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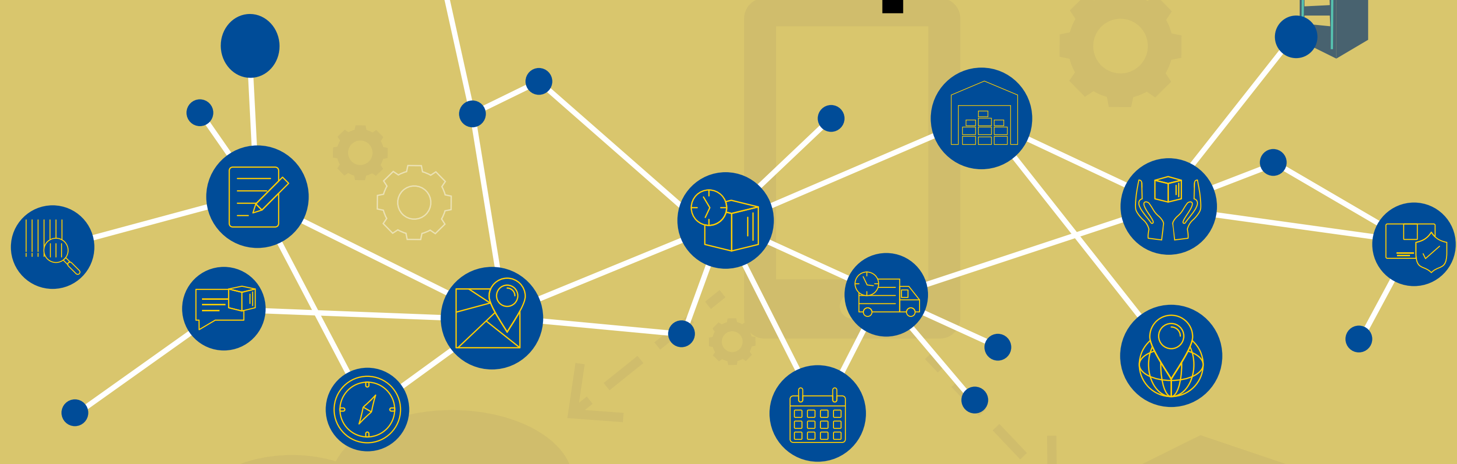
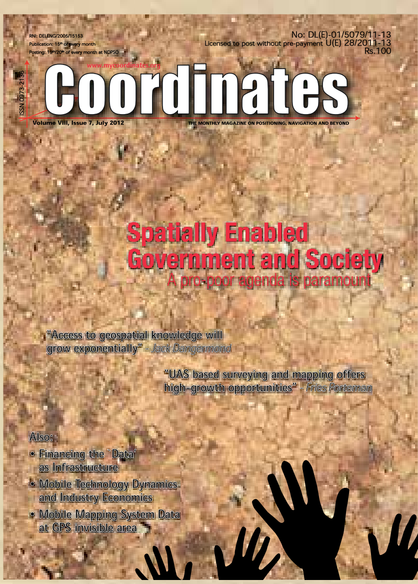
Logistics tracking system based on decentralized IoT and blockchain platform



Analysis of factors affecting industrial site selection

In Coordinates

10 years before...



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“Access to geospatial knowledge will grow exponentially”

Says Jack Dangermond, Founder and President, Environmental Systems Research Institute (Esri) in an interview with Coordinates

The next step in GIS evolution means that everyone will have access to the idea of map overlays and spatial analysis. While traditional GIS has brought greater understanding within organizations, this next step will mean greater understanding within society at large. It also means greater collaboration and communication across organizations. This will ultimately result in a geospatial platform that could potentially reach billions of people.

A case for financing the `data' as part of infrastructure

Dr Mahavir and Prabh Bedi
School of Planning and Architecture, New Delhi, India

Giving the status of infrastructure to data is surely likely to entail investments which the field is hugely lacking. Investment is the key to building the basic data as well as needs to meet the up to date status. By adding a ‘delta’ component of ‘data infrastructure’ in overall financing of infrastructure, the benefits of infrastructure development can be made more meaningful and manifold.

Mobile Technology dynamics and industry economics

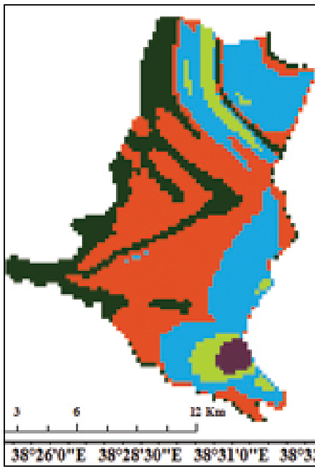
Ali Sarwar
School of Surveying and Spatial information Systems, University of New South Wales, Australia

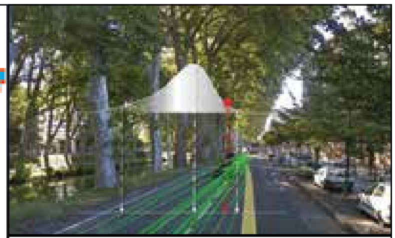
As the market economics and dynamics grow and change for both software platform owners and mobile operators may see their profits shifting with change in investment strategies in network modernization. Platform owners on the contrary might gain enough revenues to support their investment in the network upgrade sector and thus support their new business model of end-end service ownership e.g. from Skype to a user handset.

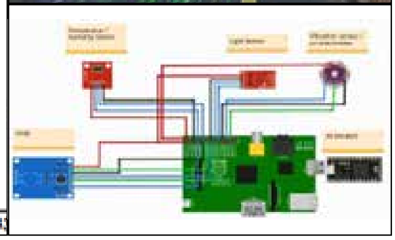
Accuracy maintenance method for mobile mapping system data at GPS invisible area

Akihisa Imanishi, Kikuo Tachibana and Koichi Tsukahara
PASCO CORP, Japan

In this paper optimal assignment method of land mark point based on the horizontal and vertical road profile is discussed. In order to examine more effective methods of assignment it is considered necessary to take into account of vehicle velocity and it is our future work.







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Columns

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Editor Bal Krishna
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This issue of Coordinates is of 40 pages, including cover.

Spectacles of the past

The first of the few glimpses,

Seizing the moments of cosmic history

Captured by the James Webb Space Telescope

Have been released.

The first image depicts SMACS 0723,

According to NASA is

"the deepest and sharpest infrared image of distant universe to date".

This takes us to the world of stars and galaxies,

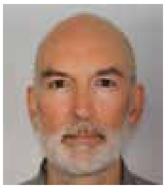
Never seen before, never visited before.

A leap into the past, and to the future too.

Bal Krishna, Editor
bal@mycoordinates.org

EN16803 European geolocation standard to certify mobility solutions

The EN16803 series of standards is designed to help users make better choices and simplify the integration of satellite technologies into onboard systems



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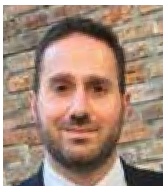

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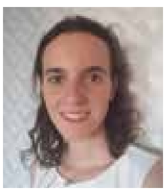

Christelle Dulery
CNES (French Space Agency), Toulouse, France

Abstract

The geolocation field has acquired a reference methodology that is essential for evaluating and characterizing GNSS terminals intended for land navigation.

The EN16803 series of standards is designed to help users make better choices and simplify the integration of satellite technologies into onboard systems. It is based on an instrumental metrology technique, identified under the term "Record & Replay" and offering several key advantages:

- Restore test environments that are "Reproducible" and "Representative" of the real world;

- Dissociate the errors of "Accuracy" and "Fidelity" to enrich the analyses;

- Establish reliable reference scenarios to "compare measurement results".

Geolocation errors, degraded signal and environmental masking

In a perfect world, the positions calculated by trilateration using the signals transmitted by the satellites would always be accurate to within a few centimetres. Unfortunately, in addition to the intrinsic quality of the receivers, many factors alter the measurements made by a GNSS receiver and degrade the final geolocation data.

To begin with, the GNSS system itself suffers from multiple imperfections including so-called "Global" errors. For this reason, the satellite navigation system is complemented with the broadcasting of assistance messages to increase the performance of receivers compatible with SBAS systems, such as EGNOS for the European continent.

In addition, for terrestrial applications, the satellite signals are affected by several phenomena caused by the immediate surrounding of the receiving antenna. These are the so-called "Local" errors, such as terrain, bridges, infrastructures, vegetation and interference of any type. Depending on the areas covered, the trajectories calculated by the terminals deviate more or less from that actually taken by the vehicle (antenna), i.e. the "reference trajectory", also called "ground truth".

Classification position errors

To study those phenomena having the greatest impact and likely to be the most frequent, the different types of errors are displayed as a risk matrix. As the "Global" errors can be considered to be handled by the regional SBAS system, the pre-eminence of the so-called "Local" errors should be addressed. In addition, they add to the Global errors and the intrinsic inaccuracies induced by the GNSS terminal.

Description of the main sources of local errors

To observe the effects of local phenomena on the propagation of signals, a dozen identical receivers – with the same configuration and sharing the same antenna – on board a vehicle, were driven through urban and peri-urban areas.

We focus on four particularly impacting phenomena to visualize the trajectories calculated by the receivers.

Positioning errors due to bridges

In the picture (figure 3), the test vehicle passes under a bridge in both directions. In both cases, the trajectories diverge under the bridge and converge further on. Here it is easy to understand the shortcomings of results based on a single pass, in other words based on a single measurement.

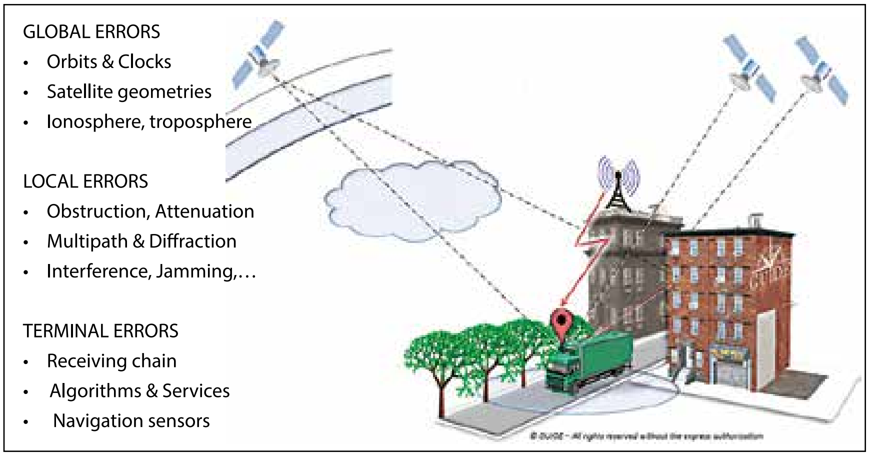

Figure 1 – Sources of error in urban geolocation

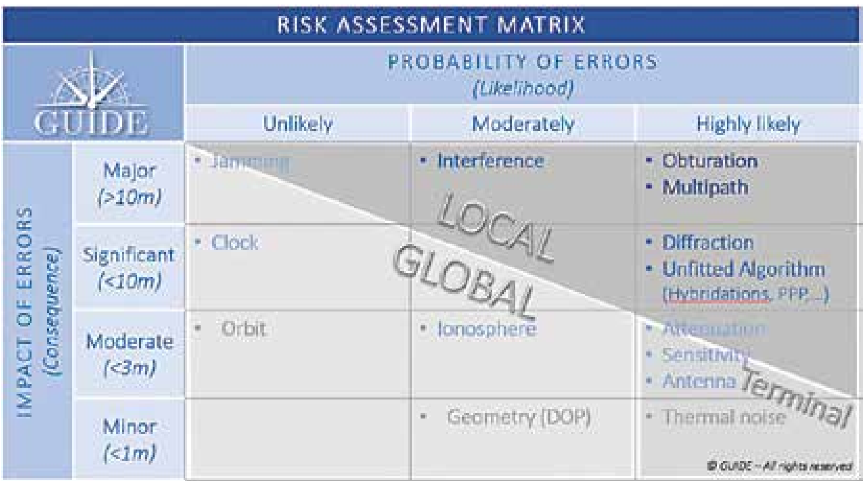

Figure 2 – GNSS Risk Matrix

Figure 3 – Effect of alteration of GNSS signals on receivers passing under a bridge

Positioning errors due to vegetation

In the image (figure 4), the test vehicle is on an avenue lined by trees whose branches and canopy cover the road. The foliage attenuates, and more importantly, diffracts the radio waves arriving from the satellites, thus degrading signal reception. This results in dispersed trajectories. Each receiver provides a different measurement. Note that due to the proximity of buildings, the centre of the position distribution, in the presence of multipath, deviates slightly from the reference trajectory.

Positioning errors due to buildings

In the composite image (in order to show the main building) (figure 5), all the receiver trajectories are deviated towards the building alongside the avenue. The situation highlights the consequences of a phenomenon called "multipath". When a receiver captures reflected waves, the signal propagation time – used to calculate the pseudo-distances – is increased and the accuracy of the end position is degraded. This effect is well known and easily observable during static measurements.

Positioning errors due to interferences

In the image (figure 6), the on-board receivers have been disturbed by "transitory" interference. On the outward journey, twenty minutes earlier, no problem had been detected for the trajectories on the other side of the expressway.

On the return journey, this unidentified interference degrades the accuracy of the receivers with a visible dispersion of the trajectories. In other situations, intentional or unintentional interference could completely block out the GNSS band preventing any position measurement.

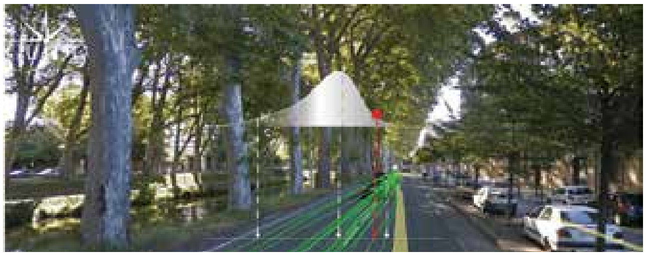

Figure 4 – Effect of diffraction of GNSS signals on receivers passing under tree canopies

Figure 5 – Effects of GNSS signal propagation on receivers near a building

Figure 6 – Effect of unidentified temporary interference on signals for GNSS receiver

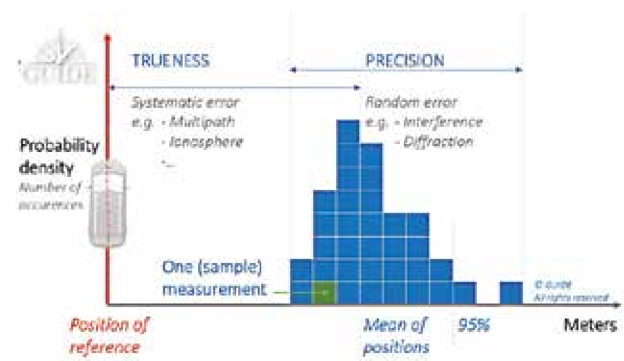

Figure 7 – Combination of deterministic and non-deterministic errors

Figure 8 – A single position measurement at a point has 2 unknowns : The weight of deterministic (Trueness) errors compared to those that are not (Precision)

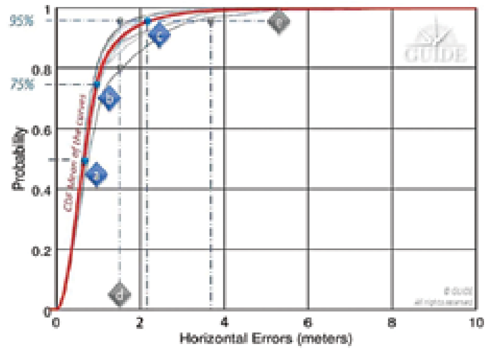

Figure 9 – Statistical distributions of errors for a trajectory (scenario), i.e. the percentage of all errors (probability) lying beneath a given accuracy level.

Figure 10 – Visualization of the combined deterministic and non-deterministic errors

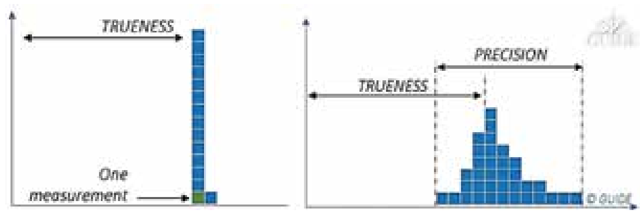

Figure 11 – Typical results for repeated measurements obtained, respectively from left to right, with synthetic signals and real-world signals

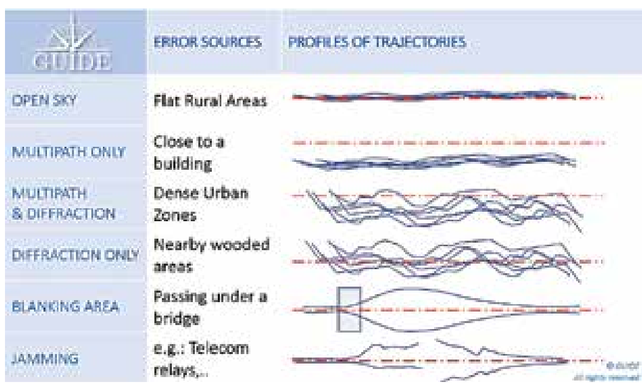

Figure 12 – Position error profiles (measured trajectories / DUT) depending on the environment.

NB.: In this case, the source of the interference seems to come from the bottom right, guided by the two lateral buildings.

Trueness and precision of position measurements

Receivers of the same batch behave differently depending on the environment. For a predominantly multipath situation, they all converge to the same wrong position. On the other hand, when the propagation phenomena become more complex with multiple diffractions, such as a reception under foliage, all the receivers produce positions with different errors. For complex environments, we have a combination of these two behaviours.

The first behaviour is deterministic. Metrology vocabulary uses the term measurement “Trueness” for: “closeness of agreement between the average of an infinite number of replicate measured values and a reference value”.

One of our test vehicles use to validate the results of the EN16803

Batch of instrumentation for GNSS measurements in urban areas

The “Tram” is a use case where GNSS is implementing in urban areas

The second behaviour is NON-deterministic. Metrology then uses the term measurement “Precision” for: “closeness of agreement between indications or measured values obtained by replicate measurements on the same or similar objects under specified conditions”.

Terrestrial applications often offer a varied mix of environments where “Trueness” and “Precision” errors accumulate. It is essential to consider both components in order to characterize and study GNSS receiver performance.

Statistic distribution of the different positioning errors:

Above, 95% of the positions calculated during a replay have an accuracy better than 1.5m; this same value is only reached with ~ 80% of the positions calculated during another replay – see vertical line [d]. The horizontal line [e] illustrates the spread of the horizontal position by considering 95% of the positions of two replays: for one the displayed accuracy is ~ 1.5m and for the other it is degraded to 3.5m. This curve will always point to the same reference points [a], [b] and [c] recommended by the standard EN16803-1 and corresponds to the percentage of measurements respectively less than 50%, 75% and 95%.

By way of example, the evaluation of a single receiver on board a vehicle travelling in an urban environment does not allow separation of these two components. Indeed, signal degradation determines the degree of dispersion of the “random” component of the measurements. Thus, in certain environments, each additional receiver will produce a different result. However, the analyses of a single on-site campaign rely on just one single sample (single trajectory of the terminal under test), where a panel of measurements is essential. In fact, the available statistics prove insufficient to characterize a receiver, even at the cost of doing long runs.

Live testing is therefore rather intended for final integration.

On the other hand:

A constellation generator will synthesize ideal signals derived from mathematical models, and in any case, not representative of the real environment. The measurements will then only be deterministic, i.e. subject to “systematic” errors. Repeated simulations on the same receiver will always produce the same measurements. Nevertheless, this type of test bench offers many advantages for simulating unobservable situations in the real world.

Disparities in analysis possibilities on position errors based on trueness and precision (figure 11).

In summary, the main error profiles are described (figure 12).

Each situation combines both Trueness and Precision errors. This latter component requires several runs in the same configuration to determine the potential measurement spread.

What is GNSS Metrology?

As a first approach, characterization of GNSS performance would require many receivers on the same test vehicle. This method is certainly useful in the experimental stage, especially to understand the impact of propagation phenomena on positioning errors. However, it has major disadvantages, both from a logistics point of view and because of the basic metrological requirements.

To obtain reliable and useful measurements, from an operational point of view, the tests must be "representative" of the areas to be covered and "reproducible" to check the results and make valid comparisons, for example, between 2 terminals, 2 firmwares, 2 settings, 2 antennas, even between 2 hybridizations.

Under these conditions, replay techniques, often referred to as "Record and Replay", meet the expected requirements. For the record, this metrology method consists in digitizing the GNSS signals received by the antenna on board the definition vehicle, taking care to collect all the data associated with the tests (VIDEO, INS, DMI, NRTK, …), above all, the ground truth. Thus at the end of the campaign the GNSS signals and other data are synchronized and restored on a replay bench consisting of an "SDR replayer".

Replaying the same scenario on a receiver makes it possible to reproduce the recording conditions identically. Each pass generates new measurements, equivalent to using an additional unit, virtually onboard. Compiling the results thus highlights the non-deterministic errors, i.e. those which by their random nature emerge from the others.

Test laboratories such as GNSS GUIDE design and market test data directly replayable on the main simulation instruments capable of operating in two modes: Simulation and Replay. The replay configurations are generally much more affordable than the larger, structurally more complex constellation generators. In addition, the implementation of replay sessions is simple, fast and requires no special training.

As well as scenarios made on request, the available libraries already cover a multitude of cases, previously inaccessible for an isolated user. They open up the possibility of testing terminals in different latitudes with varied terrain and neighbourhoods composed of typical architectures.

Conclusion

The French Space Agency (CNES) has financed several R & D contracts for the development and validation of this replay technique (Record & Replay). It is already recommended by CEN / CENELEC through the series of EN16803 standards to characterize and classify the performance of GNSS terminals. This methodology complies with the basic principles of metrology. The test conditions are reproducible and representative of operational conditions. The measurements are repeatable and allow separating the systematic errors (Trueness) from the random errors (Precision). Measurement uncertainties are also accurately established.

During an on-site measurement campaign, the statistical distributions of two identical receivers on board the same vehicle lead to different results. Thus, no characterization can be established at this stage.

With a replay bench, after several iterations of the same scenario, the average values of the measurements on a CDF tend towards a curve characterizing the performance for that scenario.

Instrumentation dedicated to replay operations is less complex and less expensive. Statistical models of simulations are replaced by scenarios of GNSS signals previously digitized in the field or on constellation generators. Thus, whether they come from a real or synthetic environment, these GNSS signals are easily restored, while drastically reducing the preparation and execution times. The economic benefits of this test technique are now evident and are favouring its adoption by the transportation industries.

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Logistics tracking system based on decentralized IoT and blockchain platform

The paper proposes an approach using a distributed ledger (blockchain) besides a configuable IoT-based system to take into account all needed data including specific case of urban area

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Abstract

Most of supply chain networks have encountered difficulties when trying to integrate all components and stakeholders (customers, warehouse, transportation, and raw material production), which make supply chain management system suffering from a lack of efficiency and transparency that make a steady increase in good's falsification and consumer's disappointment. All information about good's production, storage and transportation should flow clearly during all stages of the supply chain by tracking and authenticating to avoid product's contamination or fraud in the network. Current tracking IoT-based systems are built on top of centralized architecture and this leaves a gap for tampering and false information especially in urban area, but also the exsiting solutions cannot allow the information to be shared with authority or consumers. To effectively assess and assure traceability and transparency this paper proposes an approach using a distributed ledger (blockchain) besides a configuable IoT-based system to take into account all needed data including specific case of urban area, with an open data platform at the disposal of stockholders, authority and consumers.

1. Introduction

Over the last decades, supply chain and logistics have greatly grown, rationalized and become a key factor of competitiveness and economic success for almost all companies (industry, commerce, construction, agriculture, services). Supply chain has not only been placed at the center of economists' attention, but compagnies spend more and more amounts of their turnover on logistics and especially transportation. As the phase of delivery of products and/or services to final costumers, the supply chain is how nowadays companies turn raw materials into finished goods and services for the clients. In fact, starting with extracting ressources, through refining or manufacturing them into basic parts, assembling those parts into finished products, until selling and distributing finished products to consumer, supply chain is at the center of economic activities. As all companies, logistics ones, have adapted their processes to the dynamics of the moment in order to survive in a very competitive market. In fact, it is not only a question of integrating new technologies, but also great opportunities harness when opting for digitalization as a part of the vision of industry 4.0 [1]. This field is lucky to support a set of technical solutions such as wireless networks, internet of things (IoT), big data, blockchain. The transition from traditional supply chain to a smart supply chain will provide better visibility of the transportation and flexible management. When adopting these new techniques, supply chain can meet market expectations, face new competitors, introduce new links between both companies and partners and thus get more and more benefits. Along with, the wild range of available choices, customers are much more demanding and their satisfaction blended with cost reduction is hard to achieve. Otherwise, supply chain is tending to reach urban customers whose numbers are increasingly significant due to urban migration. Also called "last-mile logistics", this type has to take into account the congestion, externalities, emissions, space access [2].

This research is considered with the product status during and after the logistics' chain. For companies' performance, this status is taken as quality indicator since sensitive or vital products require special treatment and detailed monitoring (vibration, temperature, luminosity, location). On the one hand, the visibility of product status during transportation helps in taking the right decisions in case of an issue. On the other, traceability after chain is over ensuring compliance with specific conditions needed for the product in question. Given all supply chain levels, the information about producing, storing, transporting, and selling goods or services is usually provided by each stage organization. Hence, the reliability of information is compromised. In order to increase their profits, managers of transportation or storage operations may, voluntarily or involuntarily, provide wrong or falsified information. Due to consumer behaviour and supply chain dynamics, logistics network is facing several challenges. K. Wang [1] discussed those challenges and opportunities related to the logistics 4.0 visions and the supply chain digitalization. However, those dynamic changes and adaptations can expose companies and customers to the risk of product damaging. M. M. Aung and Y. S. Chang [3] explained the impact of those risks on the customer's confidence especially when it comes to food industry which has already experienced problems in the past (food safety scandals, genetically modified foodstuff) P. Olsen and M. Borit [4] defined traceability in the food supply chain as the ability to access to all information also considered as a record and life cycle. N. Egels-Zandén et al. [5] showed the importance of transparency and the difference between transparency and traceability in the supply chain. According to them, there are several tracking solutions such as Bar-coding and RFID combined with localisation sensors based on global positioning system (GPS). H. K. H. Chow et al. [6] presented the integrated logistics information management system. An integration of multiple tracking technologies in a common logistics platform presented as a generic web-based model with a process visualizing using RFID. Also, T. Kelepouris et al. [7] author presented a system using RFID to identify package with GPS and an overloading sensor. A review made by [8] discussed several challenges related to tracking in the urban fright. This study reveals possible interferences that could compromise the quality of the GPS signal especially in urban areas. In the same context, a denser road network due to traffic management can also make tracking more challenging. T. Yokota and D. Tamagawa [9] the author focused on the same issue by applying a map-matching algorithm using dynamic programming to reconstruct the route lengths based on route identification and GPS position data. Recently, the rise of IoT technologies has brought more solutions to these challenges. M. He and J. Shi [10] and many other related papers discussed the implementation of internet-of-things technologies in supply chain, with sensors, GPS, wireless connectivity, RFID. K. Sari [11] developed a model to detect the conditions to use RFID technology in supply chain. The model showed an example of the use of RFID technology which has comes with a lot of benefits to the firm especially when it is accompanied by a real collaboration in the chain. Using IoT and RFID, Z. Pang et al. [12] proposed an approach for food supply chain based on a value-centric framework, A. Rejeb et al. [13] discusses the benefit of IoT integration into the logistics networks and also shows examples that this integration is still suffering from inefficiency due to immature in systematic, network, and collaboration perspectives.

Besides IoT technology, blockchain has also drawn much attention in the research field. The first well-known application of blockchain is indeed bitcoin. Since its inception, blockchain has been applied in many domains including supply chain. S. Abeyratne and R. Monfared [14] discussed the benefit of blockchain in the supply chain. They pointed out that the blockchain has not only resolved the lack of trust between stakeholders but also enhanced trust through transparency and traceability within data sharing. In the same context, the distributed/shared database can become more transparent especially in the supply chain network. Also, N. Hackius and M. Petersen [15] pointed on several benefits of using blockchain in the supply chain, such as reducing paper-work, identifying counterfeit products, and tracking the origin of each good. M. Khan et al. [16] discusses the combination of IoT based systems besides blockchain network and their application and benefits to earn people's trust and transparency in humanitarian logistics. Furthermore, M. Balaji and K. Arshinder [17] presented an open data blockchain based platform capable of long-time open data (BaLOD) that can be validated by anyone. To deal with the above issues, the current contribution presents a transparent approach based on reliable and accessible data collected throughout supply chain phases (transportation and storage). The first section focuses not only on the causes behind falsified/wrong data, but also on challenges facing the supply chain especially in terms of traceability. Furthermore, the second section details the technical architecture of an IoT/Blockchain-based tracking solution carrying multi-sensors and using RFID/QR along with an open data service.

2. Research method

2.1. Logistics and traceability

Since the role of the supply chain begins with the purchase of raw materials until the distribution of finished products, the full product transportation lifespan differs depending on the number of intermediaries in the supply chain. The more intermediaries the chain has, the greater the risk of losing product quality will be, along with carbon emissions due to transportation [2], delay of payments and high transaction waiting time [18]. When the contract is signed, consumers oblige companies to justify time, place, and causes of any issues. If the latter happens, companies can receive sanctions, betray the trust of their partners, lose market share and even harm their own development. Hence the necessity to adopt traceability systems in order to minimize risks for clients and ensure at best, at worst, verification of quality and safety of goods supplied [3].

Product traceability solutions come with many benefits to businesses by helping them identify critical points in the supply chain, resolve incidents without delay, gain productivity, and provide to the company a solution for the shortage of data about product manufacture and raw materials used [14]. Indeed, companies can handle the quality reduction of the contamination of goods and increase the quality of the service they offer to their consumers. On the other hand, the solutions allow consumers to improve the level of their confidence when purchasing a product or service. An appropriate solution must encompass all features of a supply chain, transits made in different countries is also included. This is the reason why the actors in the supply chain are obliged to share the same data structure and that the products are referenced using identification for external use.

One critical element goes along with traceability is transparency. Unlike traceability that conveys granular and batch-lot data and even unverified and falsified claims, transparency refers to receiving and transfering high-level information related to the product and suppliers from and to stakeholders [5] (certifications, expiration date, location of facilities,) without a risk of loss or distortion [19]. Supply chain planning systems allow the analysis of resource capacity and constraints in order to suggest the right path to optimal production.

There are several types of product traceability such as tracking, which means the possibility of holding the data of routes travelled by a load unit or a batch of goods using unique IDs or recorded identifications such as RFID [20]. It helps to know the routing path of a product and to better calculate delivery times. Tracking is the most used type of traceability for on-line shopping. It allows us to know all the stages done by a product until its final destination. To make sure all stages of supply chain are carried out under the best possible conditions, geographic coordinates provided by a GPS are not the only information needed. Traceability can be extended to cover other parameters as well. For example, special products such as drugs, blood units, chemical products, and also food, need to be protected from degradation in each stage of the supply chain, especially from temperature, light and humidity [21].

In recent years, the amount of urban population has increased along with the demand for goods and products. Thus, the home delivery services return goods and supplied products has considerably expanded and created tense flow management and contributed to the increase of number of truck traffic in cities. This type of transportation depends on several aspects and has required much attention. In fact, urban freight is more questionable in terms of traceability and transparency due to short trips, complex roads, stops and congestions that enhance fuel consumption up to 140% [22], delay transportation and increase transportation's budget. Also, the weakness of GPS signals due to tall buildings and narrower streets in urban environments [8]. In this case and to monitor those aspects, the GPS data, temperature and vibration can be considered as an exposure due to several natures of supplied products. For example, the last two are important parameters for tracking products like frozen food, drugs, blood, and vaccines [23].

2.2. Traceability via blockchain and IoT

Internet of things the proposed tracking system relies on the combination of several instruments. The main technology to consider is Internet of Things. Theses devices, mass-produced and utilised in industry since 2012, provide new ways to approach well-known challenges of the supply chain, the most important of which is collecting real-time data. Like in many other systems [24], IoT is here integrated as a connected mean of tracking products with the purpose of renewing customers' confidence in products [25].

Also, this system is equipped with radio frequency identification (RFID). Along with IoT, RFID helps to identify packages by using electromagnetic fields to identify tags attached to any package which contains stored data. This type of identification is more effective for parts that use pallets, trucks, forklifts or boxes level storage and delivery. However, it will be less useful for the final consumer, especially if the packages contain several products to be dispatched to other final consumers item by item. In this case, an additional linked identifier is needed in every product and not the whole package.

Researchers, industrials and managers have taken a very strong interest in the use of IoT technologies together with RFID for package identification and QRcode for product identification. Due to its faster readability using a camera or personal digital assistant (PDA), larger storage capacity as identifiers and reasonable expenses, QRcode becomes more and more approved and popular with the supply chain [26].

Technically, by reading tag/code, the RFID and QRCode identify the package and the product. RFID and QRCode can be separated from the IoT architecture. However, the current architecture merges those identifiers with IoT sensing devices to make data more centralized. Based on urban freight specific needs as discussed in the previous section, temperature sensors, vibration detector, and GPS chip can be added to the IoT devices to collect environment data and send it to a third part service via a gateway. The system requirement needs to allow the functionality to meet the customer needs and maintenance costs.

- Quality evaluation & environment change control. The system collects environment changes from a group of sensors linked to the IoT device that can even monitor temperature and vibration, and GPS to evaluate the quality and safety of the products.
- Wireless communication. The device exchanges data with a gateway via wireless communication
- The device sends time/sensor information (including unusual events) for a gateway.
- Information services. The data needs to be presented to any player in the chain via services to be used for strategic purposes or to track down the sources and the storage and delivery conditions.

As proposed in Figure 1 the architecture is based on temperature, humidity, light, and vibration sensors and GPS. This device records parameters and details about the transported packages at real-time.

The device is planned to be in a box inside the transport compartment as close as possible to the transported package, the device will have the following components:

- Raspberry Pi 4 Model B: a small single-board computer, uses a 1.5 GHz 64-bit quad-core ARM Cortex-A72 processor and enough connection ports to support sensors.
- Temperature Sensor: records temperature in the form of resistance value using a thermistor. The Arduino Uno converts the measured voltage by the input pin to the real value of temperature in °C. The measurement is expected to vary between -40 to 125 °C with an approximated error of 1.5 °C.
- Light Sensor: This sensor uses a light-dependent photo-resistor that detects light and which resistance decreases when light intensity increases.
- Humidity Sensor: The humidity sensor uses capacities measurement to determine the amount of moisture in the air.
- Vibration Sensor: To detect vibration, the device uses an Accelerometer. Also, a piezoelectric sensor could be adopted for more accuracy.
- 3G modem: Ensure connectivity to the server to get the configuration and send the data.
- RFID: RFID RC522 tag writer and RFID TAG.

In the proposed architecture, each transport vehicle or package will have a pre-installed box to monitor various metrics highlighted by the logistics service agreement between various players.

The critical values for these metrics change depending on the transported goods. For example, for tracking fish transportation, the temperature is crucial, but not vibration. Also, for drug transportation, the vibration and the temperature both are crucial. Those configurations are selected and highlighted by the logistics service agreement. For urban areas and rural areas, this configuration can have a time interval. It can have additional cases such as time intervals for ocean freight or air freight. Once a vehicle is assigned to carry a package, the Raspberry Pi should be configured appropriately. The configuration sets the identifier in the RFID tag and runs the sensor. The Raspberry Pi is then programmed to perform the Figure 2 algorithm.

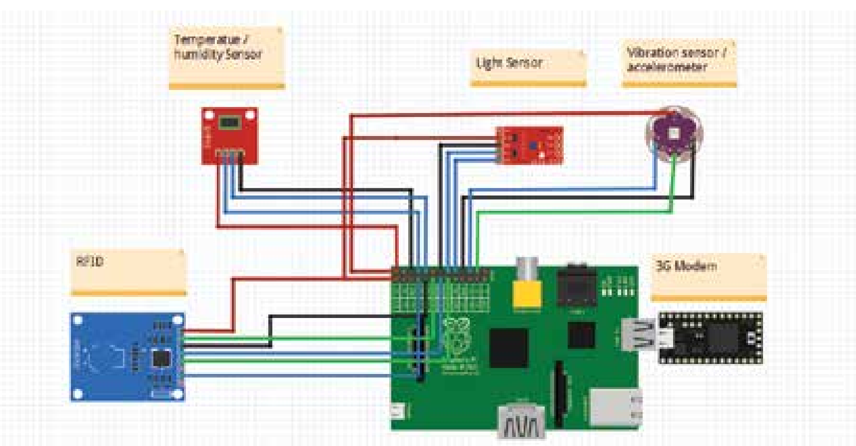

Figure 1. IoT diagram of printed circuit with all modules of tracking system

The device is programmed to get the current thresholds for warnings and alerts from the server while monitoring all sensors and sends their data to the server based on a time interval (urban and/or rural areas). When a sensor's value exceeds the configured threshold, a message (with all sensing data) is sent to the server with the corresponding gravity (info, warning, or alert). In case of weak/missed mobile network connectivity, IoT data collected are stored locally to be sent once the device connected.

Blockchain service is a transparent and secure information storage and transmission technology. The first blockchain appeared in 2008 with the advent of digital currency "bitcoin", developed by a nameless programmer known as Satoshi Nakamoto. Blockchain operates without a central control unit, allowing each of its users to check the validity of all information including new ones. Exchanges are recorded and grouped at regular intervals in transaction blocks which are linked together and form unique and tamper-proof chains of information. It consists of a database shared by its different users, which contains the history of all the exchanges made between these users since its creation. The data in each block is protected and cannot, therefore, be modified or altered after each fact, unless the whole network agrees. The ledger is made up of a set of blocks. Each block contains two parts. The first part represents the body of the block and contains the transactions that the database must record. The nature of the transactions can be any useful data, it can be monetary transactions, medical data, industrial information, system logs,. The second part is the block header. It contains information concerning the block such as the timestamp, the transaction hash,. As well as the hash of the previous block. As a result, all the existing blocks form a chain of linked and ordered blocks. The longer the chain is, the more difficult the falsification can happen. If a malicious user wants to modify or exchange a transaction on a block, he must modify all the following blocks, since they are linked by their hashes. But also, it must change the version of the blockchain that each participating object stores. Figure 3 illustrates a simplified example of a blockchain.

To prove the honest validation of a block, there are many validation mechanisms. The most used are the proof of work (PoW) mechanism and the proof of stake (PoS) mechanism. Also, when the validator of a new block needs to be a real entity in the system. proof of authority (PoA). proof of elapsed time (PoET) can be used for reducing

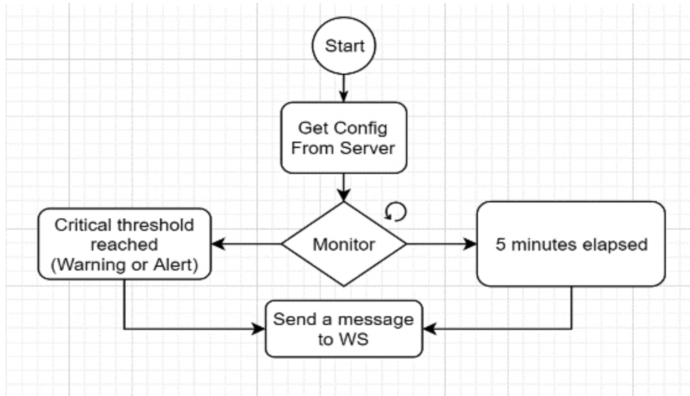

Figure 2. Diagram of the algorithm used in the IoT devices

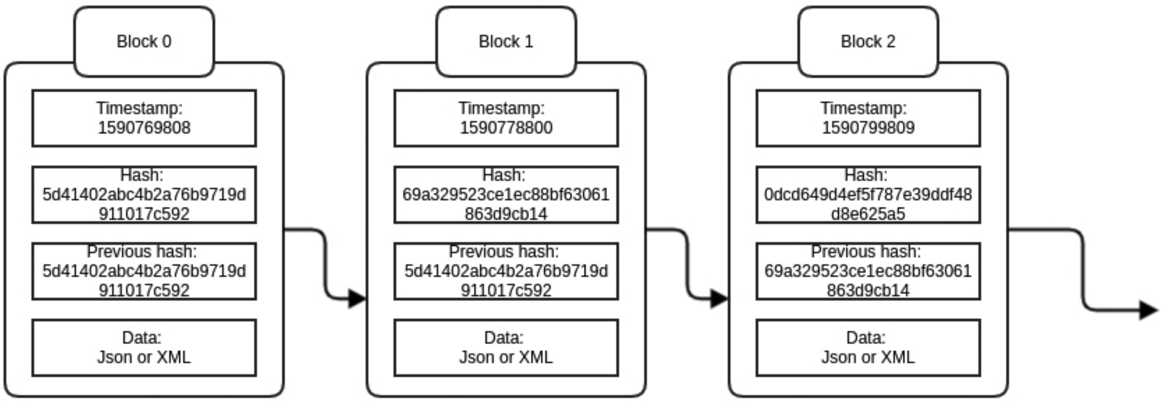

Figure 3. Modelization of data structure in the blockchain

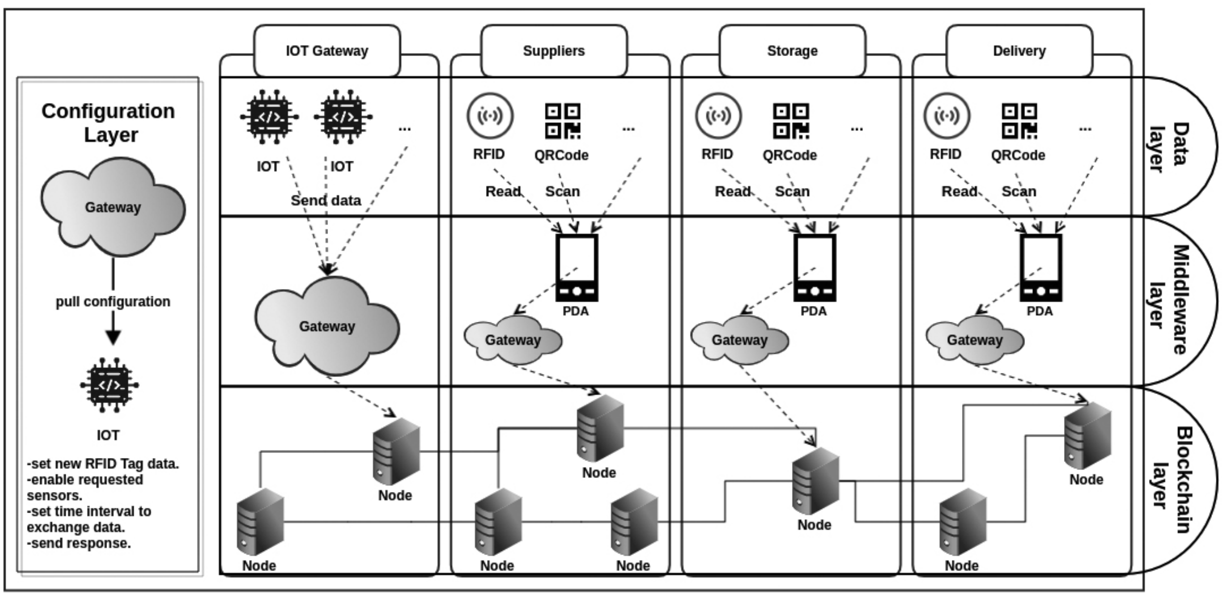

Figure 4. System architecture based on blockchain and IoT

time and resource consumption [27].

Recently, several agriculture, fresh food applications and researches, use Blockchain in order to ensure data trust and data immutability. In every system that carries Blockchain, it guarantees interaction with all players (by role) and authorization, and reduces costs of creation inspection for specific accidents like food contamination for example [28]. When Blockchain is used in logistics, it helps to track the product origin, identify products who may be contaminated, and decrease the paperwork process [15]. Blockchain applications can also be used for product traceability by providing product history for suppliers and retailers. In this way, the origin and the quality of the product can be verified [29]. As mentioned before, unverified claims, deliberate fraud, or false data are, among others, issues in the logistics industry especially when it comes to information safety. Thus, to prevent any kind of change in data, a blockchain can assure the data integrity. The proposed module is a multi-criteria traceability architecture based on blockchain and IOT. It consists of 5 layers.

Configuration layer: It refers to corresponding IoT devices. With the IoT Gateway sending data. This layer provides information about which sensors to be enabled and also to set RFID data for the device. The IoT Gateway on the other hand can keep a heartbeat token related to the device (with a keep-alive interval and different time interval between the urban area and rural area to detect if there is any sort of connection loss, specifically out of coverage area. Table 1 resume a sample of data sent to the IoT sensor.

Data layer: This part provides the data to share with other parties. The RFID and the QR code are used for physical examination. They give a tag that identifies the package. However, the data provided with IoT devices are more complex. It consists of measurements and units for each sensor. Table 2 present a sample of the json data receive from the Iot to the gateway with the details captured by the sensors.

Table 1. Configuration to describe the sensors and intervals to set for the device

Configuration data example
{tag: "MA000031", timeinterval:10, // minutes urban_timeinterval:2, //minutes data: { vibration: true, temperature: true, humidity: true, light: false, geodata: true} }}

Middleware layer: to collect events and change the status of the package, the system needs to be able to interact with the previous layer. Each player in the system can visualize package history or using a PDA or RFID/QR code scanner. Once the scan is completed, the data is sent to the internal gateway. The IoT gateway also receives the data from the devices with the collected/cached data. This data can be formatted, organized, or cleaned by the gateway.

Table 2. Data to be sent by the IoT to gateway

Data provided by the device

{ device: 132, timestamp: 1588265146,
tag: "MA000031",
data: {
vibration: "124Hz",
temperature: "33C",
humidity: "12%",
light: "120lux",
geodata: {
latitude: "33.6764062",
longitude: "-7.3840738" }
}}

Blockchain layer: To have a distributed database that can store all status for a package during all stages, it surely needs to be available for each player in the system. This layer ensures a peer-to-peer connection between each node of the network to exchange data. The supplier, storage and delivery nodes can only change the status of the package (by adding a new block to the chain referencing the package tag) in order to identify transactions status (in transit/pick up/undelivered/delivered/expired). Without changing any sensing data, the blockchain can manage data by using proof of authority (PoA) algorithm for validation in the network.

On the other hand, the IoT Gateway node is the only node that can add sensing data to the blockchain network using the data received from devices through the gateway. The gateway can set or change the status of the package in the system (Info, Alert, Warning, and Not Connected). The Figure 4 explains the integration ond communication with differents componenets and layer in the proposed approach.

The IoT devices receives configuration via the gateway as first, the configuration as showen previously, can have several information about what sensors the enable and the specification for urban area. The device can be connected to a gateway in a midlware stage, it can also have a PDA as an input into the gateway besides the IoT devices. In this layer in the propsed approach the main goal is to prepare, filter data, and make an input node to the blockchain network.

Services layer: stakeholders or players need to be notified of any change to make management decisions, statistics and creating a dashboard. However, to perform any of management actions, the data in the blockchain layer needs to be available via services. It is that service which identifies the product and each data related to it. Also, there are other collaborators such as the final customer and authority party who need to have custom access to the network data (transit status, product quality, GPS location), via services such as open data [17], or web services. Figure 5 describe the interaction of the service layer with open data platform. The goal is to make a suitable response to each collaborator, with the concerned information and to assure an integrity and security for the information. Whatever nature the data to be shared, the open data will control the authority of the request before filtering and prepare the response.

3. Comparison and results

Since the advent of Internet of Things in 1999 [30], many applications have been proposed, notably in smart logistics. IoT

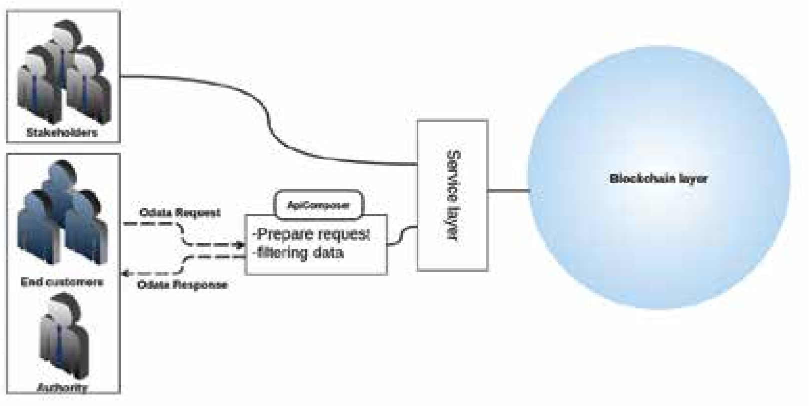

Figure 5. Schema of interaction with users and service layer with open data extension

applications in supply chain management, as suggested in the literature review, the utilization of IoT along with both RFID/QR and Blockchain has not been examined in substance. However, most blockchain-enabled solutions, even significant, are limited in scope and applicability. In [1] the author presented the evolution process of logistics and made emphasis on the fourth innovation of logistics being Internet of Thing and Service. Along with Mechanization first, Automation second and management third, the last generation of logistics relay on many technologies and technical components such as Automatic Identification, Real-time Location, Smart Sensing, Networking, Data analying and Internet of business service. This study underlines two cases of Logistics 4.0. The first, related to the function of identification, describes the intelligent and integrated RFID (II-RFID) System architecture (assest level, data acquisition level, control level, database level, decision support level and management level). Whereas, the second consists on a a real time location system.

Compared with these solutions, the logistics tracking system, as previously introduced, is a pure and simple logistics 4.0 platforms with enhanced security. In fact, by adopting a blockchain layer along with RFID technology, the tracking system increases the security aspect of the device and the integrity of collected data. The blockchain allows uniquely the addition of new approved blocks to the chain, constitutes a distributed and inviolable database with all packages' status and ensures peer-to-peer connection in order to exchange data. However, regarding the second application of the same study, the Real Time Location System introduces by K.Wong [1] consists of building production workshop or other area in order to automatically identify and track objects or people. This workshop uses Wireless RFID tags attached to objects or worm by people and fixed to reference points. Instead, Logistics tracking system based on decentralized IoT/blockchain platform includes GPS chip capable of determination of geographic coordinate and precise location with queuing system in critical cases (weak GPS signal and weak 3G). Also this system takes into consideration urban specifications and gives possibility to adjust frequency of data collecting and transfer depending on ongoing environment. This project is not only an intelligent and integrated with RFID, but a secured one as well.

Another project to consider is the Chinese Ministry of science and internet of things solution for food safety and quality control [24]. This project initiates internet of agricultural things (AIoT) which architecture is composed of data access and transmission layers, application service platform, application module layer and User application. AIot project lunched since 2011 over six Chinese universities and institues after several serious food safety incidents provides a method to easily track and trace food supply chain. By combining both global identification and parsing along with electronic pedigree, this project helps users and consumers to evaluate food quality. Once again the integrity of collected data can be compromised given its stakes, hence the need of blockchain implementation. Also the last project appears to be dedicated only to agricultural products and needs to be expanded to all types of supply chains.

Last but not least, H. Tran-Dang *et al*. [31] has modelled food supply chain (FSC) traceability using blockchain technology and smart contracts. The use of blockchain is justified to overcome obstacles to traditional FSC traceability mechanisms, such as lack of security, information sharing, and systems integration difficulties. Furthermore, in order to increase visibility and interaction with all actors of the supply chain, this architecture could have integrated an open data solution. In fact, as presented before, in order to make management decisions, statistics and dashboards, stakeholders need to access to all data at any time and place. Also, authorities and consumers need to know product details and supply chain conditions to check the conformity to requirements and decide whether to purchase it or not.

Compared to the above solutions, our Logistics tracking system based on decentralized IoT/blockchain platform differs in the following aspects:

- The current solution is a blockchain based platform for more security and integrity of data
- This platform consists of on RFID or QRCode rapid authentification
- Is consists of a hybrid modelling with a large applicability to almost all types of chains
- This model takes into account urban environment with specific requirements
- an open solution available for all players since it implements an open data

4. Conclusion

Real-time and multi-criteria tracking are important not only to make supply chain management more effective but also to ensure package safety and quality. This

This platform can be used by any type of logistics such as hospitals and cold logistics to prevent falsified and wrong data. It can help improve the quality of service and detect damaged products. The current model can be improved by ensuring a better identification between the IoT devices and the IoT-gateway

paper has proposed a decentralized IOT/blockchain-based platform with multi-sensors and RFID & QRcode technologies to simplify the interaction between stakeholders and packages while in transit. Data relative to temperature, light, humidity, vibration, and geo-position is the main data to be exchanged in the platform. However, the platform can be extended to carry other data by adding new sensors to IoT devices such as weight sensors for fragile packages. An open data API is proposed as well to give to the end customer access to the history of the product using the QRcode. This platform can be used by any type of logistics such as hospitals and cold logistics to prevent falsified and wrong data. It can help improve the quality of service and detect damaged products. The current model can be improved by ensuring a better identification between the IoT devices and the IoT-gateway. The validation in the blockchain layer can be changed based on the need or the product type. Also, securing the communication between the IoT and changing the communication protocol can be a subject to improve, besides merging the node to a cloud solution. However, the same architecture can be remaining. Some limitations of the proposed traceability model should be kept in mind such as the possible lack of network coverage particularly with long supply chains (in air planes and ships) This limitation must delay the data transfer until the network is restored. Also, blockchain is not suitable for storage of vast amount of data and most Blockchain based models suffer from lack of scalability. In addition, each components inherent some limitations, such as IoT reliability on battery or other power source.

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Analysis of factors affecting industrial site selection in Hawassa town, Ethiopia

Nine determining parameters identified in this study to identify suitable site for the industrial establishment

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Abstract

The significance of GIS and Remote Sensing techniques and technologies currently in every aspect of human beings day-to-day activities initiated the researcher to conduct this study. Industry is important to enhance the economic level of a given country and GIS and remote sensing technologies would provide a variety of options during site selection process. The overall objective of the study is to identify suitable industrial site location by using Geographic Information System and Remote Sensing based analysis in Southern Nations, Nationalities and Peoples Regional State, Hawassa town. In order to conduct this study, multi criteria evaluation system to identify factors influence during site selection by pair-wise comparison matrix was employed. Nine determining factors/parameters identified in this study to identify suitable site for the industrial establishment. These factors are slope, land use land cover, soil types, distance from geological faults, and proximity to main road, distance from residential area and distance from water bodies. The findings revealed that land use land cover factors and distance from geological faults highly determines the selection for industrial sites; and elevation and slope determines minimum compared with other factors. Majority of the study area (47.5%) is suitable to establish industries and a small portion (0.2%) are less suitable. Conducting environmental impact assessment prior to establishing industries in the study area was not fully covered by the concerned government organization. Application of GIS and Remote Sensing technologies in the study area is not fully employed. In order to select suitable sites for the industry, the town administrators should focus on those important parameters by using Geographic Information System and Remote Sensing technologies.

Introduction

Principally in developing countries of big cities, a number of directors took the initial step of creating special regions for industry, essentially to isolate them from heavily populated or affected areas. Government agencies, in charge of regulating the industry site selection commenced considering the inclusion of environmental criteria in the selection process as a measure to lessen potential environmental impacts to local communities. In the past, site selection based almost purely on commercial and technical criteria. Today, a higher degree of refinement is expected. Selection criteria must also meet a number of social and environmental elements, which enforced by law and government regulations [1]. GIS is an efficacious tool for the management and analysis of data required for any land development activity [2]. GIS system has the ability of display needed in the context of decision-making. A set of tools been used to manage the proper site for a city improvement facility, including GIS, and Multi-Criteria Decision Making (MCDM) techniques [3].

Industrial site selection is critical point in the process of starting, expanding or changing the location of industrial systems of all kinds. One of the main objectives in industrial site selection is finding the most appropriate site with desired conditions defined by the selection criteria. In a site selection process, the analyst strives to determine the optimum location that would satisfy the selection criteria. The selection process attempts to optimize a number of objectives desired for a specific facility. Such optimization often involves numerous decision factors, which are frequently contradicting, and the process often involves a number of possible sites each has advantages and limitations. Decision-making is based on numerous data concerning the problem of selection appropriate site. Decisions about industrial location typically involve the evaluation of multiple criteria according to several, often conflicting, objectives. While many decisions we make prompted by a single objective [4].

The principles of liberalization, globalization and privatization and the relative changes at the global economy have been very important for the industrial zones development. Most of the countries use this tool for development of industrial field with minimizing its negative impacts on people and the environment. This has been very important as a better environ-mental management tool used for sustainable development of the industrial sector. The best location for the industrial zone is the key factor of the accomplishment of its main objectives, which are the requirement of all facilities and the minimum of social and environmental negative impacts [5].

Site selection of industrial zones in a given area has become a critical issue and a sensitive decision making process that may create a range of socioeconomic and environmental problems over-time. Hence, several site selection criteria and appropriate methods for establishing industries have to be concerned by the decision makers and authorities before locating industrial zones in particular regions. However, at present the enormous data volume and complex criteria regarding this field are available, the suitable site selection process is still problematic [6].

Site selection is one of the primary decisions in the start-up process and town planning, development or relocation of industries of all kinds. Building of a new industrial system is related with long-term investment, and in this sense planning the site are a significant point on the road to progress or failure of the industrial system and that effect on all other services in the city. One of the main objectives in industrial site selection is finding the most suitable site with required conditions. A large number of researchers depend on GIS because of its availability and its wide uses in site selection process. GIS used in combination with other systems and methods such as the method for multi-criteria decision-making (MCDM). Multi-criteria decision analysis (MCDA) techniques used in such conditions to classify and rank options for subsequent complete evaluation, or to specify acceptable from unacceptable potentiality for many sites [7].

This article focused on how to apply GIS based analysis to select industrial sites in Southern Ethiopia, Hawassa town. Site selection with minimum impacts is very difficult to achieve considering criteria one by one, because of the big list of criteria including very important spatial factors. Still in Hawassa town, this process conducted, as politicians need. In this study, the researcher considered the criteria that need to be undertaken before establishing industrial zones in Hawassa town. That is the one of major significance of this study. The GIS based analysis was developed in a research that can be used for everywhere to get very accurate steps for site selection process. It is very important especially for the sustainable development of industrial field. Therefore, this paper assumes that, in some extent, such failures can be overcome by applying Geographic Information System (GIS) and Multi-criteria Decision Making Techniques into the site selection process of industrial zones. In this study, a GIS and Remote Sensing based analysis applied to screen most suitable locations for establishing Industrial Zones in Hawassa town.

Literature review

Concepts related with industrial site selection

Site selection

Site selection is one of the basic vital decisions in the start-up process, expansion or relocation of businesses of all kinds. Construction of a new industrial system is a major long-term investment, and in this sense, determining the location is critical point on the road to success or failure of industrial system. One of the main objectives in industrial site selection is finding the most appropriate site with desired conditions defined by the selection criteria. Most of the data used by managers and decision makers in industrial site selection are geographical which means that industrial site selection process is spatial decision problem. Such studies are becoming more and more common, due to the availability of the Geographic Information Systems (GIS) with user-friendly interfaces. Geographic information systems (GIS) are powerful tool for spatial analysis which provides functionality to capture, store, query, analyze, display and output geographic information. Geographic Information Systems are used in conjunction with other systems and methods such as systems for decision-making and the method for multi-criteria decision-making (MCDM) [8].

Site selection process

In the past, site selection was based almost purely on economic and technical criteria. Today, a higher degree of sophistication is expected. Selection criteria must also satisfy a number of social and environmental requirements, which are enforced by legislations and government regulations. The process selection of industrial site means complex multi-criteria analysis that includes a complex array of factors involving economic, social, technical, environmental and political issues that may result in conflicting objectives [9].

Nowadays, in the post-industrial society and knowledge-based society, people become the most important resource. Proximity to universities and scientific institutions, number of innovation per citizen can be one of the key factors for decision makers. All so risk management is an indispensable analysis in site selection process. Managing the risks involved in selecting a new industrial location is one of the most critical factors in determining the ultimate success or failure of a business. To keep risks at a minimum, investors should first be familiar with the stages of the site selection process. In addition, they must consider the key risks that need to be considered and managed during each of these stages [10].

One of the most important and far-reaching decisions faced by operations managers is deciding where to locate new industrial facilities. This is a strategic decision involving irreversible allocation of the firm's capital, and often has a crucial impact on key measures of the firm's supply chain performance such as lead-time, inventory, and responsiveness to demand variability, flexibility, and quality [11].

Collection of information allows the generation of a potential industrial sites that can be grouped, while the use of certain term criteria, through several iterations, gradually narrowing to a choice. In such way, the total number of available sites, the customer is aware of a certain number of them. Of these, only a certain number of locations meet the selection criteria of the decision maker, so that makes group of sites for consideration. By collecting information on these sites, it remains just making a group of sites that are included in the shortlist. Out of this group, based on the criteria used by the decision maker (investor) chooses one location [12].

Factors that are determining industrial site selection

In the past, site selection was based almost purely on economic and technical criteria. However, currently, a higher degree of sophistication is expected. Selection criteria must also satisfy a number of social and environmental requirements. Selection of industrial site means complex multi-criteria analysis, which includes a complex array of factors involving economic, social, technical, environmental and political issues that may result in conflicting objectives [13].

According to USAID research conducted on Serbia, the following points are important criteria to select industrial location. These are, labor costs, geographic position, availability of a quality workforce, transport infrastructure availability of raw materials, licensing and permitting procedures for the land and telecommunication infrastructure. Efficiency of local authorities, availability and cost of business premises, references from local partners and previous experience, cost of construction land, availability of construction land, and level of political interference in business and ecology utility costs accommodations are also determining factors [14].

As it was stated above, in Serbia, industrial sites were not selected as simply and only vacant land availability is not enough to establish industry. Different accessibilities have to exist in the area in which industry located. Besides, to physical factors that determining site selection, government commitment and security issues were also highly determining private investors to invest in the given area. In addition, previous experience of industrial establishment is also one of criteria to select industrial sites, which is important to take a lesson in order to identify failures and achievements. This would help the newly establishing industry from being stagnant and failure. Therefore, a given administration has to desire a specific criterion that ensures environmental, social wellbeing and security issues of the communities during industrial site selection phases.

Description of the study area and research methods

Description of the study area

Hawassa town is the capital city of the Southern Nations, Nationalities, and Peoples' Region, and is a capital city of Sidama Zone. Its geographical location is between 6055'30" to 7°5'15" and 38023'15" to 38°38'15"E with an elevation of 1708 meters above sea level. It is located 273 km South of Addis Ababa via Bishoftu, 130 km East of Soddo, and 75 km North of Dilla [15].

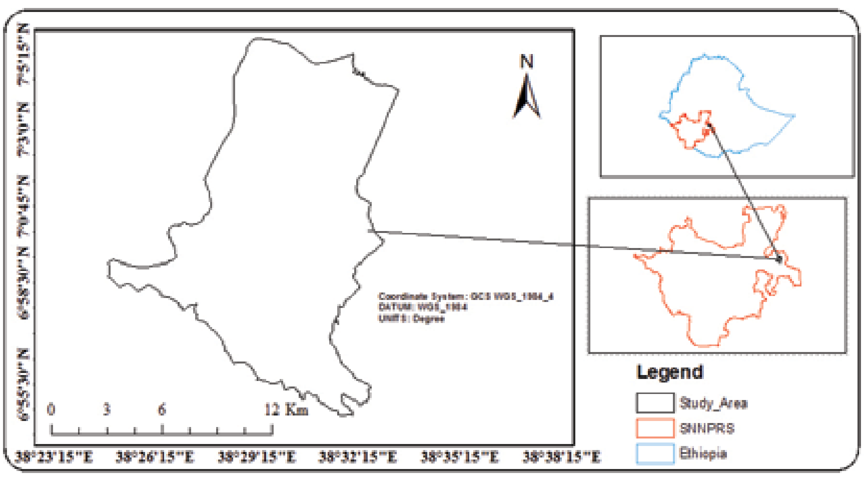

Figure 1: Location map of the study area

Research methods

Data collection

Both primary and secondary data were used for the industrial site mapping of the study area, which were obtained from field survey and concerned institutions. The data and materials used include satellite imagery Landsat8), climatic data (rainfall and temperature), Digital Elevation Model (DEM) 30 m resolution data, soil map and industrial data of the study area.

Table 1: Types of data used for this study

Types of data	Source of data
Land Sat8 image	Google Earth USGS
DEM Data	Google Earth (ASTER)
Rainfall and Temperature Data	National Metrology Agency of Ethiopia(2019)
Study Area boundary shape file data	ArcGIS DIVA
Ground Control Points	Field Survey and Google Earth Pro
Soil Map	Ministry of Agriculture (FAO, 2006)
Industrial related data	Hawassa town Industry Department
Geology data	extracted from Google earth

Source: Compiled by the Researcher, 2021

Software and material applied in this study

Table 2: Software and material applied in this study

Software	The Purpose why they have been applied
ArcMap 10.8	Reclassification of factors, weighted overlays, etc.
ERDAS IMAGINE 2015	Land use land cover classification and for accuracy assessment
ENVI 5.3	Land use land cover image classification for accuracy assessment
GPS	For collection of ground control points
IDRIS SELVA 17.0	For pair wise comparison/overweight analysis

Source: Compiled by the Researcher, 2021

Suitability requirements rating for the selected factors

Table 3: Suitability requirements rating for the selected factors in the study area

Parameters	Units	Suitability Range				
		Unsuitable(1)	Less-suitable(2)	Moderately suitable(3)	Suitable(4)	Most suitable(5)
LULC classes	type	Settlement	recreation	Business site	shrub land	Vacant land
Soil type	type	Eutric vertisol	Chromic luvisol	haplic luvisol	Fabric histosol	Eutric fluvisol
Distance from geological fault	meter	0-2000	2001- 4000	4001- 10000	>1000	-
Distance from lake	meter	0-200	201 -500	501-1000	1001-10000	-
Distance from river	meter	0-250	251-500	501- 1000	1001-2000	>2000
Distance from swamp	meter	0-250	251-500	501- 1000	1001-2000	>2000
slope	%	0-6	7-10	11-15	15-20	>2-0
Distance from residential area	meter	0-1000	1001-1500	1501-3000	3001-6000	>6000
Proximity to road	meter	0-300	301-500	501-3000	3001-5000	>5000

Source: Compiled by the Researcher, 2021

Data analysis methods for the study

Topographic factor (Slope)

Slope map of the study area was generated from ASTER GLOBAL 30 meter resolution Digital Elevation Model. Then, the slope map was reclassified based on suitability of the slope for industry sites by using spatial analyst tools in Arc GIS. When the degree of slope becomes high, site suitability becomes less. The slope is classified in to five degrees as: 0 - 6%, 6 - 10%, 10 - 15%, and 15 - 20% and >20% and assigned new values as 5, 4, 3, 2, and 1 respectively [16]. Slope based industrial suitability level is described as Most suitable, suitable, moderately suitable, Less suitable and Unsuitable, respectively.

Proximity to water bodies

Proximity to lakes

Proximity to lakes map is generated and reclassified in Arc GIS by using ring buffer distance calculation in spatial analyst tools. New values were assigned for regions located within 0 – 200 meter, 201 - 500m, 501 – 1000 m, 1001 – 10000 m, and above 10,000m [16]. The study area reclassified as unsuitable, less suitable, moderately suitable and suitable. The reason why most suitable criterion rejected is about its range is out of the study area boundary.

Proximity to rivers

Traditionally, industrial land is located along rivers and canals because of its

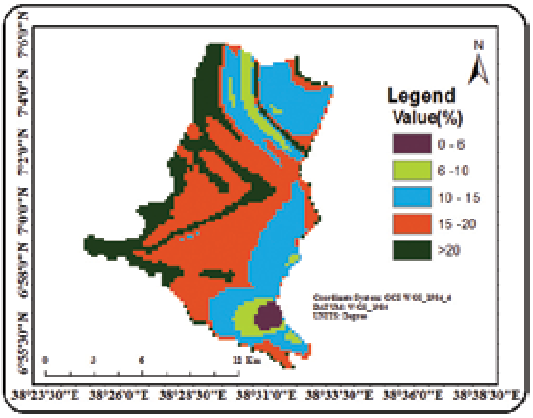

Figure 2: Slope map of the study area

proximity to inexpensive hydropower [17]. Sites overlapping or adjacent to these areas pose greater insurance costs and risk potential flooding, requiring expensive flood mitigation strategies like barriers and retaining walls. Therefore, development within river zones is an unattractive characteristic and considered an industrial location constraint.

The river through Tikur Woha and Wosha River the way to Wondegenet was digitized from Google earth. The map showing proximity to rivers is generated by using ring buffer distance in spatial analyst tools of Arc Map from digitized rivers and canals. The reclassification of rivers map is based on suitability criteria. Areas found 0- 250 m, 250 – 500 m, 500 – 1000 m, 1000 – 2000 m and above 2000 m from rivers. The assigned new values as 1, 2, 3, 4 and 5 and classified as unsuitable, less suitable, moderately suitable, suitable and most suitable, respectively.

Proximity to swamps

As it mentioned above, swamps digitized from shapefile data obtained from [18] and the map generated in ArcMap 10.3.1 environment by using ring buffer distance calculation. The reclassification done based on industrial site selection criteria. New values were assigned for regions located within 0 – 200 meter, 200 - 500m, 500 – 1000 m, 1000 – 2000 m and above 2000m. The assigned new values were 1, 2, 3, 4 and 5.

Land use land cover factor

Land use situation with regard to different environmental effects and the condition of industrial establishment is very important. Forest and farming lands should not change to industrial land use and only a negligible damage to the plant cover can be allowed. Undersigned, in boundary, open space and free lands is preferable [19]. The reclassification was done because of industrial site selection criteria. New values were assigned for regions located within forest and water bodies are restricted it does not be represented with value whereas, settlements assigned as new value 1, recreation center as 2, business sites as 3, shrub lands as 4 and vacant land as 5. Then reclassified as unsuitable, less suitable, moderately suitable, suitable and most suitable, respectively.

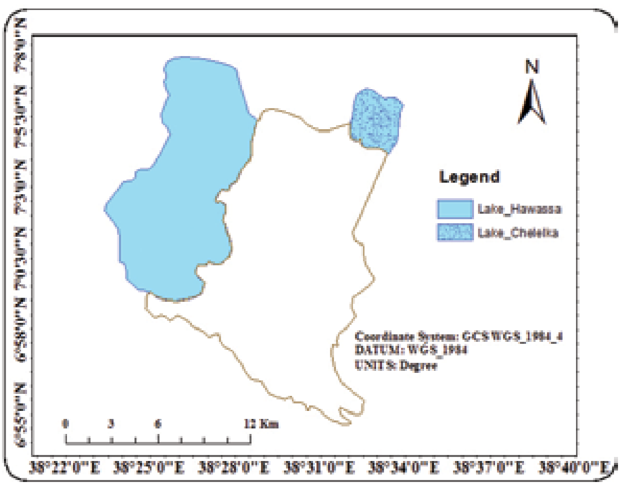

Figure 3: Proximity to lake

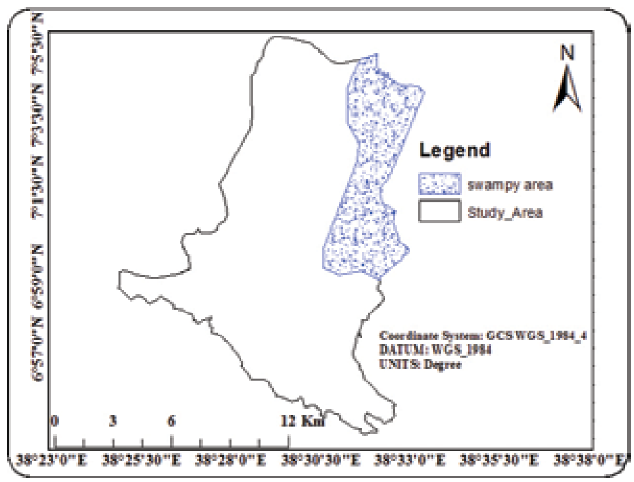

Figure 5: Swamp map of the study area

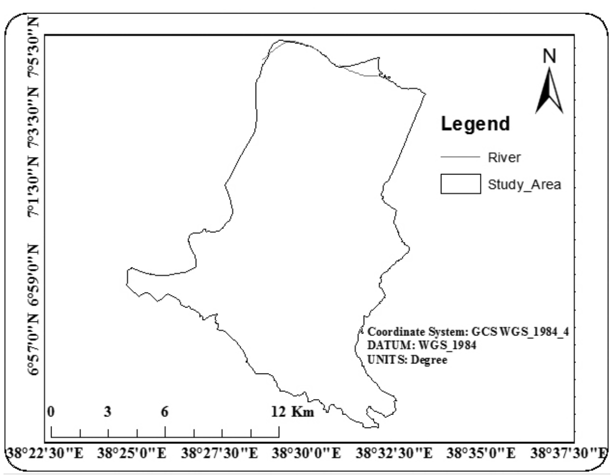

Figure 4: Proximity from river

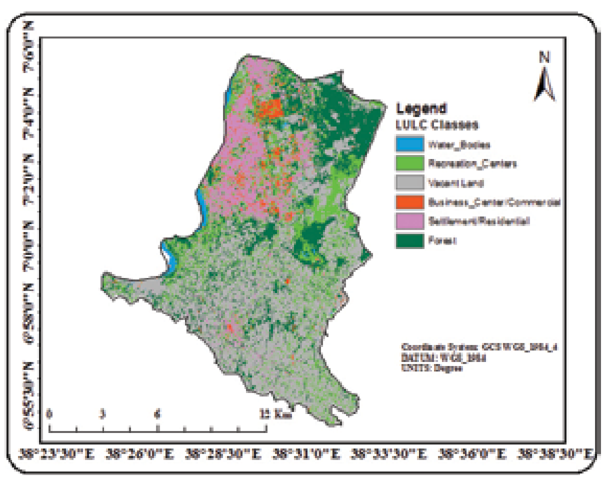

Figure 6: Land use land cover map of the study area

Road network

Roads and other infrastructures that facilitate different cities and regions connection are very important in industrial site selection. According to the data obtained [16] industries needs transport facility and therefore its establishment should be near to the road. The reclassification was done based on industrial site selection criteria. New values were assigned for regions located within 300 meter as 5, 301 – 500 meter as 4, 501 m – 1000 meter as 3, 1001 - 5000 meter as 2 and above 5000 meter as 1.

Residential area factor

The reclassification was done because of industrial site selection criteria. New values were assigned for regions located within 1000 meter as 1, 1000 – 1500 meter as 2, 1500 m – 3000 meter as 3, 3000 – 6000 meter as 4 and above 6000 meter as 5. Then, the newly reclassified value represented as unsuitable, less suitable, moderately suitable, suitable and most suitable respectively.

Geological fault factor

Hawassa town has a volcanic origin. It was formed due to intensive tectonic activity. This tectonic activity is a direct result of the Main Ethiopian Rift valley. The geology of the Awassa area consist of different volcanic deposits such as alkaline and peralkaline rocks Late Miocene, Basaltic lava flows from Pleistocene to recent, Acidic volcanics from Pleistocene to recent, and Volcano clastic lacustrine sediments from Pleistocene to recent [20].

Distance to geological fault is one of the hindering factors for industrial site selection. The more far away from this event is the better. The map of fault distribution was constructed from geological maps. The geological fault zones of the study area were digitized from Google Earth pro and converted to the shapefile data format in order to undertake further analysis. The reclassification was done on the basis of industrial site selection criteria. New values were assigned for regions located within 2,000 meter as 1, 2,001 – 4,000 meter as 2, 4001 m – 10,000 meter as 4, and above 10,000 meter as 5. Then, the newly reclassified value represented as unsuitable, less suitable, suitable and most suitable respectively.

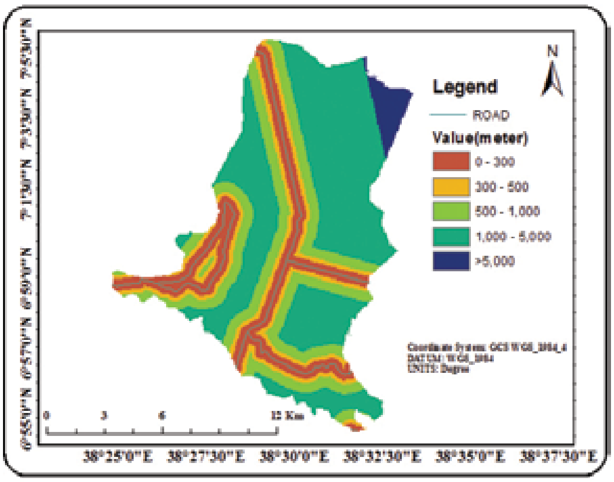

Figure 7: Road network of the study area

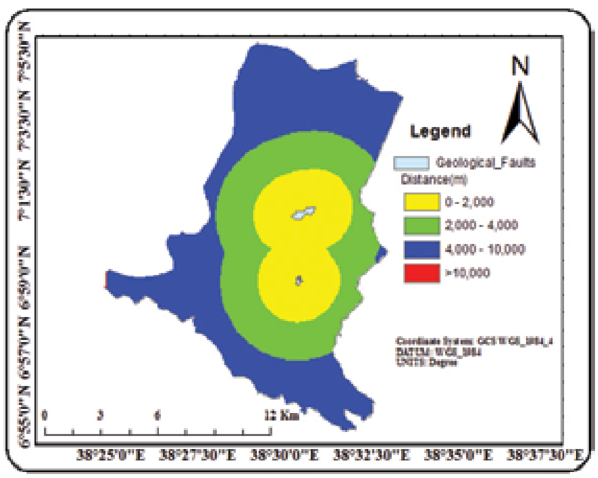

Figure 9: Map of distance from geological fault of the study area

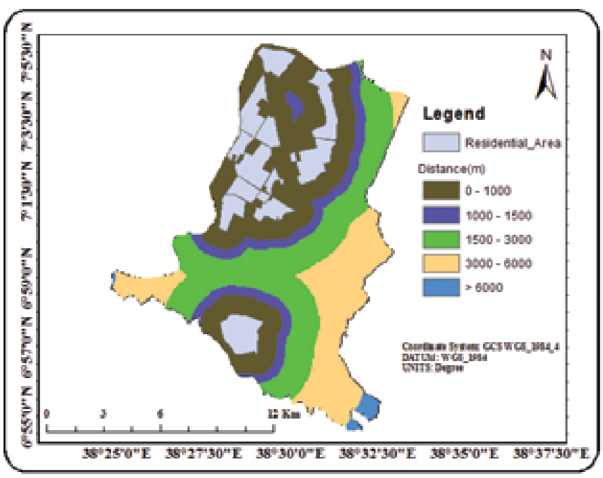

Figure 8: Residential area map of the study area

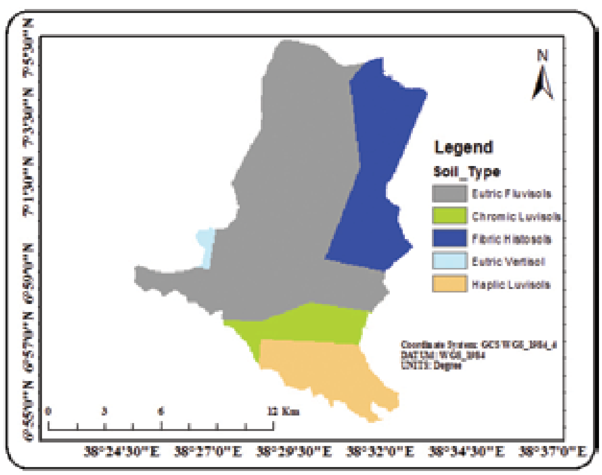

Figure 10: soil type map of the study area

Soil factor

According to [21], those soils with clay, alluvial and loam deposits are suitable for industrial establishment, whereas soils with cracking, swelling and porous are not suitable for industrial establishment. The reclassification was done based on industrial site selection criteria. New values were assigned for regions located within eutric vertisol as 1, chromic luvisol as 2, haplic luvisol as 3, and fabric histosol as 4 and eutric fluvisol as 5. Then, the newly reclassified value represented as unsuitable, less suitable, moderately suitable, suitable and most suitable respectively.

Interview and discussion

The primary data collection was accomplished by using an interview and discussion that is one of the important social research methodologies. The discussions were held with experts of manufacturing site evaluation and implementation core work process teams in identifying industrial site selection criteria and finding out the buffer distance that the site should be separated from relevant geographic features.

Direct and indirect unstructured interviews were conducted with the experts during the field survey to gather more information. The information derived from this study was used to identify and develop priority criteria and factors for the selection of industrial site. It was also used to identify problem in the study area and prioritize the potential industrial sites in the study area. Additional discussions made particularly with those experts, who are involved in the urban land preparation of Hawassa town, in order to acquire some appreciation of the study area. In particular, the following experts working at the town Industrial and Enterprise department, Housing and Urban Development Department and finally with Regional Bureau Industry experts discussion were held. Those who were involved in the discussion were interviewed: Mr Matusala Semaye, Yaregal Debebe, Sileshi Getahun and Walelign Awashe.

Multi-Criteria Decision Making (MCDM)

This research study was mainly used spatial Multi-Criteria Decision Making (MCDM) approach integrated with Geographic Information System (GIS) techniques in order to determine suitable site for industry. Spatial multi-criteria decision-making is a process that combines and transforms geographical data into a decision (Malczewski, 1999).

MCDM, combined with GIS data, is a powerful approach systematically and comprehensively analyze a problem. The fundamental components of a multi-criteria problem are human value judgment and assessments of the importance of criteria. The main purpose of the multi-criteria evaluation techniques is to investigate a number of alternatives in the light of multiple criteria and conflicting objectives (Voogd, 1983).

To combine and determine the importance of each factor, multi-criteria decision-making method was applied.

Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is a widely used method in MCDM and introduced by [22]. It is easily implemented as one of the MCDM techniques. AHP is a decision support tool, which can be used to solve complex decision problems. It uses a multilevel hierarchical structure of objectives, criteria, sub criteria and alternatives. AHP uses a fundamental scale of absolute numbers to express individual preferences or judgment (Table 4). This scale consists of nine points. In general, nine objects are the most that an individual can simultaneously compare and consistently rank.

The score of differential scoring assumes that the row criterion is of equal or greater importance than the column criterion. The reciprocal values (1/3, 1/5, 1/7 have been used where the row criterion is less important than the column criterion. To ensure the credibility of the relative significance used, AHP also provides measures to determine inconsistency of judgments mathematically. Based on the properties of reciprocal matrices, the consistency ratio (CR) can be calculated. CR < 0.1 indicates that level of consistency in the pair wise comparison is acceptable. According to [22], if CR is smaller than 0.10, then the degree of consistency is acceptable. However, if it is larger than 0.10, then there are inconsistencies in the evaluation process, and AHP method may not yield meaningful results.

Table 5: The preference scale for pair wise comparison in AHP

Intensity of Importance	Definition and explanation
1	Equal importance: two activities contribute equally to the objective
3	Moderate importance: Experience and judgment slightly favor one activity over another.
5	Essential or strong importance: Experience and judgment strongly favor one activity over another.
7	Very strong/demonstrated importance: An activity is strongly favored and its dominance is demonstrated in practice
9	Extreme importance: The evidence favoring one activity over another is of the highest possible order of affirmation.
2, 4, 6, 8 Reciprocals of the above numbers	Intermediate values between the two adjacent judgments when compromise needed.
1/2, 1/3, 1/4., 1/5, 1/6, 1/7, 1/8 and 1/9	Reciprocal values of the previous appreciation

Source: Adopted from [22]

Results and discussions

The following factors deeply discussed in this part. These are Land use land cover types, distance from geological faults, distance from main roads, soil types, and distance from residential areas, distance from water bodies (lake, swamp and river/stream), slope and elevation.

Relation of topography (slope) and industrial sites

In this study, slope factor generated from the Digital Elevation Model (DEM) using the ArcGIS 10.3.1 spatial analyst extension of surface module, which enabled to classify the area according to the steepness and the gentleness of the terrain. Every cell in the output raster had a slope value. The lower the slope value, the flatter the terrain was and the higher the slope value the steeper was the terrain. Then the slope raster was reclassified in to five classes of slope percent by examining the value and the frequency of slope percent in the study area. The reclassified slope was given a rank value 1 to 5 with the higher value of 5 showing high influence, i.e. highly suitable, while the lower value of 1 showing low influence, least suitable. According to [16], slope with degree ranges from 0-6 considered as level slope, 6-10 degree as gentle, 10 -15 degree as strong sloppy, 15- 20 degree as moderately steep slope and > 20 degree slope as considered as steep slope). As indicated in the figure 11 below, most of (68.6%) the study area has gentle slope and 3.2% has a moderately steep slope.

The less the slope amount, the more suitable will be the area for the industry. Based on the suitability of the slope for industrial sites, the reclassified slope map shows 108.2 km² (68.6 %) area is most suitable, 23 km² (14.6%) is suitable, 11.7 km² (7.4%) is moderately suitable, 5.1 km² (3.2%) is less suitable and 9.8 km² (6.2%) unsuitable for industrial location. From the total area of the study, majority of the slope initiates public and private investors to participate on industrial sectors in which Plain areas have especial importance because of lesser costs during site preparation.

Proximity to water bodies and industrial locations

Proximity to lake

Water accessibility is one of the main affecting factors for industrial site selections. Industry must be located at some safe distance from water bodies. Water bodies and areas within 1000 meter are considered unsuitable for an industrial establishment. Wastewater from industry is one of the major sources of pollution in river distance of at least 1000m [23]. According to [16], land suitability for industrial location within proximity to lake as follows:

Table 6: Reclassified Proximity to water bodies and Suitability Level

Distance from Lake (m)	Rank	Area (km²)	Area (%)	Suitability Level
0 - 200	1	6.8	4.3	Unsuitable
200 - 500	2	8.1	5.2	Less suitable
500 - 1000	3	21.3	13.5	Moderately Suitable
1000 - 10000	4	121.2	76.8	Suitable
total		157.7	100	

Source: Extracted from Reclassified Water Body, 2021

The proximity to water bodies map is the result of overlaid proximity to Lake Hawassa and Chelelka maps. As indicated in the figure 12 below, 6.8 km2 of the total area is within 200 meter of the water bodies, 8.1km² is found between 200 meter up to 500 meter, 21.3km² is found between 500 meter up to 1000 meter, and the remaining 121.2km² found beyond 10000 meter. This implies that most parts (76.8%) of the study area are suitable, 13.5% is moderately suitable, 5.2% is less suitable, and 4.3 % is unsuitable for industrial location.

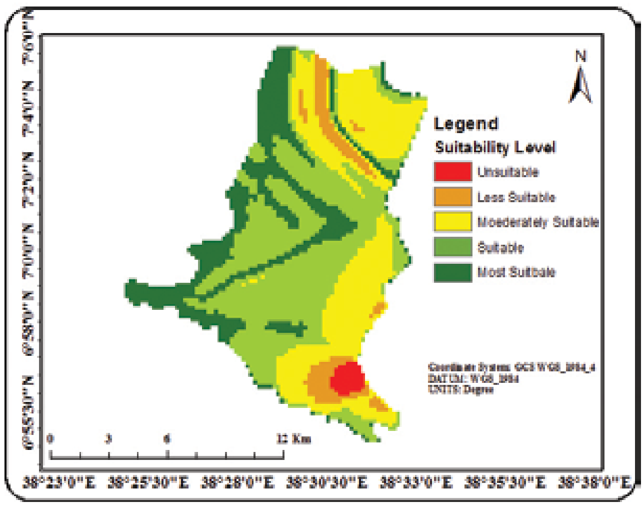

Figure 11: Suitability map of slope

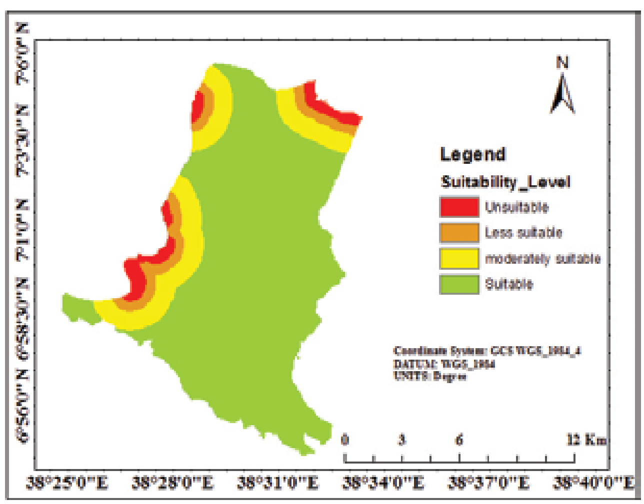

Figure 12: Lake Suitability map of the study area

Proximity to river

Both stream flow of the Wosha and Tikur Woha River, which found in North Eastern part of the study area were taken as the base line to measure the proximity. During rainy season, runoff would be high and that could disturb if there is industry near at those stream flow area. According to [24], land suitability for industrial location within proximity to river as follows: those areas up to 500 meter far from the river are unsuitable, 501 meter -1000 meter are less suitable, 1001 meter - 3000 meter are moderately suitable, 3001 meter up to 5000 meter are suitable and above 5000 meter are most suitable to establish industry.

As indicated in the figure (13) below, majority of the study area which is suitable to settle industry is 2000 meter far from the river. Those areas, which are within 1000 meter from the river, are not suitable for industrial location. The reclassified map of distance to rivers indicates that most suitable sites for industrial establishment cover 86.5 km² (54.8%). The remaining 27.7km² (17.5%) is suitable, 29.8 km² (18.9%) is moderately suitable, 5.9 km² (3.7%) is less suitable and 5.4 km² (3.3%) is unsuitable to locate industries in the study area.

Proximity to swamps

Cheleleka Swamp, which found on the way to Wendogenet gradually transformed in to a swamp around 1970, fed with around 11 perennial rivers emerging from the eastern highlands. A few decades ago, Lake Cheleleka was the second lake in the area located about five kilometers to the east of Hawassa. This lake was about 11 km long and 6 km wide, but disappeared decades ago [25], [26], [27] and [28]. The former Lake Cheleleka is now a swampy area. Swampy areas are not suitable to establish industry in a given area because they have a reputation for being unproductive land that cannot easily be utilized for human activities, other than perhaps hunting and trapping. According to [24], land suitability for industrial location within proximity to swamps as follows:

Table 7: Reclassified Proximity to Swamp and Suitability Level

Distance from Swamp (m)	Rank	Suitability Level
0 - 250	1	Unsuitable
250 - 500	2	Less suitable
500 - 1000	3	Moderately Suitable
1000 - 2000	4	Suitable
>2000	5	Most Suitable

Source: Extracted from Reclassified Swamp Value, 2021

Based on the proximity to swamps, the majority of study area is most suitable for industrial location. As described in the figure 14 below, 94.5 km² (60%) of the total area is most suitable and 34.7 km² (22%) is unsuitable to locate industry in the study area. Besides that, 3.7km² (2.3%) less suitable, 7.7km² (4.88%) is moderately suitable and 16.6km² (10.5%) is suitable to locate industries in the study area.

Land use land cover maps

Land use classification is the process of categorizing the data based on their data file values. If pixels fulfill a certain set of criteria, then the pixel is assigned to the class that corresponds to that criterion. In this study, the existing land use map was extracted from LandSat8, 2021. Based on the supervised classification done for the satellite image, the study area has seven major land use land cover types, such as recreational center, shrub lands, water body, vacant land, forest coverage, commercial or business centers and residential. Mixed type of land use is dominant, especially residential development mixed with commercial and other activities that are common in the central parts of the study area. In general, the majority (65.7 km²) of land use land cover map of the study area was vacant land since newly desired master plan of the town incorporates the surroundings of Sidama zone and 32.2km² of the total area is residential/settlements and 30.6 km² of the total area is shrub lands and 17.7km² is about forest coverage. On the other hand, water bodies, recreational centers and business activities covered a small portion of the study area.

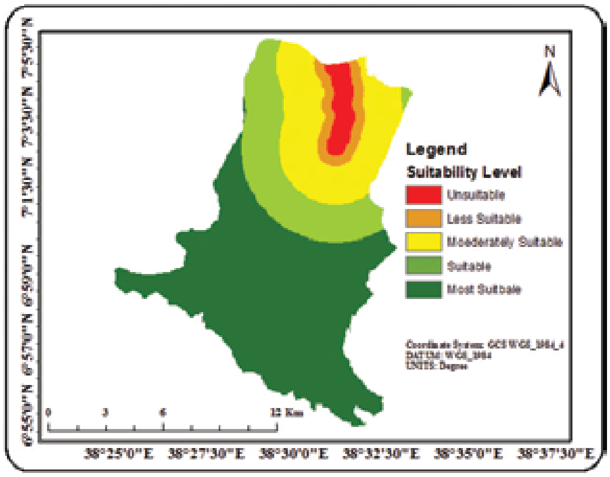

Figure 13: River suitability map of the study area

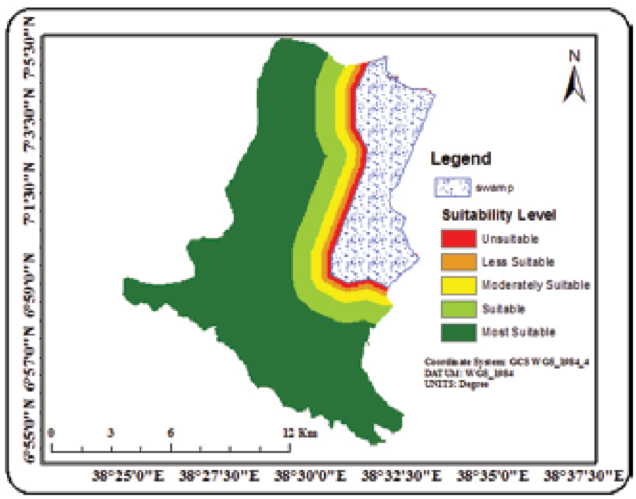

Figure 14: Swamp suitability map of the study area

According [24], water bodies, swamps, forest coverage and residential areas are not suitable for industrial establishment. Whereas areas like open spaces, vacant lands, range lands area suitable for industrial site location. From the total area, the reclassified map in the figure 15 below shows that 32.2 km^2 (20.5%) is unsuitable, 30.5km2 (19.3%) leveled as less suitable, 3.52km^2 (2.23%) is moderately suitable, 4km^2 (2.5%) as suitable and 65.6km^2 (41.6%) leveled as most suitable. From the total area, 22.05 km^2 (13.98%) are forest and water bodies were assigned zero weights (restricted), hence these sites are not considered for industrial development.

Distance from the road and industrial location

Road is also an important criterion in site suitability analysis. The need to transport raw materials, processed materials and other important things, carcasses, are dependent on the proximity to transportation facility. In order to find out better accessibility to the existing road, buffer zones have been created by taking distances from 0 to 300 meter from the existing major roads to generate suitable accessibility map. Then the buffer distance zones have been categorized into five levels based on the level of proximity to industry site. Accordingly, the low buffer distance ranked as highly suitable whereas the longer buffer distances ranked as least suitable. Thus, the rank value of 5 was given for highly suitable road buffers and the rank value 1 was given for unsuitable road buffers.

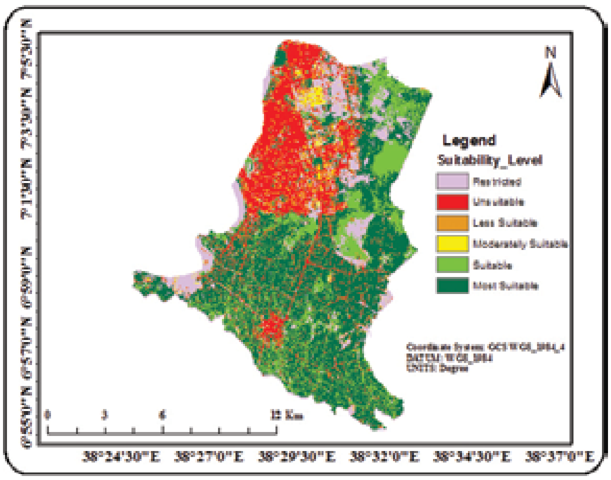

Figure 15: Land use land cover suitability map of the study area

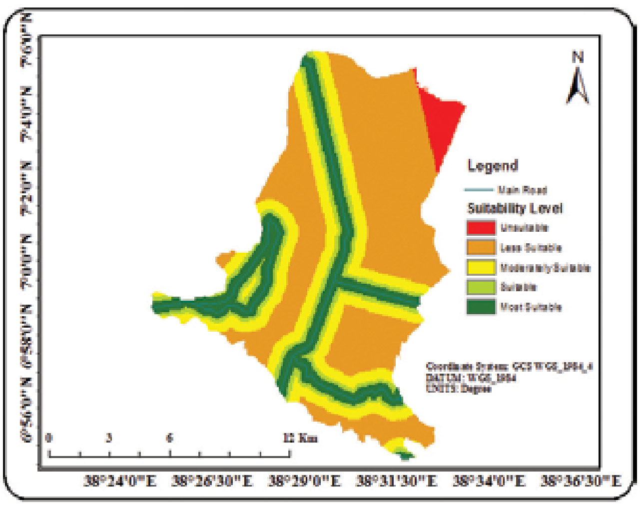

Figure 16: Road suitability map of the study area

From the total area, about 26.6 km^2 (16.8%) is most suitable for industrial sites and only 4.8km^2 (3.04%) is unsuitable for the industrial establishment. About 76.4km^2 (48.4%) of the study area is less suitable to settle industry, which is related transport accessibility. As newly proposed structural plan of the town stretched to the fringe of rural area, it requires road construction in the future.

Distance from the residential area and industrial location

A logical distance should be selected between residential areas and industrial sites. A buffer should be defined as well. These areas are barriers for industries development. The more distance from industrial areas the higher suitability and consistency will be. According to the data obtained from [16], an industry needs to be established far from the residential areas. These areas are barriers for industries development. The more distance from industrial areas, the higher suitability and consistency will be.

As indicated in the figure 17 below, from the total area 70.03km^2 (44.4%) is unsuitable as the area occupied by the residents of the town and only 2.07km^2 (1.4%) is most suitable for industrial site selection. In addition, 40.5km^2 (25.7%) is moderately, 40.2km^2 (19.3%) is suitable and 14.5km^2 (9.2%) is less suitable for the site selection of the industry.

Distance from geological fault and industrial location

Geology considered as it plays an important in the suitability decision of sites for industries. Strength of the rock and absence of fault zones will make the site suitable at the first place. Without this consideration, it is difficult to go forward in the process of site selection at any cost. Seismology and faults are very important in the development planning. The fracture resulted from geological faults will affect neighborhood sediments and rocks. Regarding legal buffer from fault lines and avoiding industrial developments in such areas are considerable factors in the industrial site selection. Faults are one of the geological phenomena that cause problem for industrial buildings and infrastructure construction. Industries should be 2000 m away from faults. The area that are within 2000 meter are unsuitable, 2001 – 4000 meter are less suitable, 4001 – 10000 meter are suitable, and area >10000 meter are most suitable to establish industries [29].

Soil type and industrial site selection

The soil has a significant impact on the amount of recharge, which can infiltrate into the groundwater and hence, influences the ability of contaminants to move vertically into the industry zone (Burden and Sims, 1999). In the figure (30) below, the extracted soil type of the study area were described. Those are eutric fluvisols, chromic luvisols, fibric histols, eutric vitricsol and haplic luvisols. According to Harmonized World Soil Database [30]:-

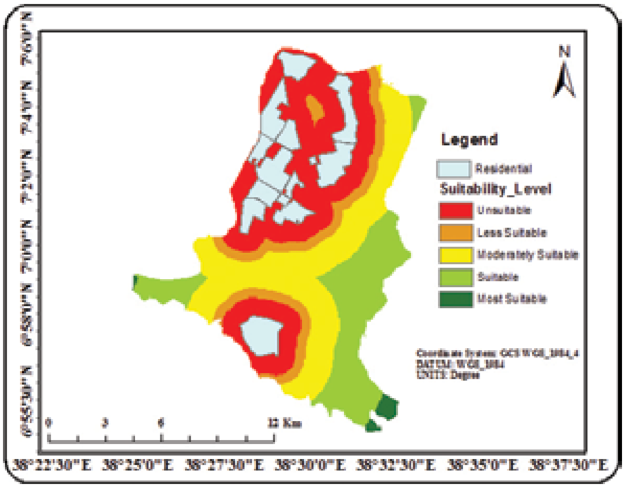

Figure 17: Residential area suitability map

Table 8: Geological Fault Suitability

Distance from residential areas	Rank	Suitability Level	Area in Krm^2	Area in %
0 - 2000	1	Unsuitable	32.4	20.5
2000-4000	2	Less Suitable	50.1	31.7
4000-10000	4	Suitable	74.9	47.5
>10000	5	Most Suitable	0.3	0.2
Total			157.7	100

Source: Compiled by the Researcher, 2021

Fluvisols: These soils are young soils and rich in alluvial deposits.

Luvisols: Soils with subsurface accumulation, low activity clay, high basic saturation, are porous and crumb characteristics.

Vertisols: they are dark colored cracking and swelling clays.

Histols: Soils that composed of organic materials

According to [21] report, those soils with clay, alluvial and loam deposits are suitable for industrial establishment, whereas soils with cracking, swelling and porous are not suitable for industrial establishment.

As indicated in the table 19 below, from the total area 92.5km^2 (58.7%) is most suitable and only 1.4km^2 (0.9%) is unsuitable for industrial site selection as the area filled by the Eutric vertisol. Moreover, 18.2km^2 (11.5%) is moderately, 31.6km^2 (20.03%) is suitable and 11.8km^2 (7.5%) is less suitable for the site selection for the industry. Figure (29), above portrays soil type suitability for the industrial site selection

Calculation of the Weight Normalized

The normalization of criteria values allows for the direct comparison of criteria when calculating suitability and reflects the conceptual relationship between the criteria value and a suitability score [31], Priority vector called normalized Principal Eigen vector. To normalize the values, divided the cell value by its column total and calculated the priority vector or weight by determining the mean value of the rows [22]. In order to check whether the set criteria is correct or not, the researcher computed normalization.

As can be seen from the suitability map (Fig 20), about half (50.7%) of the study area is suitable for industrial location. The suitable areas are mainly located in the Southern, South Eastern,

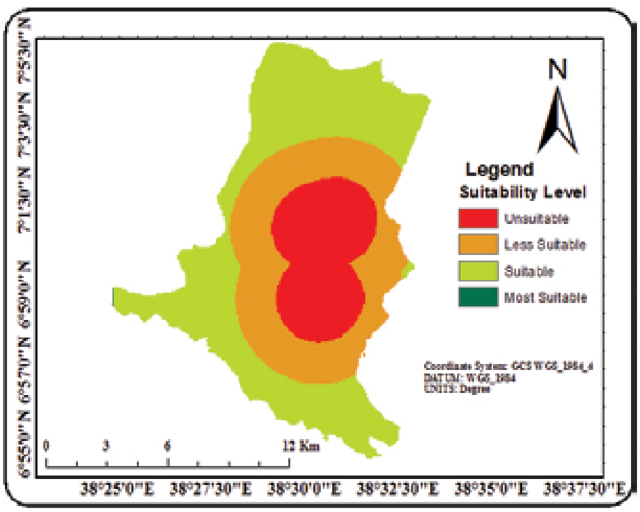

Figure 18: Suitability map of geological fault

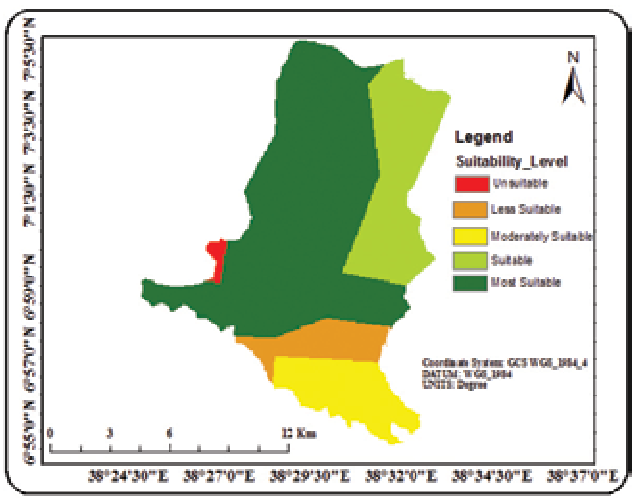

Figure 19: Soil type suitability map of the study area

Table 9: Normalized Criteria Selection for Industrial Site Selection

	LULC	geology	Soil type	Settlement	road	lake	swamp	river	slope	value	weight	Influence (%)
LULC	0.3	0.51	0.5	0.12	0.2	0.15	0.15	0.16	0.15	2.24	0.25	25
geology	0.09	0.18	0.2	0.33	0.3	0.24	0.15	0.2	0.09	1.78	0.2	20
Soil type	0.06	0.09	0.11	0.33	0.2	0.24	0.25	0.2	0.09	1.57	0.17	17
reside	0.15	0.03	0.02	0.07	0.14	0.1	0.1	0.12	0.15	0.88	0.1	10
road	0.09	0.03	0.04	0.04	0.07	0.14	0.25	0.09	0.09	0.84	0.09	9
lake	0.09	0.03	0.03	0.04	0.02	0.05	0.04	0.09	0.16	0.55	0.06	6
swamp	0.09	0.05	0.03	0.04	0.02	0.05	0.03	0.09	0.15	0.55	0.06	6
river	0.07	0.03	0.03	0.02	0.03	0.02	0.02	0.04	0.09	0.35	0.04	4
slope	0.06	0.05	0.04	0.01	0.02	0.01	0.01	0.01	0.03	0.24	0.03	3
total	1	1	1	1	1	1	1	1	1	9	1	100

Source: Compiled by the Researcher, 2021

Table 10: Statistical Analysis for Overall Weights for the Industrial Sites Selection

Suitability class	Area (km^2)	Area (%)
Restricted area	18.5	11.7
Less suitable	0.3	0.2
Moderately Suitable	54.8	34.7
Suitable	74.9	47.5
Most Suitable	4.9	3.2
Total	157.7	100

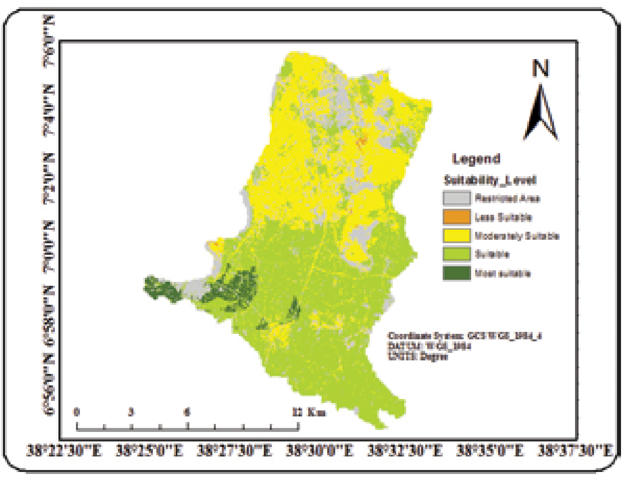

Figure 20: Weighted overlay suitability map of the study area

South Western and central part approaching to the corner of the town. These areas were mainly vacant, bare lands and away from water bodies. In the Eastern part of the study area, on the way to Wondogenet, the new structural plan incorporated vacant lands to the town which favors good condition for the industrial site selection; and areas are free from urban settlements; and are occupied by sparse vegetation. For this reason, those parts are suitable for industrial implantation.

On the other hand, most parts of Huwella Tula sub-city were moderately suitable for industrial sites. Even if the areas were sparsely populated and free from water bodies, because of optimum transport inaccessibility up to the fringe the sub-city; it was a little bit important for the industrial sites. And also, those areas with shrub trees and bare lands are suitable to plant industry for the future. Obviously, those parts in the stated sub-city, the existing weather roads were considered as hindrance for the transportation of raw materials. This would impose private investors not to invest on that transport inaccessible areas. So in this area, small proportions of the study area were leveled as moderately suitable.

Swamps, lakes, streams and forest coverage through Lake Hawassa up to Tikur Wuha area were considered as restricted. For this reason, the researcher masked out those areas and leveled as restricted parts. Therefore, about 11.7% of the total study areas were not permitted to suitability criterion on this study. In the study area, about 35% of the study areas were less suitable and moderately suitable for industrial site selection. This is because of, central parts were occupied by the recreational centers, settlements and built up areas, business sites and around Hayk Dar areas were considered to be constraints for industrial establishment.

Concluding remarks

GIS and Remote Sensing as analysis tools are valuable tools that can support the decision makers to find best possible industrial sites. The GIS analysis requires collecting data from different sources with different formats to create a complete uniform database. Thus, the GIS data should be updated regularly in order to reflect the current situation of an area under investigation. Remote sensing data can assist to have updated information of the study area.

The analysis has taken land use/cover, slope, surface water, proximity to main roads and streams/river, swamps, distance from residential areas, distance from geological faults and soil types. From those parameters, land use land cover, geological faults and soil types were highly determining the selection of industrial sites in the study area. Since the study area is relatively flat slope, elevation and slope parameters play small portion in determining site selection. After weight over lay computed, about 50% of the study area is suitable for industrial location and only 0.2 % is less suitable to locate industry.

In the study area, the town Urban Development and Housing Department utilizes AutoCAD highly to administer land. However, there is shortage of experts who are GIS and Remote Sensing backgrounds. This resulted in ignorance of appreciating those best technologies like GIS and Remote Sensing.

The GIS based multi criteria evaluation technique is simple and flexible which can be used to analyze the potential sites for urban development and encourage public participation in the urban decision making process. Thus, planners and authorities in order to formulate suitable plan for sustained development of the town, they have to undertake the application of GIS and Remote Sensing technologies. In the study area, industries were accumulated in the central and main parts of the town. This may result in different social and economic problems (interruption) on the residents. Therefore, the town administration has focus in order to plant industries far away from residential and other economic areas of the town.

The study area selects industrial sites if there was a vacant land. Existence of a vacant land itself is not enough to establish industry. Those listed factors in this study and additional parameters have to be taken in to account for further industrial development. The town Industry and Enterprise, Housing and Urban Development, Forest and Environmental Protection Departments have to provide short term and long term GIS and remote sensing training for the experts.

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New batch of RS satellites by China

China successfully launched three new remote sensing satellites from the Xichang Satellite Launch Center in southwest China's Sichuan Province on June 23, 2022.

The satellites were launched as the second batch of the Yaogan-35 family at 10:22 a.m. (Beijing Time) by a Long March-2D carrier rocket and entered the planned orbit successfully.

This launch marked the 424th mission for the Long March series carrier rockets. *https://english.news.cn*

Remote sensing helps track carbon storage in mangroves

Mangrove forests store huge amounts of carbon but figuring out how much is stored globally is challenging. Now, researchers from Japan have developed a new model that uses remote sensing of environmental conditions to determine the productivity of mangrove forests.

In a recent study in Scientific Reports, researchers from the Institute of Industrial Science, The University of Tokyo, developed a model to assess the productivity of coastal mangroves in China. Mangroves grow along tropical coastlines and are regularly inundated by seawater. These unique species are well adapted to tropical coastal habitats and have special features such as aerial roots and salt-tolerant tissues that enable them to thrive under dynamic conditions. As a result, the productivity of mangrove forests is influenced by a range of environmental factors, such as sea surface temperature, salinity, and photosynthetic active radiation.

In the past, light use efficiency models have been used to assess the productivity of terrestrial forests but there are no such models for more complex mangrove ecosystems. *https://phys.org*

UK satellite navigation signal generated

An Inmarsat-led team of companies in the UK, building on national expertise and prior experience within the group, has begun broadcasting a satellite navigation signal as part of a programme to explore the creation of a sovereign national capability in resilient positioning, navigation and timing (PNT) for the aviation and maritime sectors. The signal, being broadcast in coordination with the US Federal Aviation Administration (FAA), the European Space Agency (ESA) and the European Union Space Programme Agency (EUSPA), is now stable and operational, enabling on-going testing and validation by industry, regulators, and users.

Inmarsat alongside British partners Goonhilly Earth Station Limited and GMVNSL Limited, is delivering the UK Space Agency-funded tests with the European Space Agency via the latter's Navigation Innovation and Support Program (NAVISP).

UKSBAS – the UK Space-Based Augmentation System – generates an overlay test signal to the US GPS, fully-compliant with International Civil Aviation Organization (ICAO) standards, to enable assessment of more precise, resilient and high integrity navigation for maritime and aviation users in UK waters and airspace. It increases accuracy in positioning to a few centimetres of accuracy rather than the few metres provided by standard GPS. This is a similar system to that already under evaluation in Australia and New Zealand, supported by Inmarsat.

Since leaving the European Union, the UK is not part of the Galileo satnav system and cannot use the European Geostationary Navigation Overlay Service (EGNOS) safety of life (SOL) services, which enable the use of GPS for airport approach and landing operations for aircraft. By repurposing the SBAS transponder on Inmarsat's I-3 F5 satellite in geostationary orbit at 54° west, the UKSBAS signal enables testing of this potential alternative system to begin. Built by Inmarsat's Athena partner Lockheed Martin and launched in 1998, I-3F5 covers the UK as part of its Atlantic Ocean region service overlay. This makes it an ideal candidate to participate in this test and demonstrates the commitment to sustainability of Inmarsat with a satellite that has already served the equivalent of several low Earth orbit (LEO) satellite life cycles.

These tests will assess whether UKSBAS can develop into a full operational capability to support safety-critical applications such as airport approach and landing operations or navigating ships through narrow channels, especially at night and in poor weather conditions. Goonhilly provides the signal uplink for the system from Cornwall and software from GMVNSL, based in Nottingham, generates the necessary navigational data. *www.inmarsat.com*

EUSPA publishes HAS SIS ICD

The EU Space Program Agency (EUSPA) has published the first Galileo High Precision Space Interface Management Document (HAS SIS ICD). It was published by EUSPA in collaboration with the European Commission and the European Space Agency (ESA).

By providing free, high-precision accurate point positioning correction (PPP) both via the Galileo signal (E6-B) and via the Internet, HAS offers users improved positioning performance with an accuracy of less than two decimeters. *www.gsc-europa.eu*

#myEUspace competition winners!

Launched in September 2021 as part of the European Commission's CASSINI initiative and with over EUR 1 million in prize money on the line, #myEUspace is one of the biggest competitions ever organised by EUSPA. Innovators and entrepreneurs were challenged to develop and commercialise products/applications that use data and services from the EU Space Programme. While the solutions ranged from diverse sectors such as location-based services, smart mobility, geomatics and smart agriculture, they all share a foundation in their use of Galileo or Copernicus data as well as leveraging the synergies between the two.

Following are the winners of the #myEUspace competition:

In Track 1, the innovators had to develop their theoretical idea into a prototype:

- SANGENE: Integrated GNSS based passive radar for detection and first localisation of obstacles
- EO4RT: Web application for artistic and personalised products based on satellite images acquired over a specific region of interest –

ALTIWAVE: Satellite-derived regional wave heights for the marine energy sector

- Master Map: Automatic road mapping status for maintenance optimisation
- VirtualCrop: Application for sustainable precision farming that turns phones into data gathering and analysis tools
- RIGOROUS: Efficient and effective development and deployment of solutions based on using Randomness-Intensive algorithms for near-real-time route optimization

…while in Track 2, the innovators had to turn their existing prototype into a product and launch it on the market:

- C-ITS Platform: C-ITS Platform to increase road safety, powered by Galileo and Copernicus
- E20.Green: Intelligent Platform powered by GNSS, AI, EO and IoT to enable Golf Course and Urban Green Space Management companies to effectively manage assets, operations and land fields
- SPAI: Solution to easily integrate satellite analytics in the work practices of experts and nonexpert users, extracting the EO value through AI effortless
- SOILSPECT: Automatic monitoring of ground settlement at construction sites
- Agricircle: Dashboard for Outcomes of Regenerative Agriculture. *www.euspa.europa.eu*

NASA Moon mission set to break record in navigation signal test

As the Artemis missions journey to the Moon and NASA plans for the long voyage to Mars, new navigation capabilities will be key to science, discovery, and human exploration. Through NASA's Commercial Lunar Payload Services initiative, Firefly Aerospace of Cedar Park, Texas, will deliver an experimental payload to the Moon's Mare Crisium basin. NASA's Lunar GNSS Receiver Experiment (LuGRE) payload will test a powerful new lunar navigation capability using Earth's Global Navigation Satellite System (GNSS) signals at the Moon for the first time. GNSS refers to satellite constellations commonly used for position, navigation, and timing services on Earth. GPS – the GNSS constellation operated by the U.S. Space Force – is the one many Americans are familiar with and use on a daily basis.

"In this case, we are pushing the envelope of what GNSS was intended to do – that is, expanding the reach of systems built to provide services to terrestrial, aviation, and maritime users to also include the fast growing space sector," said J.J. Miller, Deputy Director of Policy and Strategic Communications for NASA's Space Communications and Navigation (SCaN) program. "This will vastly improve the precision and resilience of what was available during the Apollo missions, and allow for more flexible equipage and operational scenarios."

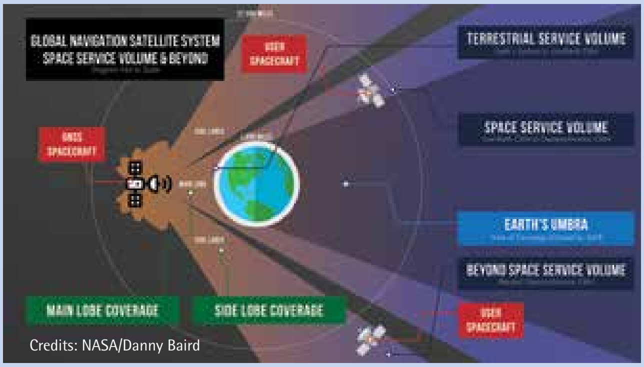
LuGRE – developed in partnership with the Italian Space Agency (ASI) – will receive signals from both GPS and the European GNSS constellation, Galileo, and use them to calculate the first-ever GNSS location fixes in transit to the Moon and on the lunar surface.

"Space missions close to Earth have long relied on GNSS for their navigation and timekeeping," said Joel Parker, LuGRE principal investigator at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "In recent years, NASA and the international community have pushed the boundaries of what was considered possible by using these techniques in the Space Service Volume and beyond."

Missions in the GNSS Space Service Volume – from about 1,800 miles to 22,000 miles in altitude – receive signals that spill past Earth's edge from GNSS satellites on the opposite side of the planet. The first Space Service Volume experiments occurred around the dawn of the new millennium. Since then, numerous missions in the Space Service Volume have reliably used GNSS to navigate.

In 2016, the NASA's Magnetospheric Multiscale Mission (MMS) employed GPS operationally at a record-breaking 43,500 miles from Earth. Then, in 2019, MMS broke its own record by fixing its location with GPS at 116,300 miles from Earth – nearly halfway to the Moon.

At these extreme altitudes, missions need extremely sensitive GNSS receivers.



A graphic detailing the different areas of GNSS coverage.

The LuGRE mission will use a specialized weak-signal receiver developed by Qascom, an Italian company specializing in space cybersecurity and satellite navigation security solutions, and funded by ASI.

LuGRE teams are now testing the payload in preparation to deliver it for integration onto the Firefly "Blue Ghost" lander in November of this year. Launch is currently slated for no earlier than 2024 from Cape Canaveral, Florida, aboard a SpaceX Falcon 9 rocket.

During the multi-week flight to the Moon, LuGRE will collect GNSS signals and perform navigation experiments at different altitudes and in lunar orbit. After landing, LuGRE will deploy its antenna and begin 12 days of data collection, with the potential for extended mission operations as well.

NASA and ASI will process and analyze data downlinked to Earth and then share results publicly.

"LuGRE is the latest effort in a long line of missions designed to expand high-altitude GNSS capabilities," said Fabio Dovis, LuGRE co-principal investigator at the Italian Space Agency. "We've developed a cutting-edge experiment that will serve as the foundation for operational GNSS systems at the Moon."

The LuGRE mission seeks to spark further development of GNSS-based navigation capabilities near and on the Moon, even as NASA plans to begin using high-altitude GNSS operationally for future lunar missions. NASA and ASI will bring the results of this work forward to the space community through the International Committee on GNSS, a United Nations forum focused on ensuring the interoperability of GNSS signals. These capabilities are also a key stepping stone towards building LunaNet, an architecture that will unify cooperative networks into seamless lunar communications and navigation services.

"The lunar deliveries we're sourcing from commercial vendors are providing a number of innovative new technologies and opportunities to conduct experiments with affordable access to the lunar surface," said Jay Jenkins, Commercial Lunar Payload Services Program Executive. "LuGRE is one example of the progress that government and industry can make when united in their exploration objectives."

Developing new uses of GNSS for emerging space operations is a priority for the SCaN program at NASA headquarters, as the lead organization responsible for implementing guidance from Space Policy Directive-7, which directs NASA to develop requirements for GPS support of space operations and science in higher orbits and beyond into cislunar space.

By Danny Baird

NASA's Goddard Space Flight Center, Greenbelt, Md. USA

www.nasa.gov

Dubai completes hydrographic data survey of all marine areas

Dubai Municipality has announced the completion of a first-of-its-kind hydrographic survey of the territorial waters of the Emirate, conducted to generate comprehensive marine data in accordance with the specifications of the International Hydrographic Organization (IHO). The survey is part of the Municipality's efforts to support the development of major world-class marine infrastructure projects launched by the United Arab Emirates.

The advanced marine survey boat was used for the project, the first vessel of its kind deployed in the country to carry out comprehensive hydrographic and geophysical surveys of deep layers of the sea floor across marine areas of Dubai. The survey covered not only Dubai's coastline and its entire territorial waters but also parts of international waters bordering it. The boat, with an operational capacity of 72 continuous sailing hours, contains integrated state-of-the-art monitoring systems.

The project aims to develop nautical charts according to the specifications of the IHO, in addition to providing hydrographic data to international specifications. With the completion of the project, Dubai Municipality is set to become the first government department in the country to provide this global service. *https://mediaoffice.ae*

Marine navigation system to increase safety, commerce in Northwest

Mariners can breathe a little easier when sailing in and around Naval Base Kitsap in Washington state in the US.

The base is now fitted with a NOAA system that helps ensure safe and efficient marine navigation. The technology is part of a nationwide network called Physical Oceanographic Real-Time System, or PORTS.

Kitsap PORTS is the 37th system in this network of precision marine navigation sensors, and is the result of a partnership between NOAA and the U.S. Navy. The sensors track oceanographic and meteorological conditions as they unfold around Naval Base Kitsap.

Naval Base Kitsap is the nation's third-largest U.S. Navy installation and provides base operating services to submarines, aircraft carriers, Puget Sound Naval Shipyard and the largest fuel depot in the Continental U.S. The Kitsap PORTS will help personnel plan for, and respond to, changing oceanographic conditions in the area. The system will allow all local mariners to have access to real-time water level, currents, and meteorological information, helping them better plan vessel transits and prevent accidents. *noaa.gov*

Seaforth Geosurveys adds iXblue USBL System

Seaforth Geosurveys recently acquired iXblue's new Gaps M5 USBL system to support data acquisition for marine geophysical survey projects. These include one in the Canadian Arctic and multiple other projects, such as support of sidescan sonar operations during lost and abandoned fishing gear (Ghost Gear) identification and retrieval efforts.

Bluesky LiDAR data helps farmers apply for carbon credits

A new UK government funded project is using LiDAR data captured by aerial survey and mapping company, Bluesky International to identify areas of hedgerow and subsequently the amount of carbon captured by hedgerows, enabling landowners to claim correct levels of carbon credits.

Carbon Keepers is a UK fintech start-up that has received a SPRINT grant, a government innovation grant, and has partnered with University of Leicester and Lowther Estate Trust to develop an algorithm that uses LiDAR data to identify how much carbon is actually being sequestered by hedgerows. *www.bluesky-world.com*

M-code compatible navigation system by Collins Aerospace

Collins Aerospace has introduced NavHub™-200M, the first non-ITAR vehicular navigation system for the international market compatible with Military Code (M-Code) receiver technology.It provides Assured Positioning, Navigation and Timing (APNT) capabilities while improving overall resistance to existing and emerging threats to GPS, such as jamming and spoofing. *www.collinsaerospace.com*

Small SWaP Time-space navigation information system

The Curtiss-Wright Corp. Defense Solutions division in Ashburn, Va., is introducing the MiTSPI nTTU-2600 miniature network tactical time-space position information system. It provides positional information for location and orientation in space to capture critical data that involves navigation, inertial measurement unit (IMU), and GPS information. *www.curtisswrightds.com*

Fixposition releases the Vision-RTK 2

Fixposition has announced a centimeter-level positioning sensor, the Vision-RTK 2. The low-power and compact, industrial-grade device is ideal for autonomous delivery and logistics vehicles, agriculture, mowing and landscaping machines, as well as any other application where precise, uninterrupted positioning must always be available everywhere. *fixposition.com*

Trimble GNSS receiver module designed for industrial autonomy applications

Trimble's BD9250 dual-frequency OEM GNSS receiver module supports the Trimble RTX correction services. The receiver is designed to deliver high-accuracy positioning for a range of high volume; autonomous-ready applications. It is a compact receiver with an industry-standard form factor and pinout, allowing for easy system integration and configuration. Equipped with Trimble's advanced ProPoint positioning engine, it delivers robust and accurate positioning. It is compatible with Trimble RTX correction services or RTK and supports all major GNSS constellations, including GPS, Galileo, GLONASS, BeiDou, QZSS and NavIC. *www.trimble.com*

Grab to be fully powered by its own mapping technology

Grab Holdings Limited has launched GrabMaps, a new enterprise service that will allow the company to tap into the US$1 billion market opportunity in Southeast Asia per year for mapping and location-based services. It was created to address Grab's need for a more hyperlocal solution to power its services. *grab.com*

M-Code GPS receiver with precision strike capabilities in contested environments

BAE Systems has unveiled its newest advanced M-Code GPS receiver for guided weapons and other small applications, enabling precise geolocation and strike capabilities in highly contested battlespaces. The Strategic Anti-jam Beamforming Receiver – M-Code (SABR-M) delivers accurate position, velocity, altitude, and timing data, as well as strong protection against GPS signal jamming and. *www.baesystems.com*

Ricoh announces second-generation GPS unit

Ricoh Imaging Americas Corporation has announced the PENTAX O-GPS2, a versatile GPS unit designed for use with PENTAX digital SLR cameras that makes it easy to capture stellar images of the night sky. It provides more reliable and higher-precision positioning data gathered from GPS, QZSS,GLONASS and Galileo. It records the latitude, longitude, altitude, universal time coordinated and direction of shooting location onto captured images. *www.us.ricoh-imaging.com*

Edge 1040 Solar by Garmin

Garmin® International, Inc announced the Edge® 1040 Solar. Harnessing the power of the sun, it features a Power Glass™ solar charging lens, giving cyclists even more ride time between charges – up to 100 hours in battery saver mode – while multi-band GNSS technology provides more accurate GPS positioning in challenging ride environments, such as dense urban areas or under deep tree cover. *garmin.com*

Harxon new GNSS zntenna HX-CSX633A released

Harxon has recently launched a high-precision GNSS antenna HX-CSX633A with brand new design. The structure has been highly upgraded for more durable use and more flexible installations. This ruggedized antenna is enclosed in a durable, IP67 waterproof housing and meets MIL-STD-810-H for vibration and shock, increasing robustness for use under high vibration conditions. *https://en.harxon.com*

Thales Alenia Space TAKES new steps in satellite navigation programs

Thales Alenia Space, joint venture between Thales (67%) and Leonardo (33%), has signed a new contract with the EU Agency for the Space Programme (EUSPA) to develop, qualify and deploy the new European Geostationary Navigation Overlay Service (EGNOS) version.

Thales Alenia Space will provide EUSPA and the EU Navigation community with a new version of EGNOS (V243), whose operations will be secured by a new state-of-the art Navigation Land Earth Station technology developed by Thales Alenia Space – NLES-G3. The NLES transmits the EGNOS message containing all accuracy & integrity corrections to the Geostationary satellites for broadcast to users as aviation operators. Thales Alenia Space NLES-G3 will be integrated with a new geostationary satellite "GEO3" which will enhance the EGNOS system and its end-to-end performance. *thalesaleniaspace.com*

Telit SE873K5 GNSS receiver

Telit has announced the release of the SE873K5, the latest addition to its SE873 family of modules and the natural migration path from SE873 and SE873Q5. Based on AG3335 series from Airoha, the SE873K5 is a new multi-constellation receiver in the ultra-high L1 frequency band, with a 7x7x2.25 mm QFN-like semiconductor package including embedded SPI flash, RTC and TCXO. It simultaneously tracks and navigates all four GNSS constellations — GPS, Galileo, GLONASS and Beidou — providing GNSS information over a UART, I2C or SPI interface serial port using the NMEA Protocol. *www.telit.com*

Single-band GNSS positioning module LC76G by Quectel

Quectel Wireless Solutions has released its LC76G module, a single-band compact GNSS module featuring fast and accurate location performance as well as ultra-low power consumption. Based on the Airoha AG3352 platform, the LC76G can concurrently receive and process signals from all constellations (GPS, GLONASS, BeiDou, Galileo and QZSS). *quectel.com*

MARK YOUR CALENDAR

August 2022

GeoCart'2022
24 - 26 Aug
Wellington, New Zealand
www.cartography.org.nz

September 2022

International Symposium of Commission 4: Positioning and Applications
5 to 8 September 2022
www.iag-commission4-symposium2022.net

15th Conference on Spatial Information Theory (COSIT)
5-9 Sep 2022
Kobe, Japan
cosit2022.iniad.org

Commercial UAV Expo Americas
6-8 September 2022
Las Vegas, USA
www.expouav.com

17th Symposium on Location Based Services (LBS2022)
12-14 Sep 2022
Munich, Germany
lbsconference.org

18th International Conference on Geoinformation and Cartography
14-16 Sep 2022
Zagreb, Croatia
www.kartografija.hr

EuroCarto 2022
19-21 Sep
Vienna, Austria
www.eurocarto2022.org

ION GNSS+ 2022
19-23 September
Denver, CO, USA
www.ion.org/gnss/index.cfm

October 2022

2nd United Nations World Geospatial Information Congress (UNWGIC)
10-14 October 2022
Hyderabad, India
https://ggim.un.org/2unwgic

The 7th Geospatial Conference The 6th SMPR and 4th GIResearch
15-18 October 2022
Tehran, Iran
https://geospatialconf2022.ut.ac.ir

Intergeo Hybrid
18-20 October 2022
Essen, Germany
www.intergeo.de

November 2022

Trimble Dimensions+
7-9 November 2022
Las Vegas, USA
https://dimensions.trimble.com

AgEagle reports backlogged sales of $2 million

AgEagle Aerial Systems Inc. has reported that steps taken to increase supply due to significant demand for its new MicaSense Altum-PT and RedEdge-P sensors, and its legacy RedEdge-MX sensors, will enable the Company to ship more than $2 million in backlogged purchase orders in the third quarter, ending September 30, 2022. *www.ageagle.com*

NovAtel SMART7 GNSS receiver in JCB Fastrac iCON

JCB launched their new Fastrac iCON tractor to the public. It features NovAtel's SMART7 GNSS receiver and optional TerraStar Correction Services driving the iCONNECT precision technology package and offering operators an easy-to-use customisable experience. With the availability of TerraStar Correction Services, operators can have the highest accuracy and year-over-year repeatability globally. *novatel.com/agriculture*

Mapping and surveying solution by Drone Nerds

Drone Nerds has announced its latest mapping solution for enterprise customers, the viDoc RTK Rover. Created by Pix4D, the viDoc RTK Rover is a handheld ground photogrammetry solution designed to facilitate mapping and surveying with 3D scanning. The viDoc RTK can connect to any NTRIP (Network Transport of RTCM via Internet Protocol) service of choice, allowing users to walk areas of interest and acquire high-precision positional data for individual images. *dronenerds.com*

OriginGPS' new product

OriginGPS offers a broad range of high-efficiency solutions; traditional miniature GNSS modules and cellular IoT systems and devices to dramatically shorten time to market. The ORG4572-MK05, a new miniature GNSS module, is the smallest Flash-based module of its kind and today has a lead time of just 12 weeks! *https://origingps.com*