THE FUTURE OF TRANSPORTATION – IN THE INFORMATION AGE

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Introduction

Information technologies are combining with advances in mechanical and other branches of engineering to create significant changes in transportation technology. The word SMART (Self-Monitoring Analysis and Reporting Technology) is used in connection with various other nouns (home, environment, computer, etc.) with the connotation of incorporating superior ideas or materials. In transportation, it is often taken to mean intelligent transportation systems, or when used with transportation vehicles, using better manufacturing materials to build them, using sustainable forms of energy to operate them, making them environmentally friendly, etc. The Internet of Things (IoT) refers to the connection of objects with the additional property of being able to communicate and/or being controlled. In transportation, IoT connects communication (vehicle to vehicle, vehicle to infrastructure, vehicle to network, vehicle to satellite, etc.) and information (data, traffic, global positioning, weather, etc.). Information Communications Technology (ICT) refers to the convergence of audio-visual and telephone networks with computer networks through a single cabling or link system. This paper examines the changes in information and transportation technology that are being predicted to occur between now and the mid-point of the 21st century.

More advances in technology are being envisioned than can be properly addressed in such a short paper. This survey identifies changes in aviation, rail, road and marine transport, but makes no attempt to evaluate their probability of success. Innovations will occur that are not envisioned at the moment, and some of the ideas that seem so powerful today, will remain unfulfilled. This article is presented as food for thought and with an optimistic perspective of the future. In the discussion at the end, some economic implications of these predictions are considered.

Air Transportation

Air transportation of passengers is predicted to rise from roughly 4 billion in 2017 to 7 billion in 2034 or 11+ billion 50 years into the future (i.e. 1.5 billion every 10 years). Air freight, including express traffic will rise from roughly 252 billion Revenue tonne kilometers (RTKs) in 2017 to 509 billion RTKs in 2035 or 967+ billion RTKs 50 years into the future (i.e. 143 billion RTKs every 10 years). In 2017, more than 50% of this freight was transported in the 1900 freighters with the demand rising to 3010 freighters in 2035 or 5000 freighters 50 years from now (620 every 10 years).

Intercity passenger aircraft will be larger, smarter and faster. Airbus indicates five smarter innovations for the future: 1. Electricity, hydrogen, solar and other sustainable aviation fuels will be used; 2. Takeoffs will be assisted to minimise noise and reach efficient cruise altitudes more quickly; 3. Express air highways will be used by intelligent aircraft to select the most efficient and environmentally friendly routes flying in formation to reduce drag and energy use; 4. Planes will glide into airports to lower emissions and noise; 5. Landing and ground operations will be rationalized leading to switching landing engines off earlier (reducing CO2 emissions by six million tonnes), optimizing landing position and terminal spacing, etc.

Intracity and personal air passenger aircraft will include: 1. Electric aircraft for air taxis; 2. Vertical-takeoff-and-landing, passenger-carrying aircraft (autonomous electric-powered aircraft) designed to help

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provide aerial relief to congested city streets; 3. Aeromobile flying car; 4. Personal vertical takeoff and landing (VTOL) aircraft, powered by a battery pack; 5. Other types of VTOLs, etc. will be used to reduce congestion on the road and to provide an alternative to the automobile.

NASA is of the opinion that "In the future, aircraft will consume half as much fuel compared to today, generate one-fourth the emissions they do now, fly so quietly that airport neighbors won't hear annoying noise and fly passengers at supersonic speeds while burning biofuels. … We will see advanced drones, personal air vehicles, and air taxis on demand. All of this and more offers a snapshot of a very possible future that NASA's aeronautical innovators are making progress toward every day." [1-13]

Cargo Service/ Expedited Service: Four expected innovations often noted in the literature are: 1. Solar/electric powered freight aircraft; 2. Unmanned freight aircraft; 3. Cargo airships; 4. Robotic or fully automated cargo handling. Besides innovations in aircraft, to facilitate the movement of air freight, IATA believe that the likely five innovations are: 1. E-freight – documenting electronically, e.g. electronic air waybill; 2. Digital cargo **-** creating a single digital record that can be accessed by multiple supply chain parties**;** 3. Interactive cargo **-** "making cargo talk" to improve supply chain visibility; 4. Smart facilities **-** aiming for excellence in ground handling and the warehouse; and 5. Air cargo incidents database **-** using big data to collate and describe any incidents.

Intracity/rural locations will experience an increased use of flying drones. Civilian drones are increasingly being used in European countries, such as Sweden, France and the UK. According to the EU Commission "The drone services market is expected to grow substantially. Estimates vary between €10bn by 2035 and €127bn for the coming years. A recent forecast predicts that by 2020 the global drone market size will grow by 42% in precision agriculture, 26% in media and entertainment, by 36% in inspection and monitoring of infrastructures, and by 30% for leisure activities." [1-14]

Airports

The top hundred airports in the world today do not have much excess capacity, so major infrastructure projects and developments are necessary. Airports terminals will evolve into "little cities", where travellers enjoy themselves, relax and spend money. Many of the problems associated with travelling (passenger and check-ins, security screening, etc.), will disappear.

Landside of the airport building: 1. Automatic check-ins will send information to travellers smartphones; 2. Biometric scanners (facial expression, iris, etc.) will be used for security; 3. Laser molecular body scanners will replace physical search; 4**.** Baggage drop of in the airport and outside will replace baggage check; 5. Smart Baggage will contain chips for tracking by radio frequency and smartphone notification; 6. Robots in the airport will assist passengers; 7. Pods will take passengers to their chosen points; 8. Touch screen shopping and shopping centres with make delivery possible to their home; 9. Indoor gardens and other amenities will be built to entertain travellers; etc.

Airside of the airport building: 1. Automated, Smart and Space based Control Towers will replace human tasks where possible and help to chart shorter and safer routes; 2. Expanded runways will be built to accommodate larger planes; 3. Automatic, smart vehicles and equipment will be used to assist planes; 4. Automated Airport parking will economize time and space; and 5. Commuter, rail and water modes may be connected directly to the airport.

In Canada, smart technologies are beginning to gain a toehold with facial recognition technologies to assist at Canadian airports and border checkpoints. Research on the use of cargo airships to remote areas has been going on for some time. The use of drones for recreation and aerial photography has led to the passage of regulations for its use.

Space Travel
Space tourism development provides an interesting alternative vision of future space transportation activities. Recent market research shows that the large majority of people, 60% want to visit space for themselves, and would be prepared to pay high prices for such a service. Richard Branson says "We will never be able to build as many spaceships. The demand is enormous." It could begin as early as the end of 2018.

Rail Transportation
In 2014, rail transportation accounted for 2,954 billion passenger kilometres in the world with China, India, Japan and Russia accounting for a major share. "The future of train transportation will be dictated by the price and availability of oil, the determination of governments to find alternate modes of travel and the public demand for economical, fast transportation." [2-2]. In 2014, rail transportation accounted for 9,486 billion freight tonne kilometres in the world, with the USA and China accounting for 29% each and Russia accounting for 22%. The OECD's International Transport Forum estimates that by 2050 freight transportation will rise by as much as 150 percent to 250 percent in the same time frame.

Intercity passenger trains: Autonomous and Smarter trains do not necessarily mean driverless trains but trains embedded with high performance computer platforms (with Software Defined Networks and Train Function Virtualization). This could be combined with IoT enabled Gateways and Fog/Cloud processing. Autonomous and smarter trains will rely on lighter materials and renewable sources of energy like liquid natural gas (LNG) and hydrogen fuel cells that produce zero or less emissions than the diesel-electric trains. One regional railway in the US, the Florida East Coast Railway, has completely converted to LNG.

Magnetic levitation (Maglev) trains first debuted in Germany in 1979, but the country best known for the Maglev is Japan. Japan operates two independently developed maglev trains. One is HSST by Japan Airlines and the other, which is more well-known, is SCMaglev by the Central Japan Railway Company. A new high-speed maglev line, the Chuo Shinkansen is planned to become operational in 2027. Maglevs are under construction in Georgia, Tel Aviv, Beijing, and Tokyo and Maglevs have been proposed in several countries.

The Hyperloop credited to Elon Musk plans to provide transportation even faster than Maglev. It is seamless travel just under the speed of sound – 760mph. Musk prefers to call it a fifth mode of transportation. Like Maglev these trains do not run on wheels. Passengers will be transported in pods through a tube or pipe, underground or over ground. The first hyperloop is scheduled to begin operations between Dubai and Abu Dhabi covering the 150km journey in just 12 minutes. Regulatory approval to build the hyperloop has been received in some US states. To provide passengers with greater comfort the railways will focus on customised information and options relayed to the customers' cellphone, integrated journey information and seamless connections to other transport modes to create a hassle-free, holistic travel experience, removing barriers to the journey.

*Intracity passenger trains***:** The OECD's International Transport Forum reported that, by 2050, the mobility of the common passenger will increase by 200% to 300%. Automation in urban metro systems will increase (e.g. to Copenhagen Metro). More imaginative proposals are: 1. Hyperloop. 2. Skytran carrying two passengers in a pod via linear electric motors on an elevated maglev track. 3. JPods powered on solar energy. 4. ET3 (Evacuated Tube Transport Technologies) that travel in a tube.

Automatic and Smarter freight trains: Driverless trains (already in service to Australian mines) have an onboard, GPS-based computer system that tells engine drivers the optimum throttle, speed and brake settings to achieve maximum fuel efficiency; advanced software technologies to ensure trains move faster and more efficiently, potentially increasing average train speed (already in use by NSF); nanotechnology to make train materials and infrastructure "lighter, stronger, smarter and greener"; new systems that allow containers to be lifted directly off of trucks and loaded straight onto trains – or driven onto trains; and use of renewable sources of energy like liquid natural gas (LNG) and hydrogen fuel cells that produce zero or less emissions that the diesel-electric trains.

Rail and infrastructure maintenance: Some of the rail freight innovations on the drawing board or in use are: Solar-powered dispensers pumping friction modifiers on the track; "phased array" ultrasound technology; track geometry and track ballast; drones inspecting tracks; robots inspecting tunnels and bridges, etc.

Rail Terminals

ARUP envisions a number of enhancements for future terminals: 1. Mobility and lifestyle hub for business, leisure and connectivity. 2. Drones for monitoring predictive maintenance and improved security. 3. Ticketless and security technology for eliminating gate-lines in stations. 4. Virtual shopping wall offering convenience and ease. 5. Intelligent robots to repair and maintain infrastructure. 6. Energy flooring that generates electricity from footfall. 7. Driverless pods powered by clean energy. 8. Underground freight pipelines for moving goods in cities. 9. Electronic tagging of cargo for reliable tracking and reduced delays. 10. Automatic gauge change for cross-border travel. 11. Intelligent robots unloading and sorting cargo. 12. Automatic freight trains distributing freight and goods on the go. 13. Alternative power sources from hydrogen, nuclear, air propulsion or magnetic levitation. 14. Smart window glazing dims automatically to control heat and glare. 15. Flexible interiors that cater for different passenger needs. 16. Automated passenger trains optimizing running time and reliability. 17. Real-time passenger info for seamless journey planning.

In Canada, interest has already arisen in hyperloop passenger service. Transpod Inc. has provided estimates of such a service between Toronto and Windsor and is also considering a Toronto-Montreal service. CP is planning to use driverless trains in remote areas and CN is investing in autonomous inspection of rails. Smart technology is also being used in trains and along rail infrastructure.

Water Transportation

The demand for passenger travel (cruises) will increase in the future with the increase in population, income and leisure time. Global passengers will jump from 24 million in 2016 to 40 million by 2030 and 75+ million 50 years from now (i.e. one million per year).

Passenger traffic: Environmental cruise ships (i.e. using liquefied natural gas, fuel cell technology, modern technology for disposable waste and water efficiency, solar panels and sails, etc.). 2. Incredible ships designs (ranging from The Floating Island, The City, The Shark Fin, The Submarine, The Skyscraper, The Horseshoe, The Boomerang to The Lilypad, etc.). 3. Revolutionary internal designs using modern technology (e.g. 1. Screens on every surface; 2. Wearable tech; 3. Virtual butler; 4. Robot bartenders and floating platforms; 5. Virtual Reality; 6. Holographic staff; 7. Pilotless ships and robot crews; 8. Cabins with high tech gadgets).

Containerized Freight traffic: If current growth rates continued over the next 50 years world container movement should rise from 679 million TEUs in 2014 to 2.7 billion TEUs or by 3 times the present volume. This is unlikely to occur because the industry is maturing, but many technological changes are on the horizon. 1. Container ships may be bigger on the average (the largest is over 21,000 TEUs), more fuel efficient and emit less pollutants. 2. Container ships will employ more autonomous functions (auto ships/auto pilots) and use types of energy that are environmentally friendly (biofuels, liquid natural gas and hydrogen) and engine innovations will reduce emissions (Sulphur Scrubber System; Exhaust Gas Recirculation; Water in fuel injection; etc.) 3. Technology to improve engine propulsion efficiency will be used increasingly not only to improve efficiency but also to reduce emissions, such as nuclear propulsion, alternative fuels, batteries, fuel cells, renewable energy (solar, sail and kite), superconducting electric motors and hybrid propulsion together with non-conventional propulsors, magneto hydrodynamic propulsion, etc. Other energy saving devices will also be used (Advanced Rudder and Propeller System; Hull Paint; Waste Heat Recovery System; Improved Pump and Cooling Water System, etc.). 4. Modern communications, satellite communications and technology to provide optimal routing in case of poor weather, ship speed, proper maintenance of ship machinery, etc. will also be used to increase efficiency by reducing fuel consumption. 5. Containers on ships will be smarter being embedded with technology for easier tracking and communicating.

Bulk Freight traffic: Bulk carriers (41% of world ship fleet) and tankers (37% of world ship fleet) play an important role in ocean transportation of freight. Many of the future innovations noted above will also apply here. Some specifically applicable to these ships and those recurring often in articles are: 1. Automated cargo ships - Rolls-Royce Holdings Plc. which has already built such a vessel says it could be in international waters by 2035. BHP Billiton Ltd. the world’s biggest mining company, is studying the introduction of giant, automated cargo ships. Rio Tinto Group the largest dry bulk shipping business in the world which already is using autonomous trucks and rail in Australia is also considering automated cargo ships. 2. New energy propulsion systems - Wind propulsion technology, LNG fuelled ships (the first fully powered bulker, Greenland, launched by shipyard Ferus Smit Westerbroek Yard). 3. Battery and hybrid solutions for the bulk carrier; composite materials for hatch covers (eg. glass-reinforced plastic), coating technology for tankers (coating made up of nanotechnology creating a layer of air between the ship and the water, reducing drag drastically and increasing speed and efficiency).

Port Terminals

Port terminals of the future will also change. 1. Cranes and other equipment used on the terminal will be bigger and partially or fully automated. 2. Container terminal sizes and the development of new container terminals will increase. 3. Terminal operating systems (TOS) will evolve given the magnitude and complexity of operations on the terminal (e.g. berth planning, stowage planning, quay crane scheduling, loading/unload sequencing, and space planning). For example, commercial TOSs are being developed e.g. Navis SPARCS N4, CATOS, MainsailVanguard, TOPS, and OPUS; and the first fully automated container terminal system was opened in Victoria, Australia in September 2017. Some even visualize terminals as complete logistic ecosystems that act as global interchange points, with hyperloops for containers, the use of artificial intelligence, etc. 4. Hinterland infrastructure will be developed simultaneously to avoid port congestion. 5. Terminal operators and landside providers of service will use computers and other electronic devices to optimize strategy (internally and externally) and to track movement of containers.

Road Transportation

Private and public transportation vehicles are seeing a silent revolution. The need to reduce fatalities, congestion and emissions will accelerate this trend.

Personal Passenger Service: Intra and Intercity automobiles could witness the following innovations: Automobiles will be driverless, partially autonomous or fully autonomous. A study, prepared by Strategy Analytics in June 2017, predicts autonomous vehicles will create a massive economic opportunity that will scale from $800 billion in 2035 (the base year of the study) to $7 trillion by 2050. Another study by BCG indicates that by 2035, 12 million fully autonomous units could be sold a year globally. There will be 76 million autonomous cars on the road globally. Some automobiles may be aeromobile to avoid traffic congestion.

Automobiles could be smarter in several ways. First, they will be embedded with vehicle to vehicle (V2V), vehicle to road infrastructure (V2I), and vehicle to other network infrastructure (V2N) sensors. The information will help to reduce congestion on the roads and in parking saving billions of dollars. Second, cars will contain various types of software providing it to run more efficiently (shortest distance, speed, etc.). Third, automobiles will operate on renewable and other sources of energy (solar power, electric power, etc.) that will reduce emissions.

Shared mobility will become prominent with driverless taxis and pods or buses. These vehicles will be embedded with the above noted technology and with technology to respond to questions of commuters. For example, Uber (a TNC providing taxi service) has entered into an agreement with carmaker Volvo to purchase 24,000 of its XC90 SUVs between 2019 and 2021 to form a fleet of autonomous vehicles; Heathrow airport uses driverless pods to transfer passengers from terminal to terminal; driverless buses made its first maiden voyage in Germany in October 2017 taking Bavarian locals from the train station to the town centre, in Las Vegas driverless autonomous bus made its debut in November 2017, and in Singapore driverless buses will be used in three towns by 2022, etc).

Freight/Courier Service: In the EU, USA, CIS, China and Japan alone more than 6,000 billion tonne-kilometres of goods are transported each year. Globally, road transport carries, on average, more than 80% of inland freight volume and 70% in US and 50+% in Canada. By 2050 the market for trucks will shift to emerging economies with US and European Union accounting for only 10 percent of total sales. Trucks depend on diesel and oil based fuels that account for nearly 45% of CO2 emission of road transportation in Canada. Against this background and the shortage of drivers, it is believed that:
Trucks and Couriers will witness the following innovations:

Trucks will be autonomous or partially autonomous. This is already beginning "Mining giant Rio Tinto already uses 45 240-ton driverless trucks to move iron ore in two Australian mines, saying it is cheaper and safer than using human drivers. Now the race is on to put driverless trucks on public roads. In May 2015, the first self-driving truck hit the American road in the state of Nevada, and there have been several tests around the world since then including a convoy that drove across Europe to the port of Rotterdam in April."

Technology to improve engine efficiency will occur. The IEA says "Vehicle design improvements that reduce energy needs include improvements in aerodynamics, reduced-rolling resistance for tyres and truck weight reduction. Enhanced powertrain efficiency can be realised via improvements to the engine, transmission and drivetrain – powertrain controllers that integrate transmission and engine controls can bring additional fuel savings. Battery-powered electric auxiliary power units can provide on-demand power for climate control and other cabin devices while saving fuel."

Smart trucks embedded with V2V, V2I and V2N software and other software enabling platooning and other communications will continue and increase. Smart trucks will shift to natural gas; biofuels; electric trucks; and hydrogen fuels to reduce emissions and increase efficiency.

Couriers are experimenting with drone and robotic delivery, crowdsourcing (using the public to get parcels delivered), smartphone connectivity, route and improved delivery, together with vehicles embodying futuristic technology.

Road Infrastructure, Repair, Maintenance and Road Control Centres

Road infrastructure adaptation to the developments of vehicle innovations goes hand-in-hand. Road infrastructure technology of the future involves innovations such as: new surface materials, dynamic paints, glow in the dark road marking, anti-icing paints, interactive wind powered lights, wireless electric road charging, solar energy roads, piezoelectric energy roads, intelligent (networked) highways; digital infrastructure designed for machine vision, radar and lasers of automated cars to interpret the surrounding environment and quickly respond, advanced road markings, smart signs, wireless communications, etc. Road inspection, repair and maintenance will be done partially by automation e.g. robotic inspection of bridges and tunnels, aerial inspection by drones, etc. Road Control Centres will contain computers and software for collecting, compiling and disseminating information. Robots and autonomous technology could be used in these centres with human operating in offices far away.

In Canada, the test of the first driverless car was undertaken in Ottawa in October 2017, Uber has begun a test of driverless cars in Toronto and Audi is planning to launch partially autonomous cars in 2018. Magna, Blackberry QNX, General Motors and Uber in Canada suggest that Canadian talent is being tapped to develop the nascent sector and regulations are struggling to keep abreast.

Discussion

In a rapidly changing world, predicting the long-term future of transportation technology is challenging. Who could have imagined mobile phones, the internet, GPS and other world-transforming technologies just 50 years ago? We have attempted this task by gazing into the crystal balls of many visionaries. The future looks bright if the opportunities are realized. Most countries and large firms are investing heavily in future transportation technologies because the prize is big. An autonomous world – with driverless vehicles, where cars can even fly, drones and airships can deliver parcels, people and goods can be transported in closed loops or by magnetic levitation, ships and ports that operate autonomously, and robots that repair and maintain rail lines and roads – all may appear to be fiction and fantasy today, but could be a reality for future generations.

Having now laid out what might be possible, it is necessary to consider the economic impacts of these changes in technology on employment, carbon emissions, intermodal competition and costs. By definition, converting vehicles to autonomous operations means that fewer people are going to be employed. Given that "truck driver" is the largest male employment classification in most provinces of Canada, autonomous trucks could threaten about 300,000 jobs. Many more jobs could be eliminated in the other modes of transport, but we might also see a modification of jobs, rather than their complete elimination. For example, automated trucks may travel from city to city, but go to a depot where a human "load master" gets on board to travel to the final delivery. Someone is needed to make sure that the paperwork is completed and that goods are not damaged in transhipment. Fewer workers may be needed in total, but the scope of other tasks will be increased. Certainly, the industry will have removed the "driver shortage" problem, and the life of a "load master", who gets to go home every night, will make this profession more desirable.

Transportation contributes about 25% of the Greenhouse Gas (GHG) emissions of which about two-thirds comes from cars and trucks. The future is electric, whether provided by batteries or by hydrogen fuel cells. Technology is being pushed by carbon taxes and the recognition that the status quo is not sustainable. It is uncertain how long it will take for technological advances to have a significant impact on carbon loading of the atmosphere, but at least the incentives to move in the right direction are now aligned. Some modes will have more trouble reducing carbon emissions because of physical limitations. Jet aircraft require a lot of energy, and the only feasible fuel is a compact, portable liquid, like diesel. Notwithstanding the development of "bio-diesel" and many other incremental improvements, e.g. more efficient wing design, the increase in the demand for air transport is expected to overwhelm these individual reductions in jet airplanes' carbon emissions. As a consequence, more high-speed, short-haul transport may be provided by electric airplanes, high speed trains and hyperloops in the place of jet airplanes. Also, electric airships may replace cargo jets in the movement air freight.

The use of IoT to platoon trucks could have important impacts on the economies of vehicle size and intermodal competition. Long combination vehicles (LCVs) are more efficient than single trailers because the extra trailer only adds about 25 percent to the operating costs of a single trailer. With platooning the physical benefit of LCVs is reduced (i.e. air resistance) and the labour cost advantage disappears. Moreover, a single trailer is easier to pickup and deliver than the LCV. Depending on how many trucks are allowed to form a platoon, the competitive length of haul between the railways and the trucking industry could be altered. This could be felt most acutely in the ISO container market. Automated trucks that can operate 24 hours straight might also change the modal split with air transport, as well as with the railways.

Cost-savings and improved efficiency lie at the heart of the technological changes that are envisioned. Should many of the forecast advances come to pass, the world will be greatly improved. Automation is most desirable when it eliminates nasty, boring and dangerous jobs. Notwithstanding the advances made in the last 50 years, many undesirable jobs still exist. Also, safety is often enhanced by automation because machines do not lose attention, get tired or panic when things go awry. Congestion will be better controlled and cities may be more attractive in terms of mobility and air quality. Information will be more available and accurate thereby reducing the costs of supply chains. At the risk of being accused of wearing "rose-coloured glasses", the future looks like the world will be a better place to live. Of course, all predictions could be invalidated by macro events that are outside society's control. The four horsemen of the apocalypse are always ready to saddle up and unleash disasters that invalidate all predictions. Providing the future bears a strong recumbence to the past, the future of transportation looks very positive indeed.

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