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# Integrating Geographic Information Systems in Industrial Management: Key Drivers for Enhanced Performance and Sustainability

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## ABSTRACT

Geographic Information Systems (GIS) integration into the industrial management is a crucial aspect that has helped in boosting the operational performance and sustainability. The tools offered by GIS technology for spatial data analysis, real time data visualization and informed decision making add to greater efficiency of resource allocation and improved supply chain logistics for the industries. The aim of this paper is to identify the main reasons for the use of GIS in the industrial environments, which include the recent technological advances, the regulatory compliance, and the necessity of the operational efficiency. By illustrating how GIS tools help companies fulfill sustainability goals, including better tracking of environmental impacts, reduction of waste, and of energy, the document identifies industries that are immediately utilizing GIS tools. Additionally, the paper talks about the use of GIS in enabling competitive advantages, minimizing costs and work flow optimization. Real time data collection systems, predictive modeling and automation is studied as a feature of bringing about continuous improvement of industrial practice. Examples of applying the GIS approach to optimization of process in manufacturing, transportation and energy sectors are presented in case studies. It also addresses the challenges of GIS implementation, other than high initial costs and data integration, as the future trends and innovations that will influence the evolution from GIS in industrial management. In this paper, we stress the key role of GIS in making industrial management practices change in a way that provides organizational success in the long term due to increased efficiency and sustainability.

## 1. Introduction


### 1.1. Definition of Geographic Information Systems (GIS)

The geographic information systems (GIS), advanced technological framework to integrate, analyses and visualize geospatial data, are of much importance. GIS allows users to capture

and manage the location based information effectively, via a combination of hardware, software, and data. However, this technology is essential in its democracy and helping spatial analyses democratize across various sectors by allowing organizations to display a complex dataset overlaid on geographic maps.

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For example, the fundamental idea behind GIS is to refer general raw data to usable maps that delineate patterns and associations among the data. Such systems are developed not only for the management of geographic information but also for the excellence of analysis through spatial query capability. For example, GIS tools can be used by industries to assess the logistical frameworks, and monitor environmental changes or plan for urban development.

GIS technology is applied to many fields including urban planning, environment management, transportation logistics, etc. Thus, GIS helps organizations aspiring for operational excellence by offering insights into geographical trends and spatial interrelationships.

In addition, GIS can be an important means for resource management and strategic planning because it helps the users visualize the scenario in real time. This combination of elements of various data layers improves analytical capabilities of both business entities and government bodies. It brings together a spatial perspective that allows such challenges to emerge from geographical (or spatial) factors while simultaneously opening the door for new ranges of planning and infrastructure innovation.

As industries increasingly focus on adopting data driven practices, the need for development of Geographic Information Systems continues to rise in order to construct informed strategies in order to increase productivity and efficiency, [1], [2], [3] and [4].



**Figure 1:** Discover how Geographic Information Systems (GIS) are revolutionizing the telecom industry, [1].

### 1.2. Importance of GIS in industrial contexts

Spatial Information Systems (GIS) are crucial elements in the industrial management that are extensively utilized to improve the operational

efficiency in many industries. There are many levels of the importance of GIS in these contexts, one of which is that GIS has the potential to effect informed decision making through spatial analysis. One of the reasons

GIS is used because it acts as a vehicle to determine patterns and trends that are essential to strategic planning and the distribution of resources. The ability to do it this way implies the optimizing in terms of workflow, reducing costs, and increasing productivity is possible for industries.

In regards to the industrial management, GIS can contribute to supply chain logistics streamlining by highlighting geographical factors that impacting on the transportation route and the facilities location. Mapping of the logistics networks give companies an opportunity to streamline operations, reduce transit time and improve quality of service delivery. Also, it assists the businesses predict their need and market demands through spatial trend forecasting.

Besides its fundamental importance in meeting regulatory compliance to supply the critical spatial data for environmental assessments, sustainability initiatives and other similar projects, the technology is equally important. There is growing use of GIS to monitor the impact of their operations on the environment and to ensure conformity to legal practices while encouraging sustainable operations.

Additionally, the amalgamation of GIS with real time data collection systems facilitates the industries to respond promptly to changes happening around them. However, it is very important, especially in manufacturing and transportation, where making timely decisions can bring about unprecedented competitive edge.

Finally, GIS technology fosters collaboration among stakeholders within an organization. Through sharing geospatial data on those common platforms, teams are able to power through projects with multidisciplinary components much faster and more effectively joint. Consequently, the GIS has more impact than just the efficiency increase, since it fosters innovation through improvement of communications and teamwork, [1], [5], [6], [7] and [8].

### 1.3. Overview of the document structure

The structure of this document is carefully used in providing a complete skincare of the role of Geographic Information Systems (GIS) in Industrial Management. Foundation related to geospatial and the rationale of using GIS are discussed first while including applications in different industry and how will the main part of this document will be written.

We first introduce the reason and then move to discuss key driving factors for GIS adoption in different industries. In this section, a number of technological advances and compelling regulatory requirements are presented that necessitate a more improved sustainability effort, and how GIS can position itself to create competition and increase operational efficiency.

Following up, we evaluate how real time data collection, decision supporting system and resource management in an optimized way has improved operational performance. This therefore opens on sustainable industrial practices based on the best practices for waste reduction, energy efficiency mapping and environmental impact assessment through the use of GIS technology.

We then look into the matter of how to make efficiency better using GIS tools that may be automated for the work flow as well as the supply chain logistics. After that, case studies are presented which show how GIS has been used in practice in different sectors such as manufacturing, transportation and energy.

Then we cover the problems encountered in the implementation of GIS including high costs in the beginning, data quality issues and organizational resistance to use of new methodology. Future trends and innovations of GIS for industrial management with the aids of artificial intelligence (AI), mobile technology and cloud computing, are reflected on at the end of the document. However, this structure enables a logical approach of both theoretical foundations and practical implications of GIS in industry [9], [10], [11] and [12].

## 2. Key Drivers of GIS Integration in

## Industry

### 2.1. Technological advancements

Geographic Information Systems (GIS) have grown quickly in recent times as a system of technology used to professional management, workflow optimization and better decision making. GIS is not what was that used to be (i.e., a simple mapping tool), but rather a sophisticated solution to perform complex analytical tasks. With the advent of cloud computing, organizations are able to store and process large geospatial datasets in a way that allows it to be immediately available and data can easily be shared amongst departments. This flexibility enables business flexibility as they continue to grow in data volume without impacts to their efficiencies.

With artificial intelligence (AI) incorporated within GIS frameworks, machine learning algorithms, like artificial intelligence, are able to benefit and interpret data by determining patterns and trends through computers. By providing predictive modeling capabilities, these are used to help support the prediction of what might be ahead of taking place in given histories of data. Furthermore, the ability to integrate Internet of Things (IoT) devices with GIS has adopted the ability of collecting data with real time operational metrics in sectors ranging from utilities and transportation. Continuous data streams are generated by embedded sensors in different infrastructures which can be visualized spatially in order to be analyzed and responsive actions could be taken immediately.

It also provides GIS with the ability to work with big data analytics processing huge datasets from different sources. This combination helps run businesses to obtain insightful beneficial knowledge that aids at strategic decisions making, resource allocation optimization and operations streamlining. Real time data means that decision makers get the most current data at the tip of their fingers and that creates a situation that lends itself well to fast adjustments in the face of market changes or technical problems.

Also, mobile GIS applications have become more advanced and the field teams can access spatial information while on site instantly, which allows them to work more productively and make decisions based on spatial information, directly from the ground. These technological innovations also help organizations improve their operational efficiency and a competitive advantage in their respective industries, [13], [14], [15] and [16].

### 2.2. Regulatory compliance and sustainability goals

The regulation of sustainability and regulatory compliance require the use of Geographic Information Systems (GIS) in industrial management. With the rise of environmental scrutiny of industries, GIS is a highly robust method for collecting, analyzing, and visualizing geospatial information that is germane to compliance. Real time emissions and waste management is enabled; this gives the company means to meet legal requirements while preventing environmental violations before they occur.

GIS also facilitates sustainable practices by spatial analysis to help determine areas with large consumption of resources or pollution. Waste generation trends can be analyzed by organizations so that ways to better dispose of it can be found, thereby, helping them reduce landfill reliance and make overall recycling a more efficient process. In addition, GIS allows planning renewable energy projects based on land use and amount of available natural resources.

Given the importance of the regulatory compliance and public perception, business can use GIS technology to provide more transparency in operational process of sustainability initiative. The efforts of greenhouse gas reductions are best illustrated by clear data visualizations of promises of environmental responsibility.

GIS integration into corporate governance enables broadening of sustainability goals with broader business strategies. Comprehensive GIS is adopted by industries; and industries adopting comprehensive GIS methods are

better prepared to respond to the changing regulations of reducing carbon footprints and improving ecological resilience to retain the competitive advantages and address critical

sustainability issues. In the end, GIS helps industries to comply standards and integrate end of life and sustainability in its operation [8], [14], [17] and [18].

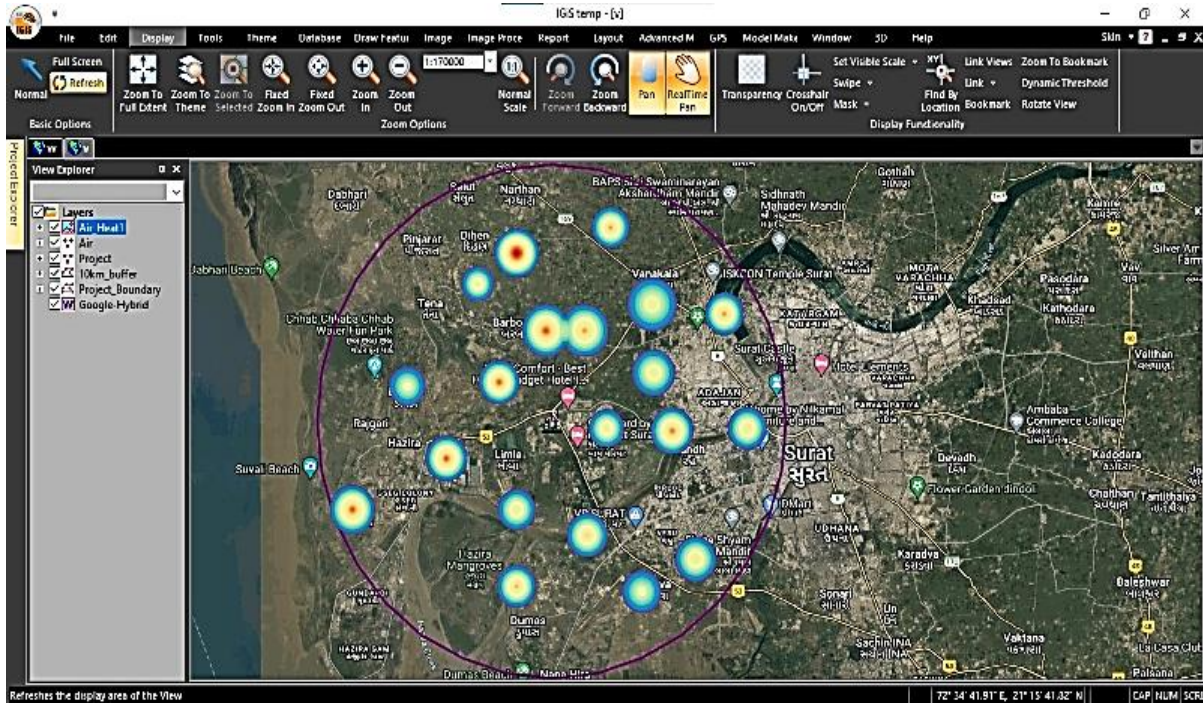


Figure 2: Real-time monitoring by integrating IoT Sensors with GIS, [15].

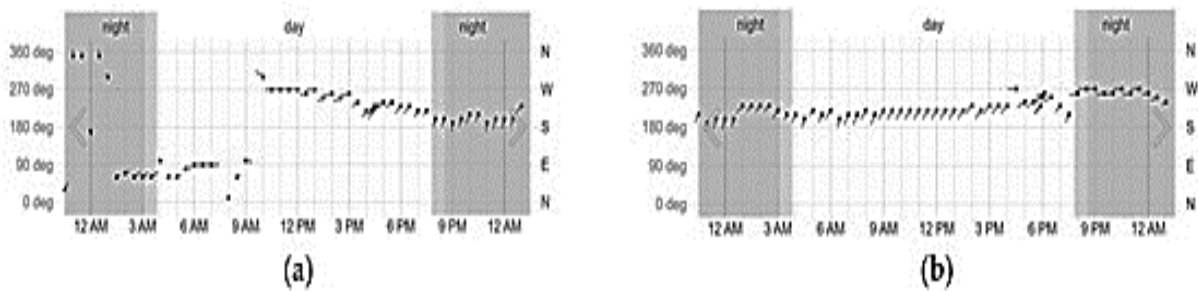
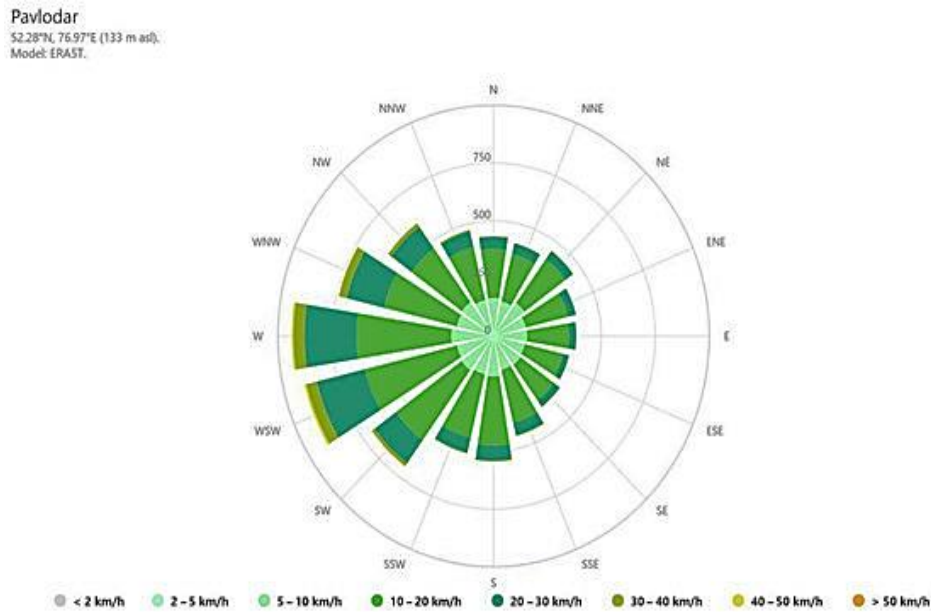


Figure 3: Pavlodar city wind directions according to the sampling period: (a) May 19, 2024; (b) May 20, 2024, measured at Pavlodar Airport at a height of about 10 meters over an open field. Shaded overlays denote night and civil twilight [19].



**Figure 4:** Average historical (from 1940 till now) wind rose diagram for Pavlodar city, [19].

### 2.3. Competitive advantages and operational efficiency

Geographic Information Systems (GIS) are a powerful boost for industrial management as it optimizes the use of the existing facility and provides an opportunity for the companies to make a wise decision. Therefore, by combining spatial data analysis in organizations, they can enhance resource allocation, streamline workflows, and increase productivity. For example, logistics companies use GIS to find the most efficient routes, so their transportation costs are lowered and delivery times are lowered, by using live look at the traffic.

Also, GIS makes supply chain transparency more transparent, so that enterprises can monitor inventory and shipment ranging from inventories to forecasts to the control of inventory. It makes operations less visible, thereby lowering costs and providing agility against market changes which gives a competitive advantage.

Above all, GIS is necessary in the locating of new facility sites that consider demographic trends, consumer behavior. Companies like Starbucks use GIS to evaluate locations, but not in the traditional sense of GIS, to see how customers might be better served and where

customers will generate the most revenue afforded the least risk of placement.

Additionally, GIS allows a business to see one's complex data sets so that it can encourage continuous improvement. Combining different information sources allows organizations to better improve their investments decisions as well as their operations.

The adoption of GIS technologies by industries improves the efficiency within the company and increases its connection with customers based on GIS insights tailored offerings. Organizations striving towards the path of continuous growth and success today look at investing in GIS, for it converts raw data into actionable insight, and also strengthens strategies and retains competitiveness, [1], [2], [6], [13], [20], [21] and [22].

## 3. Enhancing Operational Performance with GIS

### 3.1. Real-time data collection and analysis

Real time data collection and analysis have become important element for GIS success in different industrial sectors. GIS enables lines of sight into the operational lives of businesses by integrating real-time data from several sources (i.e., IoT sensors, GIS, etc.) for continuous real

time monitoring and management of business operational activities. Such capability gives industries the flexibility to quickly adjust, and it helps improve decision making greatly.

Real time data is one of the unique advantages of using real time data in GIS as it allows them to get live insights on the operational metrics such as resource usage, environmental conditions, and the status of infrastructure. An example of this is integrating live data from smart sensors that measure water or gas supply system, in the case of utility management. These type of integration is a timely update of system performance and potential problem, and hence when an emergency or maintenance need come up, they can respond quickly.

Additionally, GIS platforms that also provide real time features may display complicated databases on interactive maps. These visual tools assist stakeholders in getting a better idea of the spatial relationships of the issues at hand through highlighting crucial or problem areas. A metric selects a threshold if it exceeds a predefined value, and an alert is triggered in that case. Proactive measures of such kind increase resource allocation and risk management strategies.

Real time GIS applications are prevalent in sectors like transportation and logistics, where for example, route optimization can make use of analysis of the on-going traffic conditions and hypothesis about the future on the basis of historical data. Major usage is especially important in emergency services that have to drive as they must in major situations. With the help of real time information about road conditions or incidents, organizations can take informed decisions about service delivery which influences better service delivery.

IoT and GIS integration, however, goes beyond the operational efficiency, it performs a vital function towards supporting the sustainability goals in various industries. Incorporating this integration in organizations will enable them to leap frog competitive with increased operational transparency and responsiveness, [14], [15], [23] and [24].

### 3.2. Decision-making support systems

Therefore, Geographic Information Systems (GIS) play a very important role in improving the decision making support systems, enabling the industrial management to take their credit decisions intelligently. With the combination of the spatial data and analytical methods organizations can visualize the complex datasets and enhance understanding and outcome. GIS allows strategists to look at geographic contextual factors such as demographics and environmental factors in planning strategies.

The advantage of GIS lies in the feature that allows it to provide a real time analysis of data, as this enables businesses to monitor processes and react effectively and quickly. For example, a GIS in supply chain management will analyze the transport routes and traffic and, for logistics managers, will help them to optimize delivery schedules and reduce costs. The raw data become trends when turned onto visual representations on interactive maps.

In addition, GIS facilitates efficient resource allocation through the identification of the forgotten areas in the plane for example underserved region in the urban planning based on population density. This allows you to know which initiatives generate the most community value.

The integration of GIS with artificial intelligence maintains the accuracy of the decisions related to handling data from previous instances and projecting the future scenarios. This proactive approach fosters better management practices.

Furthermore, it allows for synergistic group working of teammates like engineering, finance, and operations by providing a common platform for geospatial data and a coordinated approach to strategy. The outcome of this kind of framework is much more cohesive planning. However, GIS is critical to industrial management's modern decision making support systems [1], [9], [14], [15], [25] and many others.

### 3.3. Resource management optimization

Geographic Information Systems (GIS) drastically improves industries' resource management through optimization of resource management. Organizations achieve this by combining geospatial data in operational strategy. GIS makes it easy to visualize resource distribution, can show where there are surpluses and deficits, and makes an organization's decisions based on this fit goal.

GIS's advantage lies in its ability to track resources with real time and analyze irregularities continuously. For example, GIS maps utility line such as power lines or pipeline in the utility sector, and can help study the trend of usage for the purpose of unraveling efficiency or maintenance needs. An approach which is proactive reduces downtimes and improves service delivery.

Furthermore, method to which GIS is aimed at scenario modeling, allowing organizations to investigate alternative resource allocation strategies without implementation. Businesses can determine possible results of given scenarios and best tools to improve performance through simulation of known historical data and Predictive analytics.

Additionally, GIS enables combining different data types in a spatial format and gives business firms the opportunity layer environmental, logistical and demographic information on maps to map out the best sites for operation and or supply chains. This approach creates an environment where the cross department decisions are informed.

GIS greatly aids in the optimization of land use in these fields by combining the spatial analysis with site suitability assessments determining sites that fit the ideal conditions like soil quality and accessibility, whilst maintaining regulatory compliance. In general, the use of GIS technology improves operations productivity, reduces waste and fosters the climate of sustainability, [6], [14], [25], [26] and [28].

## 4. GIS for Sustainable Industrial Practices

### 4.1. Waste reduction strategies using GIS

In order to devise strategies to reduce waste in various industries, one needs Geographic Information Systems (GIS). With the usage of the spatial data and analytics, the organizations can uncover the patterns of waste generation and can enhance the resource utilization. Waste production area can be visualized by GIS, this reduces processes and minimizes material loss for businesses.

One important use of GIS in waste management is to help to visualize production workflows and specifically identify inefficiencies. GIS can help manufacturers optimize the production line configuration by minimizing touchpoints of excess materials and countering scrap materials to be repurposed.

Data analysis is promoted among departments through GIS as well which also promotes collaboration between departments. Such integration enables teams to develop integrated waste reduction strategies based on the logics of the just in time manufacturing and the distribution of resource. Through the examination of geographical patterns and operational metrics, organizations can hone in on tailor waste management practices to the locale, taking into account society's region, such as each region's capabilities in recycling as well as their responsibility in the environment.

GIS is also able to provide support for predictive analytics. If one examines historical waste data alongside environmental variables, one can make sense of how organizations can predict future waste trends to prepare for the inevitable ahead and minimize waste output as a result of such predictions.

In addition, GIS improves the communication with the stakeholders regarding the sustainability initiatives. Visual data representations are a committed orientation to waste reduction and are visualizing progress with clear metrics. Geographic information system (GIS) integration into industrial practices decreases un-informed decision-making and encourages an environmental friendly culture, [2], [14], [17], [28] and [29].

## 4.2. Energy efficiency mapping and monitoring

GIS are important in mapping and tracking energy efficiency for different industries. Usage of GIS technology can be used for organizations to visualize and analyses the spatial data of energy consumption and draw out patterns and inefficiencies. By linking GIS with onetime monitoring, industries can identify points of overspending, areas of excessive energy usage.

In the field of renewable energy, GIS is used to support the site selection for solar panels and wind turbines by considering geographic criteria such as sunlight and wind patterns. That spatial analysis helps to place installation on such that the energy yields are sharp assessments of potential values. On top, GIS is important for the judgment of environmental impact of organizations and keeping them in line with good ecosystems and sustainability.

Through GIS, energy mapping also determines necessary upgrades of already existing infrastructure. Companies can overlay the consumption data on infrastructure maps to facilitate investment decision process of reducing the waste by improving energy efficiency “i.e., targeted interventions.

In addition, GIS based energy modeling can forecast future energy demand for utility provider based on demographic changes and economic activities, in order to plan for such future infrastructural needs.

With advancement in mobile tech and IoT we are having real time data collection becoming more and more attainable. Through the use of GIS platforms powered by sensors all over industrial sites, information is run in real time so that inefficiencies can be spotted and corrected as fast as possible. This approach helps in satisfying the industries’ sustainability objectives and thus lowering the carbon footprints, [2], [8], [14] and [29].

## 4.3. Environmental impact assessments facilitated by GIS

In the context of industrial settings, Environmental impact assessments (EIAs) are conducted by using Geographic information systems (GIS). GIS offers the power of providing the industry with spatial analysis tools to visualize and quantify the impacts that its operations have on the environment and thereby meet stringent regulatory requirements facing the industry.

Companies also learn how their action affects local biodiversity through mapping of sensitive ecological areas that GIS excels at. GIS can overlay industrial regions with natural habitats data for instance to make comprehensive evaluations of the potential for impacts to wildlife. This insight helps decision makers in planning strategies for counteracting impacts of events such as relocation of operations or buffer zones.

Moreover, GIS can help in collecting data on emissions and inputs of resources in various industrial processes. Integration of real time monitoring of the environment with geographic information allows industries to monitor the trends and affected areas presence in order to make informed decision regarding mitigation and allocation of resources.

Additionally, the use of GIS during the EIA process improves stakeholder engagement by presenting complex data to those in the community and regulatory agency, as non-experts, in visual, manageable formats. Interactive maps are effective to illustrate how this could affect the stakeholder.

The use of GIS within EIA therefore contributes to continuous improvement towards sustainability; the industries can examine historical data and improve their modes of practice to reduce their environmental footprint; this leads to accountability and compliance with regulations, [19] and [30].

## **5. Improving Efficiency through GIS**

### **5.1. Workflow automation through spatial analysis tools**

Spatial analysis tools have automated workflows, thus transforming industrial management processes to optimize and improve productivity of organizations. Working of the geographic information system technology takes the manual work and performs them automatically in a much less time and with lesser errors. ModelBuilder in ArcGIS allows the user to create complex models to simplify data processing and analysis.

Moreover, programming languages like Python make both easy and simple to change and fine tune GIS activities to meet specific needs, a large part of which can be automated, letting you run repetitive operations (data cleansing, report generation) with minimal intervention from a human. It frees team to do strategic planning and making decisions.

Finally, real time information based data collection systems enhance efficiency by providing the need for timely information required for operational decisions. Mobile GIS enables prompt entry of field data and ensures availability of the most up to date information to stakeholders who can then allocate resources more efficiently, optimize inventory management, and reduce any time delays associated with standard reporting.

GIS workflow automation in such sectors as transportation and utilities helps keep infrastructure and assets in good working order, proactively. Continuous spatial data analysis helps organizations predict maintenance needs, early detection of urgent issues, and reduced operational cost and hence improved service delivery.

In addition, GIS visualization tools render them useful with the provision of interactive maps and dashboards that exhibit complex datasets in a communicative way so that non-technical staff may have access to the insights. By capitalizing on these tools efficiently, organizations can increase productivity and

develop an innovative environment that is based on reliable data, [6], [24], [27] and [29].

### **5.2. Enhanced supply chain logistics using GIS insights**

Because Geographic Information Systems deliver spatial data analysis, they are very helpful in enhancing supply chain logistics. However, by using GIS with supply chain management businesses will have a better land routing, inventory control, and improve delivery schedules.

GIS has a key advantage in that it can analyze transportation networks for the most efficient delivery route. Real time traffic data thus reduces transit times and reduces costs and increases satisfaction to customers. Additionally, GIS helps companies foresee possible disruptions from road closures, bad weather or any other adverse event.

Geographical mapping of stock levels to inventory management is made possible by GIS and enables the placement of goods based on demand forecasts and inventory management. This guide allows the organizations to effectively allocate resources without wasting a lot of inventory and addressing shortages as per each situation.

It also makes visibility across the supply chain more possible, where the stakeholders have the ability to see in real time a shipment, its status change, or a delay. By operating transparently, it supports the sort of collaboration that suppliers and customers can have on the basis of reliability.

Further, GIS support the use of advanced analysis for predictive capabilities by analyzing historical sales and geographic trends for accurate prediction of future needs. And that allows for fast changing agile supply chain to respond to the market change. Integrating GIS is also helpful for improving sustainability efforts by reducing fuel consumption and carbon footprints as well as optimizing transportation routes and increasing efficiency to more efficiently run the operation, [2], [3] and [27].

## **6. Case Studies: GIS Applications in Industrial Sectors**

### **6.1. Manufacturing sector applications of GIS technology**

Geographic Information Systems (GIS) is a transforming force in the field of manufacture and helps in operational efficiency and making better decisions. In addition, spatial analysis is used for performing spatial analysis on operational components such as resource distribution, logistics in a supply chain and facility layout optimization by manufacturers who use GIS technology to visualize production data. When integrated with other enterprise systems such as Enterprise Resource Planning (ERP) and Manufacturing Execution Systems (MES), turnover is gained as organizations attain a holistic picture of their operation.

The selection of sites for new facilities is the most important application of GIS in manufacturing. On the other hand, Companies use Geospatial data to assess potential locations on grounds of transportation, proximity to suppliers, workforce availability and environmental concerns. The use of this evidence based approach allows businesses to face a decisional environment, which is either credible in their strategic objectives.

Already GIS is essential for improving supply chain logistics. Here, for example, manufacturers can investigate spatial trends for transportation routes and delivery schedule, they can reduce cost and improve the service quality. As the organizations utilize real time data analysis using GIS tools, they can quickly respond to change in demand or squeezing in the noise that occurs along the supply chain without any notice.

Additionally, GIS supports effective asset management for manufacturers. Thus, it enables building up of the location and maintenance schedules over time in order to probe into reliability and decrease downtime. Such capabilities are key for keeping high production output quality standards high as well as to increase overall productivity.

Another of the important functions of GIS is their contribution towards risk management. Geographical data of natural hazards or regulatory requirements can be used for risk based assessment of environmental hazards and environmental risks for manufacturers. It contributes positively to formulating mitigation plans, which are aimed at protecting both employees and the environment.

In summary, the use of GIS in manufacturing processes facilitates great efficiencies by optimizing the logistics supply chain, improving site selection decisions, managing assets more expeditiously, and examining completely the risks that could potentially occur to manufacturing operations, [27].

### **6.2. Transportation industry case studies utilizing GIS solutions**

Geographic information systems (GIS) integration has provided transportation sector many benefits by using different applications that help in operation efficiency, improvement of logistics, and other strategic planning efforts. For instance, the Portal of the Rail Industry Geographic Information System (RIGIS) is an example of a portal where the GIS maps and tools have been tailored to the needs of railroad companies. It facilitates users to look over, update and share this GIS data concerning their assets to achieve enhanced visualization and analysis of rail networks.

Another important example is the prediction of shipment routing under disruption in freight transportation, which is exemplified by a comprehensive multimodal freight model developed in the Washington State. The model can assess resilience of different sectors based on their dependence on critical transportation corridors, and data driven decisions can be made regarding infrastructure priorities.

GIS has enough capability to optimize delivery routes for companies like FedEx and analyze real time data on traffic conditions and road status. Such features not only reduce the fuel consumption but also promote the delivery efficiency so that the customer is satisfied overall. This approach is also adopted by Amazon, which uses GIS technology to map

the product distribution across infrastructure information for its global logistics run and in turn optimize its delivery networks.

Moreover, GIS is equally important to enhance safety and risk management in the transportation sector by means of strategic planning add Widget Most popular tools, which screen potential hazards on transit routes. On the other hand, it is possible to overlay geographical information with historical incident data, which will allow agencies to reallocate resources for emergency responses.

In urban planning, cities leverage GIS solutions to set up smart transportation systems that gather public transit schedule with traffic punctually then make available to residents lavish voyaging options. Spatial analyses of these systems can promote alternative travel modes under the reduction of congestion and improvement of air quality. These case studies taken together, illuminate the effects of GIS on operational efficiency and in decisions taken within the domain of the transport industry over various, [6], [31], [32] and [33].

### **6.3. Energy sector advancements through GIS integration**

The usage of Geographic Information Systems (GIS) in the energy industry has enabled a significant growth in the energy industry and has made it possible for the industry to be very efficient in operations and environment responsible. GIS provides energy company with tools for conducting complexity spatial analyses, such as site selection of renewable energy project (Solar and Wind installations). GIS maps these environmental factors such as solar radiation and wind strength which allow stakeholders to make these informed decisions in the planning stages. Additionally, energy generation and distribution systems that can be monitored in real time, for reliability and for greatest efficiency, is made possible by this technology.

Due to the oil and gas related mapping needs, GIS has a significant part to play in the oil and gas sector by providing mapping tools that are comprehensive and useful in exploration activities, pipeline routing and facility

management. Geological data can be analyzed alongside logistical considerations, enabling the operators to decide on drilling locations carefully that will minimize environmental impact without jeopardizing maximizing the benefits associated with differential drilling. Moreover, GIS enhances the management of resources by outlining infrastructure requirements and evaluating risks that may arise from natural resources.

Indeed, the economic exploitation of the lithium field will also enjoy important support from GIS. Spatial information is used by companies to find profitable lithium deposits while taking into account the environmental liability and transportation logistics. Not only does this method simplify the extraction processes but also in accordance with the objectives of sustainability operations reduce ecological disturbances.

A 'geospatial enterprise' emerges whereby the integration of advanced GIS analytics of their utility systems is made with existing utility systems, driving collaboration within different energy organization sectors. The strengthened decision making based on very accurate locational information also helps in improving data accuracy.

Furthermore, the GIS applications in the energy sector have also received great progress in the context of cloud computing assisted accessibility and efficiency. More sophisticated application such as microgrid development can be made possible by this progress. Generation of detailed grid models that contain geospatial information across a multitude of sources such as meteorological services, social media, etc. by utilities enable real time situational awareness thus enhancing the utility's ability to operate in a more efficient manner, [8], [23] and [34].

## **7. Challenges and Barriers in GIS Implementation**

### **7.1. High initial costs and resource allocation issues**

The application of Geographic Information Systems (GIS) to industrial management often

involves high initial investment and distribution of resources. Bumping up to advanced hardware like high performance computers and specialized servers, coupled with the cost of software licenses are often out of small organizations' reach and can stretch (financial) budgets. Apart from this, it also costs a significant amount on account of ongoing maintenance and updating.

However, the implementation is complicated further because of resource distribution issues. However, it becomes challenging for many organizations to hire skilled people in managing GIS technologies and it can cost so much as well as take significant time for training existing people, which results into delayed projects and low productivity. Similarly, GIS may not be usable to companies that do not employ dedicated GIS teams due to unmatched compatibility with existing workflows.

A key to successful GIS implementation is collaboration between departments since working with data in which the needs and expectations of different people vary is always required. However, conflicts over resource prioritization can occur between the people working on the projects that are insights based or spatial based, and this can become a hindrance to progress.

It helps that managing spatial data is no different than any other information, with organizations having to make sure they have the right equipment to integrate and share data. There are substantial barriers that organizations need to handle quite carefully when it comes to the interaction between technological demands and human resources. Businesses need to create comprehensive planning strategies in order to solve the problem of budget constraints and resource optimization so that businesses could fully utilize GIS technology with an initial financial limitation, [4], [6] and [35].



Figure 5: Challenges in GIS Implementation, [4].

## 7.2. Data quality and integration challenges across platforms

GEDIS has serious barriers to usage; the major challenge being from data quality and integration. One of the main issues with different data sources is the lack of standardization, thus making it erroneous with

respect to each other. Data formats, coding methods, or classification standards may differ from one system to another which makes it impossible to merge datasets and hence a lot of time will be spent in data cleansing, before any useful analysis takes place.

In addition, many GIS projects fail because information is siloed, meaning it is entrenched within each department or agency. It prevents collaboration and provides no full view of geospatial data. For instance, if a particular area's mapping is available on one level and not on another, then the combined planning and decision making processes can be extremely hindered.

Technical expertise for successful integration with GIS is another complicating aspect. The first problem is most organizations struggle a great deal to attract and recruit skilled professional with GIS expertise and other related topics in data science like programming, scripting, and implementation of such GIS using various platforms such as ArcGIS, QGIS, and others. Not only does this create skills gaps, but it makes it difficult to manage and upgrade already existing systems in order to efficiently incorporate new technologies or updates.

On top of this, continuous data quality also faces an additional challenge as stale or inaccurate data can lead to suboptimal outputs of decision making. However, monitoring and updating of datasets in a continuous fashion are very important but tend to set additional demands on organization's resources which are very hard to justify.

Adding real time data from all kinds of sensors or Internet of Things (IoT) devices to an existing GIS framework is a very complex affair. Being compatible, among these various sources, is very costly in terms of technology and human expertise.

The integration process, however, also takes into account privacy considerations. With the detailed geospatial databases, it is important to ensure compliance with the privacy regulations while preserving the quality of the insights drawn from such databases, [11], [36], [37] and [38].



**Figure 6:** Challenges and Future Trends in GIS for Infrastructure Development, [38].

### **7.3. Resistance to change within organizations**

The adoption of Geographic Information Systems (GIS) in organizations is strongly inhibited by resistance to change. Often, this reluctance is rooted in an enduring population that considers GIS disruptive, not beneficial. GIS benefits are not always obvious to employees and they may question the need for a new system.

This resistance is further exacerbated by skepticism on the use of data driven decision making. Until recently, decision makers have

not considered data analytics before resorting again to personal instincts, causing them to be unfairly wary of the use of new technologies like GIS. While data-centric approach is where most people want to move, this is not something new but rather a transition, and it is not simply about using new tools, but also reevaluating the conventional transitions in decision making.

This transition can become more complicated given the organizational hierarchies. Communication of GIS's value is sometimes obstructed by bureaucratic structures that could create delays or pushback because of fears of

disrupting current power dynamics. Changes that affect individuals or their roles as employees may not be accepted by them.

Also, there is little awareness regarding GIS's ability to foster operational efficiency and decision making and this leads to rejection. Employees who lack training and education on the potential functionalities of GIS may find it difficult to adjust to the change.

This is crucial because helping managers with compensating for these challenges requires ongoing support through comprehensive training. The discussions can help open departments up to encourage collaboration among each other. A clear vision on how GIS can improve operations should be provided by leadership, which should focus on role of GIS in increasing decision making across functions, [6], [14] and [37].

## 8. Future Trends and Innovations in GIS for Industrial Management

### 8.1. Integration with artificial intelligence (AI)

The industrial management is greatly increased with artificial intelligence (AI) integrated into Geographic Information Systems (GIS). However, the data processing of geospatial data is complicated and not well suited for manual intervention. AI is able to see the insight in large datasets that it's difficult to get by hand.

Another very important application of AI in GIS is predictive modelling – machine learning

forecasting trends in spatial data, for example, supply chain demand or optimal site selection under demographic and transportation accessibility. The capability gives organizations the ability to be proactive, as opposed to reactive.

AI too aids in data analysis quality, it becomes more accurate by an algorithm that detects anomalies and filters noise, thereby generating a high quality output for strategic planning. GIS platforms powered by deep learning models can draw complex spatial relationships and offer actionable recommendations.

Apart from predictive analytics, AI also helps in real-time decision making as it brings IoT devices in association with GIS technology for immediate updates from the sensors or from mobile sources. For example, such as current traffic conditions can help in the analysis of fleet management systems based on the routes.

In combination with GIS and AI, such an approach also facilitates implementation of sustainability efforts by helping organizations understand environmental impacts, evaluate their resource allocation during planning of projects. In this case businesses can simulate scenario using geospatial data and AI insights to develop a way to minimize the energy and waste they create. In general, the inclusion of AI in GIS brings about changes in industry's methods of spatial information interpretation and utilization, [14], [34], [37] and [39].



Figure 7: 25 Trends Shaping the Future of GIS and Location Intelligence in 2025, [39]



**Figure 8:** Location Intelligence Trends in 2024, [39].

## 8.2. Advancements in mobile GIS applications

In recent years there has been a great deal of development in mobile GIS applications and these mobile GIS applications have, fundamentally changed the way spatial data is collected, analyzed, and used in real time situations. However, by putting these geospatial capabilities into easy to use field personnel tools, such as their smartphones or tablets, they allow field personnel to be more efficient. Because of the advances in mobile technology, GIS software developers are making their offerings better so that they can develop more and more sophisticated mobile applications that work seamlessly with cloud environments.

The propagation of real time data analytics in the context of mobile GIS becomes a major advancement. The benefit of this innovation is that users can collect more than just location data and use it to gain contextual insights that can be processed instantly resulting in better decision making process. For example, in the case of a time-sensitive industry, such as infrastructure management, field inspectors can assess conditions directly on site and immediately keep updated databases which is essential in time critical cases.

Moreover, mobile GIS with augmented reality (AR) helps to engage users by adding digital information over the real world. For individuals that work in fields such as urban planning and construction, this functionality enables visualization of projects in a physical context prior to construction. AR helps users conceive how new constructions will fit with existing

buildings and landscapes and improves planning and risk assessment.

Since sensors and computing capabilities of smartphones keep improving exponentially, so does the possibility of mobile GIS. These applications are becoming progressively quick to feature such things as GPS tracking, live mapping, and interactive visualizations. Additionally, the dissemination of data across platforms is easier, as technologies within the communication sphere become more and more advance and allow such actions to be done with just a flip of a button.

Mobile GIS is increasingly relied upon for all types of industries from agriculture for crop monitoring, environmental management for habitat assessment, transportation for route optimization. The continued use of these technologies by organizations will see mobile GIS applications used in forming industry operational strategies and to increase productivity in such frameworks [29], [40] and [41].

## 8.3. The role of cloud computing in enhancing accessibility

Today its (cloud computing) force is truly transformative for Geographic Information Systems (GIS) as in any other sector it makes its accessibility and usability much more easily available. With the migration of GIS resources to cloud platforms, organizations can store, process and analyze large volumes of spatial data without any logistical restriction of the commonly accepted on site infrastructures. The results of this shift do not only get rid of hardware constraints, but also make the playing

field even for a very wide range of stakeholders from public institutions, to private enterprises, that can make use of GIS tools effectively.

Cloud solutions are scalable so businesses can quickly adjust their GIS performance in accordance with the fluctuations of demands or requirements consideration of a project. So, for example, they can use services tailor made to their particular needs using such models as Software as a Service (SaaS), Imagery as a Service (IaaS) and Applications as a Service (AaaS). They help facilitate a customized use of geospatial technologies with low capital investment in physical infrastructure.

Also, cloud GIS allows different users to collaborate in real time based on sharing and analyzing data. Centrality databases provide for the collaboration among the stakeholders seamlessly, making it easy to make decisions. This collaborative environment of transparency and opinionated talks arise out of resource management and urban development initiatives actions.

Additionally, cloud computing advances makes integration with the other advanced technologies simple, for instance artificial intelligence and machine learning. With these integrations, versions of capabilities like predictive analytics and scenario modeling are there to quickly derive actionable insights from the organizations' geospatial data.

Since GIS is within the cloud computing realm, as cloud continues to grow, it is clear that organizations involved in cloud computing will be able to achieve higher operational efficiency and better access to essential geospatial information, [40], [42] and [43].

## 9. Conclusion:

### Leveraging GIS for Long-Term Industrial Success

For sustainability success in the long run, industrial management cannot go without a geographic Information integration (Geographic Information Systems (GIS)). GIS spatial capabilities allow organizations to minimize mistakes in decision making, allocating and managing resources, and

consequently increasing operational efficiency. The more industries develop, the more evident it is that data driven approaches are becoming importance. GIS goes beyond the visualization of complex geographical datasets and helps to understand the patterns and to predict.

The use of GIS in the industrial field has an important role due to innovation. Applications of state of the art technologies like artificial intelligence and Internet of Things (IoT) helps in real time tracking of the assets and enhance the predictive maintenance can greatly. The synergistic relationship between GIS and the emerging technologies promotes a proactive resource and infrastructure management and resolution of operational problems.

Beyond that, sustainability is becoming a definite criterion that all industries take into account. GIS enables organizations to explore and predict environmental impacts, enhance the energy efficiency, and execute waste reduction strategies efficiently. Integration of GIS into their work by organizations helps them not only satisfy the regulatory requirements but also give them an advantage in the market.

However, to enable full use of the many advantages GIS provides in industrial management, there are problems that organizations have to cope with, such as high implementation costs and employee resistance to change. Clearly, it is possible to educate staff as to what GIS technology can do. DGIs must collaborate across departments in order to make sure geospatial data is used to inform decisions at all levels.

The continuous progression of technologies will increase the power to industries that would adopt GIS solutions. Even with use of the tools becoming more intuitive and user friendly, smaller businesses will also be able to use geo spatial analysis without the need for extensive resources or even specialized expertise. It is no longer an option to get into GIS, but rather an essential way of contributing to the resilience and adaptability of industries in an ever more complicated global environment, [8], [14], [20], [38], [41] and [44].

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