, the infrastructure, and mobile devices to improve safety and mobility and reduce environmental impacts of human-operated vehicles. The US National Highway Traffic Safety Administration (NHTSA) has stated that DSRC 5.9 GHz communications capability will be required as a standard for light vehicle manufacturers beginning in 2019 with all models of vehicles including the technology by 2023. Similar mandates are expected in EU, UK, and Japan over the next coming years. There are current research efforts between private telecom providers, universities, and national governments to demonstrate the feasibility of 5G wireless technologies for both near-real-time and real-time, safety-critical applications.
1.3 Technology readiness

SDT operations have been classified into Levels by the Society of Automotive Engineers (SAE). Figure 2 describes these levels and shows the current status of public transport modes.

**Level 0**

SAE level 0 is non-automated operation. The driver is in control of both steering and braking. Sensor technology may still be used to provide warnings to the driver, but the vehicle will not control itself.

**Level 1**

Automates either the steering function, or the throttle function, but not both. Adaptive cruise control is an example of Level 1 operation.

**Level 2**

Automation allows the vehicle to control both steering and throttle/braking, but assumes the driver will always be vigilant and available to take control in a matter of seconds. This is the level of automation currently available on the Tesla AutoPilot, Mercedes E-Class and other currently-available production vehicles or vehicles to be available over the next 1-3 years.
Level 3

Automation allows the vehicle to control both steering and throttle/braking and can perform more complicated maneuvers for path planning and basic route planning from a given origin to a destination. The driver would be given ample time to take back control when the automated system is incapable of driving in the approaching environment (e.g. an arterial street with traffic signals). This is the level of automation planned for testing in Gothenberg, Sweden by Volvo in 2017 and the Mercedes CityPilot begun in July 2016. The Mercedes Automated Bus operates at level 3 in a dedicated BRT guideway.

Level 4

Automation allows the vehicle to operate with or without a driver on a complete trip on approved roadway facilities with pre-programmed routes, typically separated from other types of vehicle traffic. Higher levels of sophisticated software and perhaps additional sensor systems and connectivity to infrastructure are necessary for moving from Level 2-3 to Level 4. SD shuttle systems such 2GetThere, Olli, EasyMile, and Navya are Level 4 vehicles. They typically have capability for supervisory control by a remote operator if the vehicle encounters unusual circumstances.

Level 5

Automation allows the vehicle to operate with or without a driver on a complete trip anywhere including parking garages, freeways, two-lane roads, arterials, and local neighborhoods. There are no known automated vehicles with this capability today.

As global research and development of automated driving systems continues, it is expected that all modes will advance their capabilities but the pace of each mode may vary. SD shuttles will likely advance from low-speed demonstration operations to speeds that can sustain competitive revenue operation by 2027. Similarly, aTaxi and AV Bus capabilities should advance to Level 4 operation in approximately the same time frame. Many factors will affect the path of progress. Notably, the efforts in Dubai will contribute to accelerating the pace, particularly for self-driving public transport systems.

Ensuring system-wide safety is a critical component of moving SDT technologies into Level 4 and Level 5 operations. While computer reaction times can be much faster than humans and their situational awareness can be much more comprehensive than a human’s field of vision, unlocking the full safety potential of SD vehicles requires more sophisticated artificial intelligence and deep learning software systems. More sophisticated software will be required to allow SD vehicles to negotiate more and more complicated driving scenarios, such as those that require quick decisions by humans today.
1.4 Worldwide legislative activities

Several countries have been working towards preparing a legal framework to allow testing and operations of self-driving transport in their respective jurisdiction. See Figure 3. In the United States, more than eight States now allow SD vehicle testing and two States (Florida, Michigan) allow self-driving vehicle operations on public streets. Specific legislative actions have been taken in those States to modify driver and vehicle licensing regulations to allow these activities. Many other States are considering legislative actions to allow SD vehicles over the next two to three years. At the federal level, NHTSA published the automated vehicle policy guidance in 2016. This policy forms a recommended Code of Practice for SDT testing which shapes the information that SD vehicle suppliers should submit (currently on a voluntary basis) to NHTSA and State authorities regarding their SD capabilities. This information includes provisions for cyber and physical security, protections for user privacy, recording of data related to crashes, and test protocols. The province of Ontario, Canada has passed legislation allowing SDT testing and several other Canadian provinces are expected to pass legislation allowing SDT testing in 2017.

In the European Union, the Vienna Convention on Road Traffic governs road safety regulations. In March 2016, the regulations were updated to allow self-driving technology testing as long as the system can be overridden by a driver. Another amendment is currently under evaluation to remove the restriction that automated steering is only allowable below 10km/hr. This amendment is expected to pass in 2017 and then be adopted by the World Forum for Harmonization of Vehicle Regulations. The United Nations Economic Commission for Europe (UNECE) is amending specific regulations to allow the sale of vehicles with automatically commanded steering functions. In April 2016, many of the Transport Ministry Secretaries of the EU member states signed the Declaration of Amsterdam. This agreement is a landmark step forward for the European continent to agree to basic rules and steps for cooperating in the deployment of connected and automated vehicles so that SDT and CV technologies can operate seamlessly across Country borders. The legislative actions in each member Country are likely to occur in 2017-2018.

Singapore, Japan, and China allow SDT testing and are likely to pass legislation in 2017-2018 allowing SDT operations. The UK and South Australia have also passed legislation allowing SDT testing on public roads. The National Transport Commission (NTC) of Australia has proposed legislative changes as of November 2016 that will allow SDT testing and operation across all Australian States. This legislation is likely to pass sometime in 2017-2018.

Figure3: Worldwide SDT/CV Legislative Activities

https://one.nhtsa.gov/nhtsa/av/av-policy.html
1.5 SDT test and development programs

In conjunction with necessary changes to laws and regulations enabling self-driving and driverless transport systems, most first-world governments have a research and development program that is focused on demonstration of SDT technologies in a variety of application areas. Some high-profile and significant efforts are highlighted in Table 3.

Table 3: Major SDT

<table>
<thead>
<tr>
<th>Agency</th>
<th>Program Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Union</td>
<td>CityMobil2</td>
<td>Demonstration of SD public transport shuttles in 13+ European cities</td>
</tr>
<tr>
<td>European Union</td>
<td>ADAPTiVE</td>
<td>Evaluation of human-machine interfaces for L3 and L4 SDT</td>
</tr>
<tr>
<td>United States</td>
<td>Smart City Challenge</td>
<td>Demonstration of SD public transport and CV applications with Smart Mobility apps</td>
</tr>
<tr>
<td>United States</td>
<td>CV Pilots</td>
<td>Demonstration of CV applications in real-world locations (Wyoming, New York, and Florida)</td>
</tr>
<tr>
<td>United States</td>
<td>MCity</td>
<td>SDT test facility</td>
</tr>
<tr>
<td>United States</td>
<td>GoMentum Station</td>
<td>SDT test facility</td>
</tr>
<tr>
<td>Netherlands / EU</td>
<td>Truck Platooning Challenge (Companion)</td>
<td>Cross-manufacturer truck platooning demo</td>
</tr>
<tr>
<td>Sweden</td>
<td>Drive Me</td>
<td>Demonstration of 100 L3 SDT with common people</td>
</tr>
<tr>
<td>UK</td>
<td>GATEway</td>
<td>Demonstration of L4 public transport shuttles</td>
</tr>
<tr>
<td>UK</td>
<td>Autodrive</td>
<td>Demonstration of L4 pod vehicles</td>
</tr>
<tr>
<td>Japan</td>
<td>SIP-ADUS</td>
<td>Demonstration of L3 HMI issues; preparation of public transport shuttles for 2020 Olympics</td>
</tr>
<tr>
<td>Singapore</td>
<td>One North test site</td>
<td>aTaxi testing with common people</td>
</tr>
<tr>
<td>Singapore</td>
<td>CETTRAN</td>
<td>L3/L4 SDT testbed</td>
</tr>
<tr>
<td>South Korea</td>
<td>K-City</td>
<td>L3/L4 SDT testbed</td>
</tr>
</tbody>
</table>
1.6 SDT technology hurdles

It is important to recognize that while the SDT technology is moving at a rapid pace, any projection for when the technology will be available to deploy on public streets – as a revenue based service, is still prone to significant inaccuracies. The following is a list of factors which will greatly influence the pace of technology:

01 Solutions to providing universal V2V and V2I communications that are secure from malicious hacking;

02 Adequacy of computer processing speed necessary to support artificial intelligence that is required for self-driving vehicles in any environment;

03 Capability of communication infrastructure and HD mapping to support the huge increases of demand as the connectivity of vehicles with other vehicles/infrastructure increases;

04 Sufficiency of funding for actual deployment of SD vehicles along with the necessary communications, command and control systems.
1.6.1 Global Challenges

There are several challenges to be overcome by the SDT technologies and legislative efforts before SDT systems can be safely deployed to the public streets. These challenges include:

**Legislation:**
Currently, the majority of legislation around the world for SDT focuses on the testing/demonstration of SD vehicles. However, legislation related to the operation of SD vehicles still poses a significant challenge. It is not yet clear how the liability of SDT crashes could be fairly allocated to vehicle manufacturer, software provider, remote operator, and facility owner.

**Safety:**
it is envisaged that ultimately SDT would greatly improve highway safety by removing many risky driver behaviors such as impaired and distracted driving. However, in the interim, solid solutions are needed for drivers to be able to safely resume control of their level 2 or 3 vehicles. Some believe that the safety of all involved (including vulnerable road users and other drivers) may be challenging and development of Level 4 and 5 SD vehicles should be accelerated.

**Infrastructure:**
Significant investment will be required to upgrade the existing infrastructure to ensure compatibility with SDT modes. Additional infrastructure including roadside and in-vehicle equipment would be required to ensure that the SDT vehicles are able to communicate to other vehicles, infrastructure and other road users.

**Technology:**
Technology improvements are rapidly being developed and tested, but there remain significant additional challenges in artificial intelligence, mapping, sensors, and cyber security before Level 4 SDT will be made both universally safe and affordable.
1.6.2 Local challenges

Additionally, Dubai offers its unique challenges to the SDT with extreme weather conditions, cultural diversity and challenges related to first mile last mile applications due to the high temperatures in the summer.

- **Extreme Weather Conditions**
  - Humidity, fog, sandstorms

- **Cultural Diversity**
  - People Acceptance

- **First Mile/Last Mile**
  - High Temperatures
Dubai Strategy

Multimodal SDT
Worldwide SDT Competition
SDT Operations Policies/Legislation
Strategic Alignment
Stakeholder Coordination
Dubai Strategy

The uniqueness of the Dubai SDT Strategy is focused on the provision of comprehensive, multi-modal SDT services. SD public transport services have the potential to transform mobility in Dubai as a key component of the Dubai Smart City and Smart Life strategies. While vehicle manufacturers are generally taking an evolutionary, driver-centric approach to providing SD vehicles, SD public transport can evolve quickly in Dubai using BRT and first-mile, last-mile connections. Dubai can meet the 25% SDT trips goal faster by focusing on systems that RTA can control and bringing more travelers to the Metro and other public transport modes.

Dubai is also among a small number of governments unique in the world with an integrated transport agency structure. Transport management in the U.S., Canada, Australia, UK, and Europe includes a patch-work of local, regional, State, and Federal agencies that have varying levels of responsibility and jurisdiction. While the collective resources of regions such as the U.S. and Europe may be larger that Dubai and the UAE, the distributed nature of funding, regulatory authority, and inter-regional politics makes the path to progress less smooth. In particular, the management of public transport services and traffic services is generally separated in most other first-world transport agencies, and will slow progress in public transport service provisions. With the inspirational support provided by Dubai leadership, the pace of development and deployment in Dubai will be accelerated with respect to other first-world regions with targeted investment, smart partnerships, and unwavering dedication to implementing the activities on the roadmap and the building blocks.

Overall, three (3) areas have been identified for Dubai to be the leader in the world for SDT:
2.1 Multimodal SDT

As described in the previous sections, a lot of major cities have allowed SDT testing in their respective jurisdictions. However, these places have been focusing primarily on automation of private vehicles, and freight movements through automation of heavy vehicles (trucks). In contrast, Dubai should target self-driving transport across all 7 modes of public transport. This will enable a harmony of SD systems across transport modes and will accelerate the conversion of traditional trips to SDT trips.

2.2 Worldwide SDT Competition

As part of the SDT target announcement by His Highness Sheikh Mohammad Bin Rashid Al Maktoum, he envisioned Dubai to host a worldwide SDT competition which will be unlike any other such competition. The details of this competition will be announced very soon, but it is important to note that this will be an opportunity for all manufacturers, operators, researchers and academics to showcase their strengths and capabilities, to further propel SDT in this region and throughout the world. This competition will be a key part of Dubai’s strategy.

2.3 SDT Operations Policies/Legislation

While there are many trials/demonstrations of self-driving vehicles underway throughout the world, there exists a clear and significant gap in policies and legislation related to the revenue based operation of self-driving vehicles. Dubai should lead the world in developing these policies and legislation to allow full operation of self-driving vehicles on the public streets in Dubai.
2.4 Strategic Alignment

Dubai has a vision to become the smartest and the happiest city on earth through technology innovation, and maximizing efficiency to create the most enriched life and business experience possible for all. The Vision for Dubai is supported by a set of strategic pillars – efficient, seamless, safe and impactful. The overall vision and goals is seen to be enabled by a suite of technology strategies – internal and external.

Table 4 shows a list of existing technology strategies and how the SDT strategy aligns with the other strategies.

Among the external strategies, the SDT strategy is considered fully aligned with the UAE vision, Smart Dubai, Happiness strategy and the National Innovation Strategy. Among the internal strategies to RTA, the SDT strategy is considered fully aligned with the Green Strategy, Innovation Strategy, Security Strategy, Communications Strategy and Transportation Strategy.

<table>
<thead>
<tr>
<th>External Strategies</th>
<th>SDT Alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>UAE Vision &amp; National Agenda</td>
<td>III</td>
</tr>
<tr>
<td>Dubai Plan 2021</td>
<td>II</td>
</tr>
<tr>
<td>Smart Dubai</td>
<td>III</td>
</tr>
<tr>
<td>Dubai EXPO 2020</td>
<td>II</td>
</tr>
<tr>
<td>Dubai data initiative</td>
<td>I</td>
</tr>
<tr>
<td>National Innovation Strategy</td>
<td>III</td>
</tr>
<tr>
<td>Happiness Strategy</td>
<td>III</td>
</tr>
</tbody>
</table>

LEGEND
I: Not covered  II: Partially covered   III: Fully covered
2.5 Stakeholder Coordination

The SDT strategy was developed through extensive coordination with RTA internal stakeholders to ensure that the strategy is robust, relevant to each stakeholder and that it takes into account various current and planned initiatives from each agency:

- Rail Agency
- Corporate Technical Support Services
- Public Transport Agency
- Dubai Taxi Corporation
- Strategy and Governance Agency
- Traffic and Roads Agency
- Licensing Agency

Additionally, the SDT strategy was developed in working with the Dubai Future Foundation to align it with the initiatives across Dubai government.
<table>
<thead>
<tr>
<th>Agency</th>
<th>Coordination Required</th>
<th>Level of involvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telecommunication Regulatory Authority</td>
<td>Stakeholder meeting</td>
<td>Define and reserve the required spectrum for DSRC</td>
</tr>
<tr>
<td>Dubai Police</td>
<td>Stakeholder meeting, document review</td>
<td>Implement law enforcement and safety initiatives related to SDT and CV</td>
</tr>
<tr>
<td>Supreme Legislation Council</td>
<td>Stakeholder meetings, document review</td>
<td>Develop legal and policy framework to enable SDT and CV in Dubai</td>
</tr>
<tr>
<td>Insurance Authority</td>
<td>Stakeholder meetings, document review</td>
<td>Define insurance requirements and regulations, implement strategy</td>
</tr>
<tr>
<td>ESMA</td>
<td>Stakeholder meetings</td>
<td>Develop and enforce SD and CV vehicles standards</td>
</tr>
<tr>
<td>Private Developers</td>
<td>Stakeholder meetings</td>
<td>Assisting in deployment of SDT and CV in existing and future developments</td>
</tr>
<tr>
<td>Automakers and dealers</td>
<td>Stakeholder meetings</td>
<td>Test, develop new vehicles, standards, inspection and tests</td>
</tr>
<tr>
<td>RTA Sharjah</td>
<td>Stakeholder meetings</td>
<td>Define requirements for seamless driving between the Emirates</td>
</tr>
<tr>
<td>Abu Dhabi DMAT</td>
<td>Stakeholder meetings</td>
<td>Define requirements for seamless driving between the Emirates</td>
</tr>
<tr>
<td>DEWA</td>
<td>Stakeholder meetings</td>
<td>Provide infrastructure for electric vehicles</td>
</tr>
<tr>
<td>Other international organizations (e.g. NHTSA, UNECE, CCAV UK etc.)</td>
<td>Scanning Tours and Delegates visits</td>
<td>Understand the best practices around the world and contribute to standards development</td>
</tr>
<tr>
<td>Dubai Municipality</td>
<td>Stakeholder meetings</td>
<td>Provide supporting infrastructure for SDT</td>
</tr>
</tbody>
</table>
03
SDT Roadmap

SD Public Transport
SD Public Transport Deployment
Connected Vehicle Roadmap
SD Private Vehicle Roadmap
Key Performance Indicators (KPI)
SDT Roadmap

Planning for achieving the SDT goal of 25% individual trips by 2030 requires a clear roadmap, milestones for each of the public transport modes as well as detailed planning of the building blocks and enablers. This will ensure that the technological, legal and other foundational work is in place to support the deployment of SD public and private transport systems. Figure 5 shows the high level roadmaps and the key building blocks. Figure 6 provides a list of the key initiatives.

3.1 SD Public Transport

RTA currently operates (or plans to operate soon) a comprehensive set of public transport services throughout the city including metro, bus, taxi, marine transport, tram, shuttle (under trial now), and cable car (under planning). Among these public transport modes, Dubai Metro is currently self-driving and is the largest self-driving metro system in the world. Other modes are also planning for expansion, SDT trials and implementation depending on the technology adoption opportunities. For example, the Tram fleet is partially self-driving and a trial for SD tram is planned as part of the tram expansion project. PTA is planning to bring SD BRT system to Dubai with a strong focus on EXPO 2020. Furthermore, Dubai Taxi Corporation is studying feasibility of SDT taxi operations with the international operators, with plans for pilot schemes in the very near term. Additionally, there are efforts underway to bring SD marine transport, and SD shuttles to Dubai.
3.1 SDT targets

The cornerstone of the Dubai strategy will be the deployment of SD public transport systems. Based on our expectations for the readiness of self-driving technology, trends and other key considerations specific to the public transport modes, Table 6 shows 2030 targets for self-driving technology adoption for each of the public transport modes. For example, 63% of the trips served by taxi/rideshare is expected to be self-driving trips.

Based on the 2030 trip projections and above technology adoption targets, it is estimated that the percentage of SDT individual trips in 2030 by public transport alone will be 25%. This will ensure that Dubai can exceed the 2030 target (i.e. 25% SDT individual trips) without relying on private transport.

Table 6 shows the SDT targets for each of the public transport modes in 2030. The table shows how each of the public transport modes are expected to contribute to achieving the overall SDT goal.

3.3 SDT Public Transport Deployment

To achieve the targets listed above, each of the public transport sectors will require deployment of self-driving systems starting with the SD BRT lines and first-mile, last-mile (FMLM) SD shuttle connector systems. The FMLM SD shuttles are a key enabler to increasing the ridership of METRO to over 12% of total trips and BRT Rider and Runner systems to over 7% of total trips. Given the environmental conditions in Dubai, first-mile connectivity is critical.

Testing and demonstration of aTaxi/ridesharing services in limited environments will expand to include more comprehensive coverage of the City. SD marine, cable car, and Tram systems are important elements, but with small contributions to the total trips. Privately-owned SD transport vehicles will also contribute to the total. Private SDT trips are considered to be a bonus on top of the driverless trips contributed by the RTA public transport services and public-private partnership services such as aTaxi and shared-ride services.
Figure 7 Roadmap and Building Block Chart shows the self-driving public transport roadmap. It shows the activities and initiatives that should be undertaken until 2030 to deploy the multimodal SD public transport. The key elements of the public transport roadmap are as follows:

**BRT**
The BRT masterplan will be developed in 2017 and that it will be followed up with design, testing and deployment of SAE level 3 BRT in 2017-2018. This would pave the way for SAE level 3 BRT deployment in 2019, and finally Level 4 deployment in 2027.

**CABLE CARS**
SD cable cars are expected to be studied, designed and tested by 2019 for the deployment in 2020.

**MARINE TRANSPORT**
The SD marine transport will be designed/trialed in the second half of 2017 and the SD marine transport will be deployed in 2018.

**TAXI / RIDE SHARING SERVICES**
SD taxi/ridesharing services are proposed to be designed, trialed and tested by 2020 to culminate into a SAE level 4 pilot deployment in 2021. Finally, the Level 4 “Go Anywhere in Dubai” taxi/ridesharing services will be deployed in 2027.

**SHUTTLE**
It is expected that the SAE level 4 shuttles to be tested in 2017 – 2019. Further the SD shuttles will be designed in 2020 to be deployed for revenue services in 2021.

**BLUE WATERS GRT**
It is expected that the Bluewaters GRT will be deployed in 2019.

**TRAM**
The planned expansion of Tram will allow self-driving operations of the Tram. Therefore, the SD tram will be designed in 2020, and deployed in 2021.
3.2 Connected Vehicle Roadmap

Connectivity is an important component of a successful deployment of SDT technology systems. While many SDT developments by Original Equipment Manufacturers (OEMs) and third-party developers assume no connectivity or information from the infrastructure will be available, there is no dispute that additional information from the infrastructure can make SD vehicles smarter and safer. The most important element of vehicle-to-anything (V2X) connectivity for AVs is the frequent communication of signal phase and timing (SPaT) data to the vehicle. This information allows SD vehicles to safely navigate traffic signals without having to optically identify the signal color (red, yellow, or green). In addition, broadcasting data related to work zones, incidents, and other special events is critical for SD vehicles to navigate through unexpected environments.

A key component of the goal is that 25% of all trips in 2030 are both Smart and self-driving. The goal of all trips being smart identifies the need for CV systems and infrastructure. To achieve the goal of 25% trips to be smart by 2030, the following objectives must be met:

1. SD shuttles, SD BRT, and local buses are enabled with CV applications and equipment.
2. Privately owned SD vehicles are mandated to be CV-enabled.
3. Traffic signals, freeway interchanges, and junctions that SD public transport vehicles interact with have CV roadside equipment and applications.
4. A Dubai Connected Cloud system is developed that provides the high-speed, high-bandwidth connectivity for SD vehicles remote operations and CV-data dissemination and data collection.

The CV system architecture is based on roadside equipment (RSEs) owned and maintained by the RTA, on board equipment (OBEs) on vehicles, and a base set of communication protocols defined by world-wide standards. The CV applications in Phase 1 are aligned to provide maximum benefit to the SD public transport vehicles. The Phase 1 CV applications for vehicle-to-vehicle (V2V) safety use dedicated short range communication (DSRC) radios and sensors on vehicles to send a message between vehicles to warn of a potential safety-critical event. The Phase 1 vehicle-to-infrastructure (V2I) safety and mobility applications send SPaT and related information from the traffic signal controller to the vehicle using DSRC.

To ensure that the CV communications system is reliable and secure, the 5.9/5.8Ghz spectrum must be protected by the Telecom Regulatory Authority from interference from other wireless devices. In addition, a world-wide standard security credentials system must be put into place to ensure that cybersecurity and hacking of SD vehicles and CVs is minimized.
Figure 6 shows the overall connected vehicle roadmap. The key elements of the roadmap are:

**CV Testbed**
The feasibility of a connected vehicle testbed should be studied in 2017. If the CV testbed is deemed feasible, the CV testbed should be developed in 2018, to be utilized starting in 2019.

**In-vehicle equipment**
Detailed specifications for the infrastructure, roadside equipment and for on-board equipment will be developed for the vehicle connectivity in 2017-2018. This would lead to mandating in-vehicle equipment in 2019, and in developing and deploying CV applications starting in 2019.

**CV deployment strategy**
A detailed strategy for CV deployment will be deployed in 2018, to implement the strategy outcomes starting in 2019.

### Services
- BRT
- Automated Shuttles

### Policy
- Reserve 5.9 GHz spectrum for DSRC
- Establish COE CV/AV technology development
- Mandate for CV hardware and software on all new vehicles (Level 2+)
- Develop security credentialing system

### Location selection
- Align with BRT, shuttle locations
- RSEs at intersections, BRT stations
- SD Testbed

### Deployment
- Integrate CV and DSRC into BRT, shuttles
- Install RSEs at intersections. Broadcast SPaT messages
- Install RSEs along BRT corridor, every 1 km
- Perform communications analysis and build backhaul-communications network - Dubai Connected Cloud
- Develop Phase 1 & 2 CV Applications
- Establish back-end systems infrastructure (servers, software) - Dubai Connected Cloud
- Test applications in testbed
3.3 SD Private Vehicle Roadmap

SD vehicles owned and shared by private citizens have the potential to change the transportation industry and society for the better. This includes significant potential to decrease the number of roadway crashes, reduce severity of crashes, reduce carbon emissions and to improve mobility. Further, it is expected that these technological advancements will improve productivity, reduce travel time and in general improve the overall quality of life and happiness for Dubai residents. To achieve these benefits, the Dubai government will need to provide a legal and policy framework and testing and development facilities which would encourage SD vehicle suppliers to come to Dubai. Before these SD vehicles are ready for use by the public, it it is expected that controlled ‘real-world’ testing will be required to ensure that the technologies undergo thorough evaluation in varied and complex environments. Therefore, testing on controlled or dedicated zones of Dubai should be facilitated while ensuring public safety during the testing phase.

A Code of Practice (CoP) has been developed that requires SD vehicle supplier organizations to comply with when demonstrating and testing L3 and L4 automated vehicles. The Code of Practice for Testing is not intended to be a regulatory document but rather a set of guidelines. Certain elements of the CoP could be incorporated into regulatory amendments to become legal requirements rather than guidelines.

It is the role of RTA to monitor the test performance and ensure that testing is generally occurring in the spirit of the code of practice. A comprehensive SD testbed facility is needed for assurance that privately-owned and shared-use SD vehicles are demonstrated to be safe in a variety of traffic scenarios commonly encountered in Dubai. The SD testbed facility should include characteristics specific to Dubai such as structures, signage, markings, ramp lengths, roundabouts, and traffic signals. The more types of infrastructure and roadways the facility can accommodate, including new and innovative CV applications and roadway markings, the increased likelihood SD vehicle suppliers would locate in Dubai for testing.

The key elements of the roadmap are:

**SD Testbed**
A testbed will be developed to test new SDT technologies in Dubai. RTA will study the feasibility of the testbed in 2017, then identify the site and build the testbed by 2018 to start the operations of the testbed by 2019.

**SD Zone**
As a parallel track to the SD testbed, RTA will consider designating an SD zone where self-driving vehicles would be able to drive on real streets. The study and design of the SD zone will likely be completed by 2018, to start operating the SD zone in 2019.

**Transportation Modeling**
The self-driving vehicles and the connected vehicles will have significant impacts on the traffic operations. To study these impacts in detail, RTA will study the impacts on SDT and CV on both macro level as well as the micro level simulation and transportation modeling and planning starting in 2017. These models will be updated at intervals based on appropriate triggers, such as technology innovations.

**Incentive program**
RTA will develop an incentive programs for private SD vehicles in 2018 and will implement these programs starting 2019.
3.4 Key Performance Indicators (KPI)

To assist with the overall monitoring of the progress, a high-level result oriented performance indicator was developed which will assist in reaching the overall target of 25% SDT by 2030.

The SD trips percentage for each mode will be calculated as the number of SDT trips divided by the number of total Dubai resident trips. For example, in year 2020, Metro is expected to serve 10.7% of the overall individual trips, SD tram is expected to serve 0.15% of the overall individual trips, SD buses are expected to serve 0.44% of the overall individual trips, SD shuttles are expected to serve 1.44% of the overall individual trips and SD marine transport is expected to serve 0.04% of the overall individual trips.

Based on the above KPI, in year 2020, SDT individual trips will be 13.2% of the overall trips. In 2024, this percentage is estimated to reach 18.9%. It is expected that the 25% SDT target will be achieved in 2029-2030 and that the continuous deployment of the SDT use-cases will take the overall SDT individual trip percentage by public transport alone to 25% in 2030.
Potential benefits

- Improved Road Safety
- Reduced Parking Spaces
- Increased Public Transport Efficiency
- Decreased Cost of Mobility
- Decreased Pollution
- Improved Productivity
Self-driving transport promises to transform the entire transport industry as well as the social lives of City residents. It is expected that as SDT systems go mainstream, savings of more than AED 22 Billion per year may be achieved. Equally, it will result in making people happier by offering a less stressful and less complicated travel experience – where the journey will be a seamless, safe, worry-free experience from origin to destination.
4.1 Improved road safety

Human error has been a key contributor to the vast majority of highway crashes. However, with self-driving vehicles, the computers behind the SD vehicle operations will be able to make the decisions for the driver. These computers will be able to sense the environment much better, and will be able to react much faster than humans. Therefore, it is expected that the road safety will be dramatically improved by self-driving vehicles.

It should be noted that during the transitional stages of self-driving vehicles when the vehicles are not completely able to self-drive, the road safety would depend on how well the SD vehicles will be transitioned from automated to manual control.

4.2 Reduced parking spaces

SDT would likely change the transportation habits/behavior of the travelers such as ridesharing, resulting in reduced requirements for parking spaces. Additionally, the self-driving vehicle would not require spaces to open both doors which would mean that the parking bays could be smaller. It is expected that SD vehicles will result in 50% reduction in required parking spaces.

4.3 Increased public transport efficiency

SD public transport will be made more efficient as it would be able to integrate with control centers, roadside equipment and other vehicles (private or public). This will result in a smooth operation of vehicles, on-time arrival and greater reliability and comfort of public transport.

It is expected that overall efficiency of public transport will rise by 20%
4.4 Decreased cost of mobility

Smooth operations of SDT, as described above, as well as steam-lined mapping and journey planning will result in overall decrease in fuel expenses and vehicle efficiencies. Further, it is expected that the vehicle ownership model may change for many from single ownership to a shared ownership model. The cost of mobility is expected to decrease by 44%.

4.5 Decreased pollution

Environmental benefits of the SDT stem from three prime factors:

1. Many self-driving vehicles will also be environment-friendly electric vehicles
2. SD vehicles will be designed and operated to be environment-friendly by running them under optimal speeds, acceleration, and braking
3. SDT will encourage ridesharing/modal shift to public transport

It is expected that the overall pollution will be reduced by 12%.

4.6 Improved productivity

SD transport could free up time spent commuting for drivers to undertake other tasks. Drivers would be able to spend travel time working, relaxing and/or any other productive activities. Further, as the SDT goes mainstream, new vehicle designs may further maximize passenger productivity, providing them with workstations, sleeping pods, and infotainment units. It is expected that the SDT would improve general productivity by 13%.
05

Key building blocks

Code Of Practice For Testing
Legislations
Car Connectivity
Cyber Security
Insurance and Liability
Roadway Infrastructure and Mapping
System Readiness
RTA Agency Responsibility Summary
5. Key Building Blocks

5.1 Code of practice for testing

In order to facilitate technology development, and to ensure that Dubai not only deploys SDT but leads the deployment of SDT worldwide, Dubai’s testing regime will need to allow rapid progression from closed site testing to public running in public spaces off the highways, and on to public highway testing, live demonstrations and full deployment.

The British code of practice is a template for a liberal approach with no requirement for test licences provided the vehicles are safe and (where appropriate) street legal in terms of their crash testing, type approval, insurance and so on. The USA system is licence-based and places more explicit controls on the vehicle operator, but nevertheless provides freedom to test and demonstrate.

RTA will consider a level-based approach which combines a liberal and inviting approach to automotive vendors, while also enabling a structured licensing and approval procedure to ensure that public safety is respected, and that drivers and test organisation are appropriately trained and that records are kept of testing and outcomes. The Code of Practice will provide the standards processes/procedures/steps through which a testing organization could apply for testing their vehicles/technology in Dubai based on the level of their technology stage/sophistication. For example, a new technology which is sufficiently tested in the lab environment but not on public streets, could be allowed to test in isolated testbed conditions (this might be considered “level A”). As the vehicle meets all the required tests and parameters, the technology will then be permitted to the next level of real-world scenario testing – namely controlled environment testing (i.e. “level B”). Upon satisfying requirements and criteria of the second level of testing, the technology will then be allowed to test under controlled deployment. Under this step, trial vehicles must be compliant with required regulations and be suitably insured. Vehicle test drivers and safety pilots – including all on-board safety pilots and any remote tele-operators – must have the appropriate driving licences for each class of vehicle and must respect all other relevant legislation including working hours. Finally, upon meeting all safety, security and other criteria, the technology would be approved to be deployed on the public streets.

In parallel, RTA will study, design and implement an integrated testing facility, which will serve to accelerate this process and help attract vendors to engage in Dubai as part of their first wave of Connected and self-driving vehicle deployment in the Gulf region (MENA).

5.2 Legislation

As described in the roadmap, the wide range of enabling legislative initiatives will include driver testing and licensing product and vehicle liability; vehicle type approval standards; and traffic related safety legislation. These will mainly impact Federal laws 6, 8, 9, 14, 17 and 21 – which address traffic, transport and insurance regulations – plus several other guidance documents including the Light Motor Vehicle Handbook and the Truck and Bus handbook.

The primary focus of legislative reform will be the safe use of self-driving technology and the approvals mechanism for their live service. This will be a key role of the testing capabilities to be established at the testbed facility, in conjunction with other international centres and regulatory authorities. The learning process will heavily depend on the quality of operational reporting during testing so that crashes, near misses and any other material events can be examined openly, while still respecting the suppliers’ commercial confidentiality and the vehicle occupants’ right to privacy. An early priority is to agree on a standard for an on-board event data recorder.

The transition to the legal driver of the vehicle potentially being outside the vehicle requires a wide-ranging revision of all references to legal “drivers”. This has impact on obligations to be properly licensed, to be attentive and not to be impaired by drugs and alcohol. Remote tele-operators (for breakdown recovery and so on) will be considered as legal drivers when in charge of a vehicle. The complexity then extends to definitions of duties and responsibilities between different supporting systems which input to the vehicle’s awareness and decision making. RTA plans to collaborate with international bodies
such as the UNECE World Forum which is seeking to develop a set of harmonised regulations.

Vehicle Testing regulations also require significant reform to provide for (a) close monitoring of shared vehicles, (b) a real-time duty of care for the fleet operator, and (c) identification of tests that demonstrate the ability of and SD vehicle to recover to a minimum risk state when a failure occurs. The testing and certification of software then introduces a range of new legal requirements that mirror the various classes of passenger cars, freight and public service vehicles – and require their management systems to be regulated to be fit for purpose.

5.3 Car Connectivity

Having real time connectivity between vehicles and their infrastructure is a key requirement for fleet operations and any teleoperation or remote services critically required for public transport vehicles as well as for privately owned vehicles.

All vehicles will benefit from connected services that advise on signal phase and timing, which reduces wasted energy from braking and improves flow through signalised junctions.

All vehicles also benefit from up to date information on traffic conditions, work zones, traffic incidents and so on. Fleets of autonomous vehicles will additionally benefit from predictive demand modelling and destination dispatching and route assignment to enable efficient tasking and loading of each vehicle.

RTA will consider deploying connected vehicles roadside equipment between 2018 and 2020, with initial deployment to support Bus Rapid Transit services and site-specific shuttle operations. In a second phase from 2020–2028, local vehicles will be equipped with on board equipment, with all vehicles sold in Dubai with CV equipment by 2030. Reserved spectrum in the 5.8/5.9 Ghz spectrum is required to be set aside now for exclusive use of future connected vehicle services, adopting international ISO standards.

Vehicle to vehicle communication enables better traffic coordination. When implemented as a low latency service it provides for advanced safety functions in which cars share information collaboratively to avoid crashes and improve throughput.

5.4 Cyber Security

Self-driving and connected vehicle cyber security requires (a) resilience during unplanned system outages including platform and network system failures; (b) defence against intentional cyber-attack to corrupt or take down normal service operation; and (c) invulnerability to hostile intention including terrorist attacks, such as using the vehicle as a weapon to crash into people, vehicles or buildings.

All major international regulatory groupings have attempted to establish a consensus on cybersecurity design which enables convergence of on-board systems design with infrastructure and operational services. Dubai should establish security and privacy standards that are consistent with international best practice. Legislation is required to detect and punish hackers of all types including data mining into self-driving vehicles and connected vehicle management systems; tampering with the infrastructure; and taking control of vehicles.

The Constitution of UAE protects the personal rights and property. Vehicle vendors must adhere to local laws and international best practice; must respect driver/passenger privacy rights and be transparent about data they are collecting; and will carry significant liabilities for failing to maintain cybersecurity measures.

The related responsibility of the owner of the vehicle will include appropriate maintenance including adoption of recommended software updates to include cybersecurity fixes. In the event that hacking takes place, owners, vendors and operators must be obliged to share this information quickly, in order to update all vehicle and system wide security measures.

5.5 Insurance and Liability

Insurance of self-driving vehicles focuses on each vehicle’s systems and its software interfaces with connected infrastructure, with any external control systems and with other connected vehicles. Previously the driver carried all liabilities associated with the vehicle
unless it could be proven that there had been an equipment failure. Some jurisdictions are favouring a no fault policy in which insurer handles their own damages without disputing the root cause. Other jurisdictions are seeking to apply other existing legal mechanisms such as product liability insurance to connect the vehicle manufacturer and any intermediate service provider to insurable events.

As SDT technology matures and becomes pervasive, the progressive removal of human error is expected to result in far fewer incidents on the road, and thus reduced insurance costs and reduced demand for car body shops and costs associated with crash-related injuries. The UAE Federal Laws regarding insurance should be reviewed to enable liability to be assigned to the operator or manufacturer of a fully autonomous vehicle and that a single insurer model is used rather than relying on product liability regulation to connect with the manufacturers. In the case of incident investigation, a legal duty to provide electronic evidence will be needed.

5.6 Roadway Infrastructure and Mapping

3D digital mapping of highway and urban infrastructure is a prerequisite for the safe operations of SD vehicles. This is mostly commonly achieved using LiDAR – Light Detection and Ranging and/or visible-spectrum video. A typical methodology is for vehicles to gather up to date images as they travel, using simultaneous localisation and mapping algorithms, known as SLAM, and use these to update the master model with the presence of temporary objects such as roadworks, skips, parked cars and so on.

The mapping required for SDT operations needs to include road and lane markings and street signs, which may need to be physically encoded for visual recognition as well as being digitally encoded into digital maps. The level of detail required includes the exact position of intersections and ramps; the interpreted meaning of street signs; specific lane assignments and allowable movements at signalised junctions and roundabouts; and more accurate versions of all the data currently provided in SatNav services.

Recognising the need for a consistent environment as this technology globalises, more work is required to agree how infrastructure – and particularly information on priority and lanes – can be standardised for the benefit of all. Dubai RTA is in a strong position to be a global test bed for these evaluations. The Oxford university spin out company, Oxbotica Ltd – which is a participant in AV trials in Greenwich and Milton Keynes – is exploring the use of a stereoscopic camera system to place a vehicle in a 3D map which has been prepared by LiDAR sensors on other vehicles. Only a small section of the fleet would still need to run full LiDAR with their SLAM processors to update the maps – if successful, this approach has the potential to deliver a significant cost reduction and accelerate SDT vehicle deployment.

5.7 System Readiness

The functional testing of individual vehicles will be undertaken in detail as part of the Dubai World Challenge. Significant work has already been undertaken by the manufacturers (traditional OEMs and new entrants) and the related standards for vehicle interfaces have been developed in the leading standards bodies in USA and Europe. These developments include V2V and V2I service specifications which are an evolution of current connected car features and are mainly being driven by traditional vehicle OEM interests. By comparison, system readiness is much less mature in the service provider layer in which fleets of SD vehicles are prepared and positioned to meet the predicted demand for journeys. This reflects the immaturity of the management layer and the lack of standardisation, as in the early days of the development of rail franchises.

There is an opportunity here for Dubai to sponsor the development of an SD zone control and operations capability which can be deployed in other cities. The Dubai Connected Cloud can be used as the hosting platform for vehicle tasking, routing data and payment applications – with integrated provision of scheduling for charging, cleaning and maintenance. It is possible that existing public transport franchisees will have the best skills mix for this, but the market is wide open to new entrants with core competence in software.
Partnerships and business models

Market Makers
Incremental Revenue
Vehicle Supply Partnerships
Start-Up Mentoring and Partnership
Software Partnerships
City Partnerships
6. Partnerships and business models

6.1 Market Makers

The Dubai SDT World Challenge will seek to establish a global lead in selection of self-driving vehicle service suppliers and will likely attract their associated business models, enabling the creation of economic partnerships to support and finance the deployment of live services.

The majority focus of monetisation partnerships will likely be the software components. These software components will focus on the interaction with drivers and riders to analyse their wants and needs and supply a wide portfolio of connected and self-driving services.

The market maker will be the party with the best combination of awareness of market needs, ability to deliver services and ability to collect payment. In this context, global technology companies (Google, Baidu, etc.) are deploying their consumer data platforms with the mobility of a self-driving car as an added feature. By contrast, the high-end vehicle OEMs (TESLA, BMW, etc) are showing interest in developing their own premium value chains. It is in Dubai's interests to take advantage of its franchise with all drivers and riders and to offer services which integrate with wider offers. Using Dubai Connected Cloud as a route to market, service offers can include facilitated tourism, entertainment, retail and immersive communications.

As the data privacy challenges are resolved and drivers are able to share their information, the Dubai SDT World Challenge can act as a template for city driven services based on mobility solutions. This market opportunity can be strengthened by using the Dubai SDT World Challenge to develop shared requirements and establish active partnerships with other similarly affluent and emissions-sensitive cities which will adopt similar infrastructure that enables driverless operations.

6.2 Incremental Revenue

McKinsey see city types as the dominant market segmentation of the future, more meaningful than countries or continents. McKinsey estimates that up to 10% of new cars sold worldwide in 2030 could be shared fully autonomous vehicles, with a further 5% fully autonomous but not shared. They estimate that the total automotive revenue pool will increase by 30% (around US$ 1.5 trillion) by 2030 as a result of diversification to on demand mobility services and data driven services. This incremental US$ 1.5 trillion is driven by new car sharing and e-hailing business models and includes an estimated US$ 100 billion for data connectivity applications such as navigation, entertainment and remote services including software upgrades. In the mechanical market segments, maintenance spend will increase as vehicles are better utilised, whereas damage repairs will decrease due to the reduction in human error.

6.3 Vehicle Supply Partnerships

Dubai's vehicle supply partnerships should actively include global technology giants and new entrants. Established vehicle manufacturers typically describe their technology diffusion in terms of a series of measured and progressive steps in assisted driving tools, leading to the general availability of the option of full autonomy in ten or more years. By contrast, technology giants and other new market entrants are seeking to launch fully autonomous vehicles in one big leap in whatever local services and niche markets are available initially, then expand to mass adoption and eventually to longer distance services. Although Dubai will be able to attract strong relationships from both groups of vendors, it is the global technology giants and new entrants who have demonstrated greater urgency and market velocity at this stage and who have less to lose from rapid changes in traditional automotive market structure.
6.4 Start-up mentoring and partnership

With the Future Accelerator program, Dubai has a vision to develop entrepreneurial concepts related to self-driving transport into businesses specifically to accelerate technologies and self-driving transport in Dubai. Special focus will be laid on the local and international ideas which could potentially solve issues very specific to Dubai – for example challenges related to the weather and cultural diversity. This would help accelerate the deployment of self-driving transport in Dubai and equally, this would help create invaluable intellectual property for Dubai (e.g. the Gold, Pink, and Silver model for SDT services).

6.5 Software partnerships

The Dubai SDT World Challenge will engage a wide range of software developers who are seeking to capture market leadership and make fast progress. Some may wish to establish a significant presence in Dubai in order to increase their market visibility – and could form part of a technology cluster based around the smart mobility lab and the associated free zone.

6.6 City partnerships

Dubai’s ambition to be the world’s leading city in this market will be reinforced by the active development of collaborative city relationships with leading cities worldwide. This should offer recognition of variations in needs (climate, etc.) and include framework procurement mechanisms for partners to simplify the replication of the solutions which will be demonstrated in the Dubai SDT World Challenge.

6.7 Business models

The above-mentioned partnerships with software companies, start-up and matured companies, premium and volume car manufacturers and worldwide public agencies could be structured in innovative ways to attract investors while minimizing RTA risks in development and operations of these assets. RTA will consider several mechanisms (and combination thereof) as follows:
6.8 Public private partnerships

Under this mechanism, RTA could procure a consortium to design, test, deliver and operate and maintain certain SDT systems such as FMLM shuttles. The concessionaire would receive a share of the revenues generated by these services and would ensure a level of service and a rate of return for RTA. Under this model, RTA would be able to mitigate the risk inherent with developing the use case and would be able to expedite the system deployment and realize the benefits.

6.9 Government funded projects

Under this mechanism, RTA and other government agencies would fund the entire design, test, deployment and O&M of the SDT systems. While some initiatives such as studies, strategies would require government funding, The roadmap deployment requires significant capital investment and should therefore be implemented through partnerships.

6.10 Competition

An innovative way to design, test and develop a cutting edge technological solution for SDT, RTA plans to host a worldwide competition, which awards development of SDT systems as the final award. This will enable RTA to attract the best technologies while minimizing costs in testing and developing solutions.

6.11 Royalties/IP

Under this model, the RTA would develop technologies and processes – by themselves or in partnership with other entities and would build intellectual property. RTA would then be able to monetize the IP through licensing, royalty etc.

6.12 Business Model Summary

There are many possible mechanisms under which RTA could develop the required infrastructure and technologies for delivering the SDT. These possibilities range from delivering the entire SDT on RTA budget to delivering SDT under partnership with several private and public players. The objective of RTA will be to leverage its position and strengths to expedite the deployment of the SDT, while minimizing the risks including
Smart Mobility Lab/Center of Excellence

COE Concept
Potential Benefits
Key considerations
As SDT technology progresses from current level of automation to SAE level 4 and 5, it will require significant testing and development efforts from the private OEMs and technology/software developers. Changes to legislative, policy environment and support from the government agencies will be required to ultimately unlock the potential benefits as described in previous sections. Dubai has a great opportunity to become one of the leading countries for SDT because of the commitment and ability of the government to make fast decisions, and because of the integrated nature of Dubai government where the resources can be moved to optimize the overall benefits.
7.1 CoE Concept

Dubai RTA plans to consider a “RTA Center of Excellence” dedicated to develop emerging and upcoming concepts into deployable solutions through partnering and collaborating with the established local and international companies, start-ups, academic institutes and inter-government agencies. While the proposed Center initially might focus on SDT-related initiatives at the beginning, the scope of the Center may also go beyond the SDT and encompass all existing and future technology initiatives. This will help in developing a synergy among different initiatives which would ultimately propel Dubai to become the leader in technology innovation and adoption.

As the Center develops the technological concepts into solutions, the solutions will then be able to support other initiatives to make this a self-supporting and continuously improving research and development facility. For example, one of the key technologies identified as part of the SDT roadmap is to develop a connected cloud. The connected cloud solution could be conceptualized as part of the CoE in conjunction with the testbed, and developed into a full solution. Once the solution is ready, it would then be able to support the other initiatives, such as augmented reality or communication with drones. Similarly, solutions developed as part of other initiatives could be leveraged by SDT.

7.2 Potential Benefits

The RTA CoE would be dedicated to developing innovative and local solutions tailored for Dubai. While the CoE would learn from the international best practices, it would focus on developing the solutions to leverage the opportunities in Dubai and to address the unique challenges of Dubai. Such a self-improving facility would potentially build on the initiatives and would attract international innovators, technology providers, implementers and investors to Dubai.

7.2.1 Global technology, local solutions

Dubai has unique challenges such as extreme weather conditions and culturally diverse road users which add extra complexity to deploying a new technology in the City. For example, the first-mile-last-mile solution would face more challenging requirements from the public because of the high temperatures in the summer months. Similarly, driver education campaigns and training programs would require multi-lingual material and regular sessions to ensure that the existing and new drivers get adequately trained and stay relevant.

7.2.2 Cutting edge technology

While the new technologies such as Internet of Things (IoT), self-driving transport (SDT), artificial intelligence/machine learning have been progressing for some time, the pace of the technological advances has been very rapid in past decade. The spectrum of these technologies is so wide, and the potential impacts on our life is so significant, that for a visionary government like Dubai, it would be prudent to structure a technology and future-proof framework which would encompass the upcoming and future technologies. Further, these technologies would be able to build an ecosystem which would leverage on its components to continuously improve itself.

7.3 Key considerations

In order to conceptualize, and study the feasibility of the Center of Excellence, following factors are considered to ensure that the benefits of the Center can be maximized while minimizing the risks and potential costs:
7.3.1 Staged implementation

To realize the benefits of CoE, a future-proof framework is considered and that the implementation of the CoE is staged – starting with a small group focusing on the SDT, to culminating into a unit which encompasses all smart technologies relevant to transportation in Dubai.

7.3.2 Stakeholder involvement, leadership

A key factor for success of the Center will be its ability to bridge different technologies/applications across agencies to provide a high-level ecosystem. This would require collaboration among key stakeholders as well as the guidance from the leadership so that the Center can spearhead the technological advances in creating the intellectual property. The CoE would be advised by a board consisting of subject matter experts and representatives from the administration such as the Prime Minister’s office to give it an impetus required to make the Center successful.

7.3.3 Partnerships

Many stakeholders across the industries including OEMs, disruptive technology providers, academic institutes have been driving the research and development around smart technologies. RTA will consider partnering with the existing players would be the smartest way to accelerate the testing and development of these technologies in Dubai.
08
Strategy
Sustainability factors
8. Strategy Sustainability factors

The SDT strategy is subject to key assumptions including technology readiness, technology trends as well as the general economic, social, and transportation landscape. These conditions then, in turn, drive the investment, policy/legislative framework and social acceptance of the SDT program. Therefore, success and sustainability of this strategy and implementation would largely depend on its flexibility and ability to respond to market conditions. For example, if the technologies related to SDT are able to move faster than anticipated, the strategy would need to be updated to reflect an aggressive deployment. This would require a technology vision and flexibility in budgeting, partnership and programs to change directions quickly. On the other hand, if the technologies present safety challenges and fail to sufficiently show that the SDT can safely mix with the traditional traffic, the strategy should be updated to focus on SDT systems which run in fixed guideways without interacting with the traditional traffic.

RTA will monitor the developments in technology, legislation, insurance, and other key areas to ensure that the strategy remains relevant and sustainable. This will also help RTA in learning the best practices and in using its resources in the most optimal way.

The strategy and its components should be updated on the following timelines:

<table>
<thead>
<tr>
<th>The strategy and roadmap will be updated yearly.</th>
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<tbody>
<tr>
<td>The transportation model and impact of SDT and CV on transportation conditions be studied and monitored every two years</td>
</tr>
<tr>
<td>SDT individual trips will be monitored against the respective KPIs for each Agency every quarter</td>
</tr>
<tr>
<td>SDT technology benchmarking and coordination with global counterparts will occur on a yearly basis</td>
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Conclusion and next steps
Next Steps
9. Next Steps

Through the implementation of the proposed SDT strategy, and through the encouraged/incentivized adoption of SDT in private transport, it is estimated that the SDT percentage in 2030 will be more than 25%. However, it will require a focused approach to study, design, test and implement roadmap initiatives and building block enablers across RTA agencies. This project developed a strategy and roadmap to deliver the SDT in all public transport modes in Dubai. Additionally, the report presented a detailed list of initiatives (i.e. deployment initiatives and building block initiatives) which are required for Dubai to achieve its SDT target.

As part of developing this strategy and roadmap, the project team coordinated extensively with the internal stakeholders. As the next step, RTA will continue the coordination with the external stakeholders such as Dubai Police, ESMA, Telecommunication Regulatory Authority (TRA), Supreme Legislative Council to ensure that the required spectrum for DSRC is secured; policies/legislation for SDT and CV is developed and enforced, charging stations and other infrastructure is developed; and SD vehicle specifications are updated and enforced, respectively. Further, to minimize the risks of operations and the capital expenditure required for the initiatives, RTA will consider partnering with private entities such as premium car manufacturers, technology providers, mapping providers and operational concessionaires. RTA will prepare a partnership framework to encourage, invite and assess the quality of partners especially for the roadmap deployment projects.

RTA will further study certain initiatives, which could be the key differentiators. These initiatives include HD mapping, SD zone, policies/legislation for the SDT operations, code of practice, infrastructure analytics, connected cloud and SD BRT. Through strategic partnerships, these initiatives could help Dubai be among the leaders in SDT across the globe.

Finally, the complete SDT landscape including technology, legislation, opportunities and challenges has been changing rapidly. To keep pace with these changes:

- The strategy and roadmap will be updated frequently.
- The transportation model and impact of SDT and CV on transportatio. conditions will be studied and monitored every two years.
- SDT individual trips will be monitored against the respective KPIs for each Agency every quarter.
- SDT technology benchmarking and coordination with global counterparts will occur on a yearly basis.
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