Socio Economic Impacts of Satellite Based Navigation System

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1. Introduction

Satellite-based navigation has become an integral part of human life in 21st century with pocket size GPS (Global Positioning System) receivers used in vehicles, GNSS (Global Navigation Satellite System) enabled smart phones etc. Today, the GNSS has entered the society with its multi-facet applications that ranges much farther that traversing from point A to point B. It has made its remarkable presence in location based services, survey, GIS (Geographic Information System), agriculture, industry and service sectors, the core contributors towards any country's economy. The Socio-economic impact is a major predictor of success of a large scale technological venture in any country. In a nutshell, any new technological development and its value added services will have considerable social and economical impact on the livelihood of common man and the associated society, in addition to the industrial impacts. Satellite based navigation system is one such newly advancing technology which is offering modern navigation services to the users in terms of highly accurate position, velocity and timing solution economically all around the world on a 24x7 basis.

2. Navigation

Navigation is the art of getting from one place to another, safely and efficiently. In ancient times, mariners navigated by the guidance of the sun and stars and landmarks along the coast. They navigated from island to island across the open ocean using observations of guide stars and the moon, the winds and currents, and birds, knowledge of which was passed from generation to generation.

2.1. Early Navigational Instruments

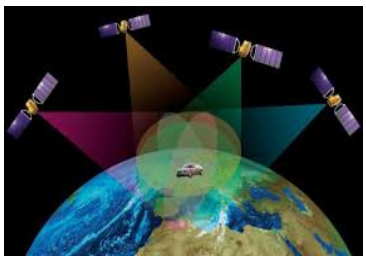
In the earlier days the elements of nature, the celestial bodies, the geographical landmarks etc guided man along his journeys. As the humans evolved, new guidance mechanisms evolved with him. Compass, cross-staff, sextants, light houses etc. were invented. Later began the times of radio navigation with systems like LORAN (Long Range Navigation) which paved way for the next generation of navigation systems the ***Satellite-based Navigation***.

2.2. Satellite Based Navigation

The era of Satellite Based Navigation began with the Timation and Transit systems. This was followed by the more advanced and currently operational GPS by USA and GLONASS by Russia.

The Chinese and Europeans are entering the arena with COMPASS and GALILEO constellations respectively.

The Global Positioning System, better known simply as GPS, sends several signals that are used to decode the position and distance of the satellite. One signal encodes the satellite's "ephemeris" data, which is used to accurately calculate the satellite's location at any time.



Accuracy offered by GPS is better than any other available land-based system at almost all locations on the Earth, with few cents of modern electronics and few dozen satellites to provide worldwide coverage. As a result of these advantages, GPS has led to almost all previous systems falling from use. LORAN, Omega, Decca, Consol and many other systems disappeared during the 1990s and 2000s. The only other systems still in use are aviation aids, which are also being turned off for long-range navigation while new differential GPS systems are being deployed to provide the local accuracy needed for blind landings.

In addition to GPS, GLONASS (Global Navigation Satellite System) developed by Russia is also operational. Galileo by European Union, Beidou/Compass by China are also under development. India is developing IRNSS as regional navigation satellite system. To further enhance the accuracy, availability and integrity of the navigation services to support Safety of Life operations, the augmented systems like EGNOS, WAAS and GAGAN have been developed.

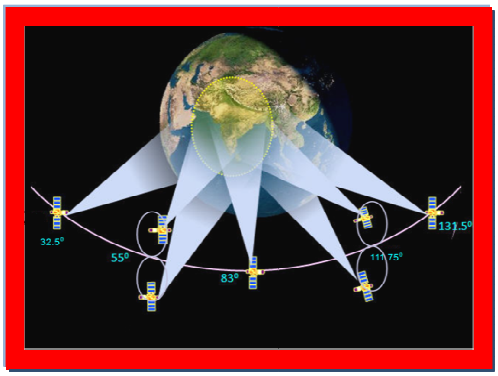
3. GAGAN

Considering the growing technological development in the field of satellite based navigation and its potential benefits to various application segments, India took early initiative in implementing satellite based navigation systems in the country. ISRO and AAI jointly developed GAGAN (GEO Augmented GPS Aided Navigation) System to provide Safety of Life navigation services over Indian airspace for different phases of flight. Also bounty of non-aviation applications in Railways, Harbors, Road transportation, Surveying, Location based services etc., can exploit highly precise GAGAN solutions to their benefit.

Director General of Civil Aviation certified GAGAN system to provide Precision Approach services over Indian land mass and Non-Precision Approach/En-route services over Indian airspace through signal broadcast via GEO satellites GSAT-8 and GSAT-10.

4. IRNSS

IRNSS, the Indian Regional Navigation Satellite System, is an ISRO initiative to design and develop an independent satellite-based navigation system to provide positioning, navigation and timing services for users over Indian region. The system is designed with a constellation of 7 spacecrafts and a vast network of ground systems operating in sync to ensure uninterrupted navigation service to the users. Four satellites (IRNSS-1A, 1B, 1C & 1D) are in their designated orbits broadcasting the IRNSS signal-in-space. With the addition of fourth spacecraft the minimum satellite requirement is met and independent position solution is being provided to its users for the first time using an Indian satellite-based navigation system. The initial performance results of IRNSS are in line with the expected design objectives using four satellites.



5. GNSS Applications

GNSS applications use GNSS Receivers to collect position, velocity and time information for their functionality. The GNSS-based applications introduced great benefits in surveying, timing, aviation, maritime, agriculture, mining and logistic market industry, as well as other fields such as construction or oil offshore platforms. The GNSS-based applications for fleet management market are also expanding due to decreasing device prices and increasing accuracy of systems at a very low cost.

The GNSS Applications range from non-critical to highly critical applications. The different criticality of GNSS applications leads to different performance requirements from the GNSS systems. GNSS applications are categorized into:

- Civil Applications
- Surveying, Mapping and GIS
- GNSS-based Products
- Space Applications
- Scientific Applications
- Military Applications
- Autonomous Applications and Other applications

5.1. Civil Applications

Even though the GNSS systems (GPS and GLONASS) were developed for military purposes, later on they were made freely available for civilian users.

Different types of civil applications which use GNSS are:

- Personal navigation for travelers
- Railways
- Maritime Applications
- Vehicle navigation
- Aviation Applications
- Automated vehicle navigation in industries
- Search & Rescue operations etc

Given the easy availability of GNSS positioning in consumer products the use of GNSS positioning for personal applications has become customary and new uses such as pedestrian navigation, outdoor navigation for hiking, social networking, photography geo-coding etc., keep emerging.

In many places, Rail systems are beginning to use GNSS to track the movement of locomotives, rail coaches, maintenance vehicles, and wayside equipment in real time. The technology helps reduce accidents, delays and operating costs while increasing track capacity, customer satisfaction and cost effectiveness. The railway domain could considerably profit from the implementation of autonomous on-board positioning systems.

GNSS technology brought innovation and progress in navigation and many other marine activities such as fishing, oceanography and oil and gas exploitation. Satellite navigation benefits all maritime applications, including leisure boats, commercial vessels, and unregulated and Safety of Life at Sea (SOLAS) regulated ships. Each application will take advantage of the new characteristics offered by GNSS augmentation: increased accuracy and integrity, certified services and high availability and GNSS is being used in every phase of marine navigation: ocean, coastal, port approach and port maneuvers, under all weather conditions.

The road sector is a major potential market for GNSS applications. Satellite navigation receivers are now commonly installed in new cars as a key tool for providing new services to people on the move: electronic charging, real-time traffic information, emergency calls, route guidance, fleet management and Advanced Driving Assistance Systems. Satellite navigation will help regulate road use and minimize traffic jams and It could be used to charge motorists for using a stretch of road, to restrict access to congested roads, or to inform drivers of congestion and suggest alternative, quieter routes etc.,

The development of GNSS has provided a supplementary positioning service for many flight phases, in leisure flying as well as commercial air transport. Refining and improving satellite navigation through augmentation systems will assist pilots in all flight phases, from taxiing, to take-off, en-route flying, and landing in all weather conditions, reaching the level of safety that will be required to cope with the continuous increase in the number of flights.

Industry uses heavy machinery for many purposes. Satellite navigation and GNSS augmentation techniques can guide these machines precisely to perform their work. The same technique can be used for automated guidance of machines working in dangerous areas or simply to save manpower in repetitive work. The computer compares the GNSS position with the desired work profile and provides visual guidance to the operator for maneuvering the vehicles. The use of satellite-based machine guidance systems in surface mines is becoming common with very positive results in productivity and costs.

5.2. Surveying, Mapping and GIS

One of the most evident uses for GNSS is the realization of surveys and production of maps. Although a simple standalone GNSS Receiver might not have the required precision for some survey requirements, most of these requirements can be fulfilled using high-end dual frequency multi-constellation receivers built specifically for surveying and by using GNSS Augmentation techniques. The use of GNSS techniques in geodesy have revolutionized the way geodetic measurements are made. An increasing number of national governments and regional organizations are using GNSS measurements as the basis for their geodetic networks.

5.3. Space Applications

Even though the GNSS systems were originally designed for earth-based positioning and navigation, real-time spacecraft navigation based on space borne GNSS receivers is becoming a common technique for low-Earth orbits and geostationary orbits, allowing satellites to self-determine their position using GNSS, reducing dependence on ground-based stations. The different launch vehicles also use GNSS-based ranging systems for the launch and initial orbit phase.

5.4. Scientific Applications

GNSS systems offer important contributions to variety of scientific research work. New and improved data analysis techniques, jointly with a growing variety of available measurements encouraged development of more and more scientific applications in various fields. It is expected that evolving new systems such as Galileo and BeiDou, will contribute to further improvements in the current available applications as well to promote new applications in the areas of earth sciences and space science meteorology etc.,

5.5. Military Applications

Since the first GNSS systems (GPS and GLONASS) were primarily developed for military purposes, the military applications are one of the drivers for these systems. For instance GPS

offers encrypted Precise Positioning Service which is available only to the US military and its allies. GNSS is used for different types of Military Applications such as Military Navigation and Target Acquisition.

5.6. Autonomous Applications

Autonomous vehicles technology is a multidisciplinary technology where different engineering areas, such as Navigation, are required. GNSS plays the pivotal role in the development of driverless car technology. GNSS systems where revolutionary in the area of Navigation by providing positioning and navigation capabilities to the autonomous vehicles. With precise positioning, GNSS can be used for lane or track determination (for road and rail vehicles) and attitude determination by using multiple antennas.

Autonomous vehicle technology is still at its infancy but currently the first laboratory prototypes are being tested and demonstrated. GNSS has been one of the key drivers for the recent developments in the area of Autonomous Driving and Autonomous Flying.

5.7. Location Based Services

Location Based Services (LBS) include applications that depend on the user location to provide a service/information that is relevant to the user at that location. LBS normally use mobile devices with positioning ability to provide the service or information to the user.

LBS can be used for personal or professional purposes such as:

- Location based Information Streams
- Tourist Information, Games
- Carpooling and Transport on Demand etc.

5.8. Other Applications

The main objective of GNSS systems is to provide positioning but by design other information is available from the measurements gathered by GNSS receivers. This led to less conventional uses of the technology in application areas that were not initially envisioned. By design GNSS systems deliver precise time along with the position and velocity of the user. This capability has been used to provide a precise time reference in different areas such as financial transactions and stock markets.

One other example of a less conventional use of GNSS technology is the use of the measured interference of the atmosphere on the GNSS signals to do atmospheric sensing.

5.9. Safety-of-Life (SOL) Services

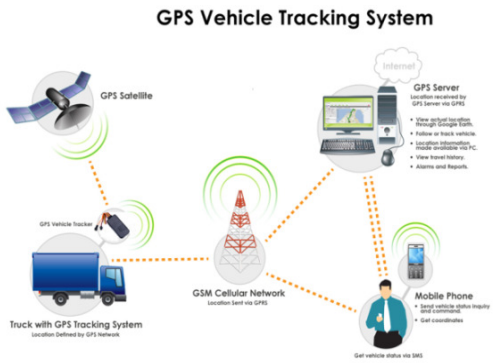
In addition to the above regular applications, GNSS also provide safety-of-life services. To provide SOL services such as aviation, maritime etc., navigation systems must satisfy several stringent performance requirements such as

- Accuracy – The information that they give must be close to the actual value.
- Integrity – If the system cannot give sufficiently accurate information, it must notify the user of this in time.
- Availability – It may not occur that the system is unexpectedly unavailable.
- Continuity of service – If the system stops working after, for example, 2 years, it's not really useful.

A GNSS system, on its own does not possess these features. The GNSS system is then augmented using a ground-based (GBAS) or space-based (SBAS) system in order to meet the safety of life performance requirements. The various SBAS systems in place are: WAAS in USA, EGNOS in Europe, GAGAN in India and QZSS by Japan.

6. Socio Economic Impact of GNSS

In the recent past, GNSS technology has transformed business and lifestyles with innovative products and services across industries Ref (1). GNSS applications have improved business operations and practices in a range of industries like surveying, precision farming, maritime, construction, intelligent transportation, location based services and applications, aerospace etc,. In addition to increasing efficiency and reducing operating costs, the adoption of GNSS technology has improved safety, environmental quality, and many other less-readily quantifiable benefits.



Technological advancement is considered as an important determinant of economic environment. It includes:

(a) Use of technological progress for economic gains,
(b) Application of applied sciences resulting in innovations and inventions and
(c) Utilization of innovations on a large scale.

With the advancement of technology, capital goods become more productive. It has been rightly stated that "A high invention nation normally attain growth at a quicker pace than a high investment nation".

For example, all transport activities depend on GNSS positioning information, and this information has even become a critical component for the logistics chain that distributes and supplies goods to consumers. Air and maritime transport show today an increasing dependence on satellite based navigation. Although terrestrial infrastructure continues to provide solid navigation systems, the trend towards increasing the density of air traffic relies essentially on the performance of GNSS, making these sectors increasingly dependent on GNSS.

There is a growing tendency in the transportation sector to incorporate GPS data into traffic information and management functions by providing vehicle-to-vehicle and infrastructure-to-vehicle communication, giving rise to so called Intelligent Transportation Systems (ITS). The timing information of GNSS is used to synchronize telecommunications networks and power management systems, especially in the framework of the development of smart grids; the banking system uses to a large extent the GPS time to stamp and certify financial transactions.

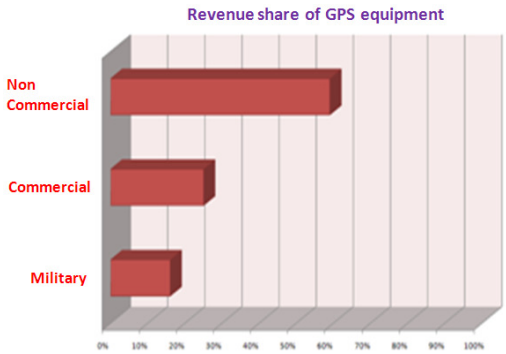
The size of economic activities that rely on GNSS is conservatively estimated as 6-7% of the whole GDP of the European Union, indicating that a disruption of the GPS signal would have a major impact on the European society.

6.1. GLOBAL INDUSTRY OVERVIEW

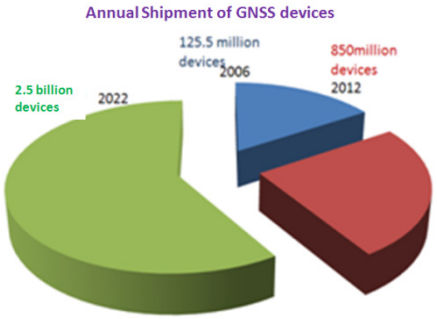
The applications of Global Navigation Satellite System (GNSS) are rapidly increasing across sectors. As an innovative industry, the GNSS industry directly affects economic activities and economic growth worldwide. During the past several decades, GNSS technology has transformed businesses and lifestyles with innovative products and services across industries. Furthermore, GNSS applications have entered into our daily life in many ways that we might not think about and the values of those services are beyond monetary values. Yet, the future potential is still far reaching (Ref.1).

6.1.1. Market segments

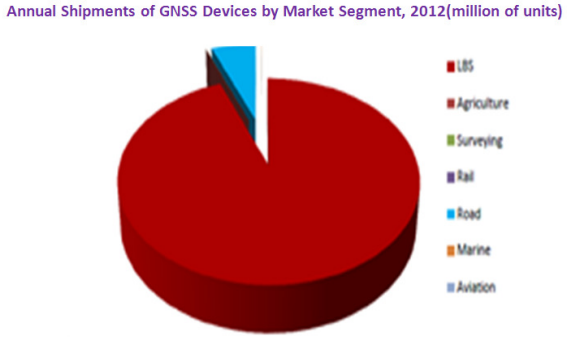
The existing GPS market can be divided into three broad categories: commercial, noncommercial (consumer), and military. During the period 2005-2010, commercial equipment sales accounted for 25 percent of the total, while noncommercial and military equipment accounted for 59 percent and 16 percent, respectively, in the United States(Ref.2).

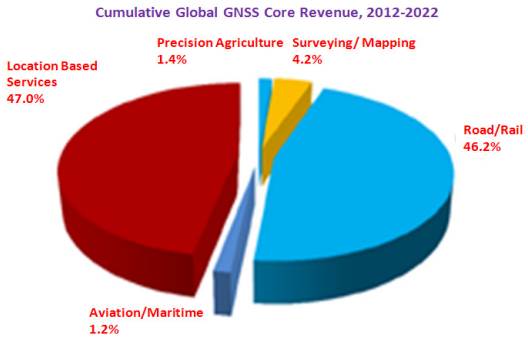


The applications of GNSS technology are rapidly developing into commercial and noncommercial industries. Global shipments of GNSS devices grew from 125.5 million units in 2006 to more than 850.7 million units in 2012. The European GNSS Agency projects nearly 2.5 billion units of GNSS devices will be sold in 2022. The Agency estimates the number of installed base units of GNSS devices will increase almost four-fold from less than 2 billion units in 2012 to nearly 7 billion units by 2022, almost one GNSS receiver for every person on the planet.



The market segment of location-based services (LBS) that covers smart phones, tablets, digital cameras, laptops, fitness and people tracking devices, and mobile data revenues has been growing exponentially and dominates the GNSS markets. Indeed, the global market of GNSS-enabled location-based services (LBS) devices alone increased more than eight-fold from 100 million devices sold in 2006 to 800 million devices sold in 2012. The European GNSS Agency expects annual sales of LBS devices will increase three-fold to more than 2.3 billion units in 2022. In terms of units, GNSS-enabled devices sold in LBS market account for more than 94% of total GNSS devices sold annually





It is estimated that global revenues of the GNSS enabled market will grow from approximately $204 billion in 2012 to approximately $340 billion in 2022. During the same period, global revenues of the GNSS core market that include only the part of the retail value attributable to GNSS (e.g., chipsets) is expected to double from approximately $68 billion to $136 billion. According to the report (Ref.3), the average cumulative revenues of LBS are expected to account for nearly half of total GNSS revenues in the next two decades.

6.2. Economic impacts on commercial & non-commercial users

Technological advancement has led to revolutionary progress in industrial development. The technology has improved the quality of manufactured goods, increased the efficiency of

industrial production and tremendously diversified and multiplied technological advancement has enhanced the quality of life and the standard of living of people. The radical developments in communication, transportation, entertainment and domestic conveniences have made human living quite smooth and comfortable.

The economic benefits of GNSS to society are substantial. Like other innovative products, the economic benefits of the GNSS technology on the economy and society are generated from the GNSS manufacturers and the benefits of the GNSS technology to consumers. GNSS manufacturers create employment, provide earnings, and generate tax revenues for governments. Far more important, GNSS technology produces cost-savings for end-users, improves productivity, and in addition provides nonmonetary values for users. Furthermore, the spillover effects from the GNSS technology to other sectors otherwise unavailable.

6.3. Impacts on GNSS Manufacturers

The Europe GNSS Agency estimates there are 1.8 billion GNSS devices currently installed globally and are expecting the number of installed units to grow by nearly four-fold to reach nearly 7 billion units by 2022. The number of GNSS devices sold in 2012 was over 850,000 units and is estimated to be nearly 2.5 million units by 2022. Total revenues of GNSS devices sold in 2012 were nearly $60 billion and are estimated to be nearly $144 billion by 2022. The estimated revenues include only the value of GNSS functionality and service revenues directly attributed to GNSS functionality. For example, only the value of GNSS chipsets in smart phones is counted and only the value of the GNSS receiver inside the Flight Management System is included (Table 1)

Location-based services (LBS), accounted for nearly 90% of number of GNSS installed-base devices. Since the price per unit is relatively inexpensive (approximately $20 per unit in 2012), revenues of LBS accounted for less than 30% of total revenues in 2012. However, revenues of LBS are expected to rise up to nearly two-thirds of total revenues by 2022 (Table 1)

Table.1 Global GNSS Market 2012-2022

Market Segment	Installed Base Units-million		Shipments Units-million		Revenue $-billion	
	2012	2022	2012	2022	2012	2022
LBS	1600	6300	800	2350	16.3	93.8
Survey	0.3	1.3	0.1	0.3	2.9	5
Agriculture	0.5	3.6	0.2	0.8	0.8	2.4
Aviation	0.8	1.5	0.3	0.4	1.1	1.2
Rail	0.1	0.4	0.1	0.1	0.1	0.1
Road	200	500	50	120	38	41
Marine	0.5	1.0	0.1	0.2	0.2	0.4
Total	**1802.2**	**6870.8**	**850.8**	**2471.8**	**59.4**	**143.9**

GNSS manufacturers are spreading in several industries including radio, TV broadcasting, wireless communications equipment, search, detection, navigation, guidance, aeronautical and nautical systems, instrument manufacturing, and other measuring and controlling device manufacturing. According to the U.S. Census data, there are 2,206 establishments in these three industries. These establishments employed 241,964 workers in 2011 and paid nearly $20.4 billion in wages. Value of shipments and value added in 2011 were approximately $91.9 billion and $54.3 billion, respectively. Annual payroll per employee averaged $81,969. Value of shipments and value added per employee in 2011 averaged $379,809 and $216,202, respectively (Ref.4). The same trend is expected worldwide in the days to come.

GNSS revenues in 2012 (estimated by the European GNSS Agency) and the manufacturing industry averages (estimated by the U.S. Census) are used to estimate the economic impacts of GNSS manufacturing companies on the U.S. economy. The European GNSS Agency estimated GNSS revenues in 2012 were approximately $16 billion in North America, which are mostly in the United States. Using averages of three GNSS-related manufacturing industries, it is estimated that GNSS manufacturers employed 42,126 workers in 2012, paid nearly $3.5 billion in wages, and contributed over $9.1 billion to the U.S. GDP (Table 2).

Table.2 Economic Contributions of GNSS Manufacturing Companies

Economic Benefits	Total
Direct Economic Impacts	
Total Revenues	$ 16.000 billion
Total Value Added	$ 9.107 billion
Total Payrolls	$3.453 billion
Number of Employees	42,126
Payroll per Employee	$ 81,969
Direct and Indirect Economic Impacts	
Output	$32.0 billion
Earnings	$6.8 billion
Employment	105,315

The Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce produces job, wage, value-added, and output multipliers to estimate the indirect and induced effects of U.S. industries. The BEA estimates the job multiplier of the related-GNSS manufacturing industries ranges between 2.3 and 3.1 and the wage and output multipliers range between $1.8 and $2.2(Ref.5). Direct effects are the dollar amount of inputs required by an industry to produce a dollar of the industry's output, while indirect effects are the dollar amount of inputs required by all other industries in the supply chain to meet the industry's initial demand for the dollar of its output. The direct effects are the input production requirements such as the paint, steel, and plastic for the motor vehicles industry to provide additional motor vehicle outputs. The indirect effects are those "trickle down" production requirements for all other industries necessary in the supply chain to support the additional demand for intermediate inputs from the motor vehicles industry, such as the additional requirement for tire cord and synthetic rubber by the plastics and rubber industry to provide the additional tires required by the motor vehicles industry. The induced effects are the impacts of household expenditures on goods and services from the income earned by all direct and indirect employees. It is estimated that the GNSS manufacturing companies supported 105,315 workers (including direct jobs) with $6.8 billion in earnings and $32 billion in outputs.

Like all other manufacturers, GNSS manufacturers create additional economic activities for upstream and downstream business entities. While GNSS manufactures purchase intermediate goods and services from upstream vendors to produce chipsets, the GNSS technology creates additional economic activities for downstream companies who rely on the technology to create other products and services. The downstream business entities include GNSS device vendors, service and content providers, original equipment manufacturers, application developers, and retailers.

Oxera Consulting Group estimates that the direct economic effects of the downstream location-based service companies (Geo services) to be around $150-$270 billion in revenues per year globally. These companies contribute around $113 billion value added to GDP per year, accounting for 0.2% of global GDP.16 The Boston Consulting Group (BCG) estimates the geospatial services industry employs the GPS technology to generate about $75 billion revenues and provides more than 500,000 workers in the U.S. to support consumers, businesses, and government agencies. The downstream effects are expected to continue growing to reach $100 billion in annual revenues between 2012 and 2017 in the United States.

Another major commercial market of GNSS applications is ground transportation that applies intelligent transportation system (ITS) technology. According to an IBM report, the ITS industry markets in North America were $52 billion in 2009 and is expected to grow to $73 billion by 2015. The industry employed over 513,000 workers and is expected to expand to 564,000 employees by 2015.

Clearly, the impacts of GNSS technology on economies and societies are large. However, there are at least three technical challenges to quantify the exact direct economic activities of GNSS manufacturers and their upstream and downstream vendors. The first challenge is related to the industry classification system. As shown earlier, GNSS manufacturers are among 2,206 establishments in three industries. However, not all of these companies produce GNSS-related products and government statistics do not have exclusive data for GNSS companies. The second technical challenge is to estimate the portion of GNSS-related activities in each company. For example, key chipset manufacturers like Broadcom, Intel, Qualcomm, and Texas Instruments produce many other products. Similarly, device vendors and application developers and stores have other products and services as well. The third technical challenge is the rapid development of the GNSS applications that affect downstream vendors. As shown in the 2013 European GNSS Market Report, the location-based services market alone increased by eight-fold in the past seven years. The number of mobile applications increased more than ten-fold within one year. As results, data becomes outdated quickly.

6.4. Impacts on Major Markets

Commercial users apply GNSS technology to increase productivity which in turn has positive impacts on cost-savings. Direct economic impacts include savings on inputs of labor, capital, and time. Noncommercial users enjoy GNSS technology for their daily life activities. In addition to monetary measures, GNSS technology creates nonmonetary benefits for noncommercial users. Altogether, GNSS technology creates values for personal and business consumers.

6.4.1. Location-based Service (LBS) Market

LBS is increasingly integrated into our day to day life. The LBS applications include personal navigation, point of interest search, LBS advertising, person and objects tracking, emergency caller location, location based gaming, sport and entertainment, weather information, and social networking. The number of applications is estimated to be around 775,000 in Apple App Store in 2013 and the number of Android Apps increased from 88,000 in 2011 to 700,000 in 2013. Various positioning technologies are integrated into one device such as cameras, watches, and binoculars. Location information is sent from devices to application layers to enable sharing and tracking functionalities.

Global personal location data

- $100 billion+ revenue for service providers
- Up to $700 billion value to end users

The economic benefits of location-based services span across personal and business consumers as well as governments. The GNSS applications enable law enforcement to improve the efficiency of disaster response, people tracking, and community safety, in addition to national security and defense services. Geospatial services become an essential element in our daily life to access information on computers, mobile phones, tablets, and GPS devices. On the commercial front, geospatial services are integrated into their core business operations, sales, and marketing by the companies. In its 2012 report, the Boston Consulting Group estimates that the multiple effects of the $75 billion geospatial services industry range between 15 and 20 times (Ref.6). The report estimates that the overall impacts of geospatial services in the U.S. economy are 1.6 trillion in economic activities and an additional $1.4 trillion in cost savings a year. The report also projects the overall impacts to reach $2.6 trillion per year by 2017.23

Studies have shown geospatial services create benefits via many channels including time savings, fuel savings, emergency response, and education. The GNSS applications help drivers to get to their destinations faster and in shorter routes which in turn save fuel consumption. In addition to personal trips, time savings add the substantial benefits for emergency services to locate and reach the scene quickly. The GNSS applications provide educational tools for students to gain information and knowledge and to sharpen their skills to enter the workforce. For example, Oxera Consulting estimates the consumer benefits from geospatial services are nearly $50 billion per year globally ($22 billion in journey time and fuel savings, $12 billion in educational benefits, and up to $13 billion in emergency responses)(Ref.7).

6.4.2. Civil Aviation Markets

The GNSS applications cover all commercial and noncommercial aviation to provide the accuracy and integrity of the position of aircrafts. Application of GNSS in aviation sector helps

comprise various socio-economic benefits and helps to increase safety, reduce congestion, save fuel, protect the environment, reduce infrastructure operating costs, and maintain reliable all weather operations, even at the most challenging airports.

Indeed, the Federal Aviation Administration (FAA) projects daily flights in the U.S. will increase by 40% from 43,000 in 2010 to 60,000 in 2030. The number of passengers will increase by more than 68% from 712 million in 2010 to 1.2 billion in 2030. Thus, operational efficiency and passenger safety are essential for the future of the aviation industry.

The economic impacts of the GNSS application on the aviation industry are significant. The FAA's initiative of Next Gen is to create satellite-based procedures to transform the national airspace system to remove bottlenecks and improve safety and efficiency to deliver more on-time and fuel-efficient flights. The FAA estimates the benefits of Next Gen to reach $123 billion through 2030. Consumers will benefit from better travel experiences through the reduction in delays resulting from on-time performance by controllers and operators. The FAA expects that Next Gen improvements will reduce overall flight delays in the U.S. by 41% between 2013 and 2020. The application of Next Gen in aviation industry also helps consumers to indirectly benefit from a reduced adverse impact on the environment through the reduction of carbon dioxide emissions.

6.4.3. Ground Transportation Markets

The role of transport is crucial in creating jobs and sustaining economic growth in growing urban/rural areas. The ground transportation systems of cars, buses, metros, and rails are required to be efficient and safe to move workers and goods around the city smoothly. Therefore, it is more important for cities and communities to ensure to implement and maintain suitable transportation systems to support the increasing demand.

The development of the intelligent technology systems (ITS) provides cities with cost-effective solutions to maximize the economic returns of the city infrastructure to build safe, smart, and efficient transportation systems. The benefits of ITS application in the transportation segment are tremendous, by reducing congestion while enhancing mobility. The study conducted by U.S. Government Accountability Office (GAO) reports (Ref.8) that the benefits are greater than the costs of the real-time information systems. The report emphasizes an important finding from the Department of Transportation (DOT) that the benefit-to-cost ratio of real-time information systems is over 25, compared to the ratio of 2.7 for conventional highway projects. The DOT study found that the present value of total cost savings are about $30.2 billion (generating from the benefits to mobility, the environment, and safety) compared to the present value of the costs of $1.2 billion of the program.

6.4.4. Other Markets

The GNSS technology is also popular in agriculture and engineering construction industries. The GNSS technology helps farmers to match production techniques including farm planning, field mapping, soil sampling, tractor guidance, and crop scouting. In addition, the technology enables more precise application of pesticides, fertilizers, and better control of the dispersion of those chemicals. Thus, farmers are able to reduce input costs and to increase yields. It is estimated that the economic benefits of GPS on agriculture are between $19.9 billion to $33.2 billion per year based on 10% yield gain and savings of 10% in labor wages, 15% in capital, and 15% in inputs.

Another market that receives significant contribution of GNSS application is engineering construction. The GNSS equipment increases productivity in the construction industries by providing accurate machine guidance and measurement technology. The technology improves accuracy and increases efficiency in many related functions such as surveying, excavating, grading, sub-grading, transportation management, facility delivery, urban planning, and jobsite safety monitoring. The benefits of GPS to the industry can be measured in terms of savings of labor, capital, and materials. In our previous report, we estimate the economic benefits of GPS technology on the industry are between $9.2 billion and $23 billion per year. Table 3 summarizes economic benefits of GNSS applications on selected industries in the United States.

Table.3 Economic Benefits of Major Market Segments in United States

Markets	Economic Benefits
Location Based Services	$1.6 trillion in economic activities $1.4 trillion in cost savings
Civil Aviation – NextGen	$123 billion cumulative money saved through 2030
Ground Transportation -ITS	$30.2 billion cumulative money saved through 2018
Precision Agriculture	$19.9 ~ $33.2 billion per year
Engineering Construction/ Survey	$9.2 ~ $23 billion per year

7. CONCLUSION

The application of GNSS technology in a number of market segments has delivered enormous benefits to global economy. The GNSS-enabled products and services create values for commercial and noncommercial users. For commercial users, the GNSS technology has made the production processes and operations to be easier, safer, and cost-effective. For noncommercial users, the GNSS technology creates monetary values of time and cost savings as well as nonmonetary values of safety and lifestyles. Like other innovative products and services,

the GNSS industry directly creates jobs and economic activities to support the economic growth.

The economic benefits of GNSS to society are substantial. Like other innovative products, the benefits of GNSS technology on the economy and society are generated by GNSS manufacturers and the advantages the technology provides to the customers. The GNSS industry directly creates jobs and economic activities to support the economic growth. GNSS manufacturers create employment, provide earnings, and generate tax revenues for governments. Far more importantly, GNSS technology imparts cost-savings and improves productivity in agriculture, industry and service sectors, which further contributes the major share of the country's GDP.

Like any other manufacturers, GNSS manufacturers also create additional economic activities for upstream and downstream business entities. GNSS manufactures purchase intermediate goods and services from upstream vendors to produce hardware, chipsets, etc. For downstream companies who rely on the technology the GNSS generates additional economic activities in the form of applications and services. The downstream business entities include GNSS device vendors, service and content providers, original equipment manufacturers, application developers and retailers. Commercial users utilize GNSS technology to increase productivity which in turn has positive impacts on cost-savings, that include savings on labor, capital, and time. Noncommercial users enjoy Satellite Based Navigation technology for their daily life activities, like visual navigation for drivers for an instance. Altogether, GNSS technology imparts value for personal and business consumers.

8. References

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