The Geo-centric Railway

Why Location Matters in the Rail Industry

Crossrail

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Introduction

The use of maps and mapping technology within the transport industry is growing as the larger digital revolution continues to disrupt and change the way in which traditional tasks are undertaken. The method of conveying information through cartographic output has been present within this industry, and particularly within the rail sector, for many years but the increased awareness and benefits seen from digital processes such as Building Information Modelling (BIM) have made the use of mapping technology more valuable than ever. This paper sets out to explain why and how location is used within the rail sector, providing a background to its use before setting out some clear and precise examples of what benefit the knowledge of where can provide. This paper will also provide some insight into what could come next for such technology within the rail industry.

"Digital processes such as BIM have made the use of mapping technology more valuable than ever."

What is GIS?

GIS (Geographical Information Systems) is the broad application of digital technology to impart and communicate information to users primarily through the medium of maps and other cartographical output. This includes the management, analysis and presentation of data and information centred around location to a variety of end users, each one having a different requirement on what they want to see.

Why Does Location Matter?

Railways typically cover large distances in a linear fashion, with a dense overlay of infrastructure located alongside the track, and with stations and other facilities dotted along the way at regular intervals. Because of this wide geographical extent it is essential that the location and nature of all relevant facilities and assets is known and understood. This can vary from relatively static infrastructure (such as the permanent way and signalling equipment) where location will not significantly alter in the short term, through to dynamic infrastructure (such as rolling stock and even staff) where location is constantly in flux.

Without the knowledge of where assets are, managing them becomes an order of magnitude more difficult. How can someone repair a signal if they do not know where it is? How can live updates of train schedules be managed without knowing the current location of a train compared to where it should be? Because of this the understanding of where objects are in relation to each other, as well as in the wider holistic view, is fundamental to the understanding of other questions that might be asked. If an incident occurs, what is nearby and therefore affected? Did that piece of equipment fail because of its location? Where are people coming from to cause the congestion at the station? For all of these questions, Geographic Information Systems (GIS) can provide the answer.

Where Does GIS Fit In?

"GIS is the optimal method for centralising and coordinating these activities."

GIS is the technology that enables the where question within any real-world geographic context to be understood and answered. Specifically within the rail industry this allows the project, owner, maintainer or operator to understand where their infrastructure and assets are at any given moment in time. Additionally, GIS can be used to analyse such data to glean insights into its performance, condition and operational capability, as well as answer plain language questions from the business such as "What assets would be affected by work carried out at location X" or "How do I get to location Y?"

For a typical railway organisation their business landscape (Figure 1) the where question, or the part that location plays, is critical in end-to-end operations, underpinning many of the decisions that are made on a daily basis. It can be seen from this diagram that location is vital to many of the operations that a railway will need to carry out, and that use of GIS is the optimal method for centralising and coordinating these activities.

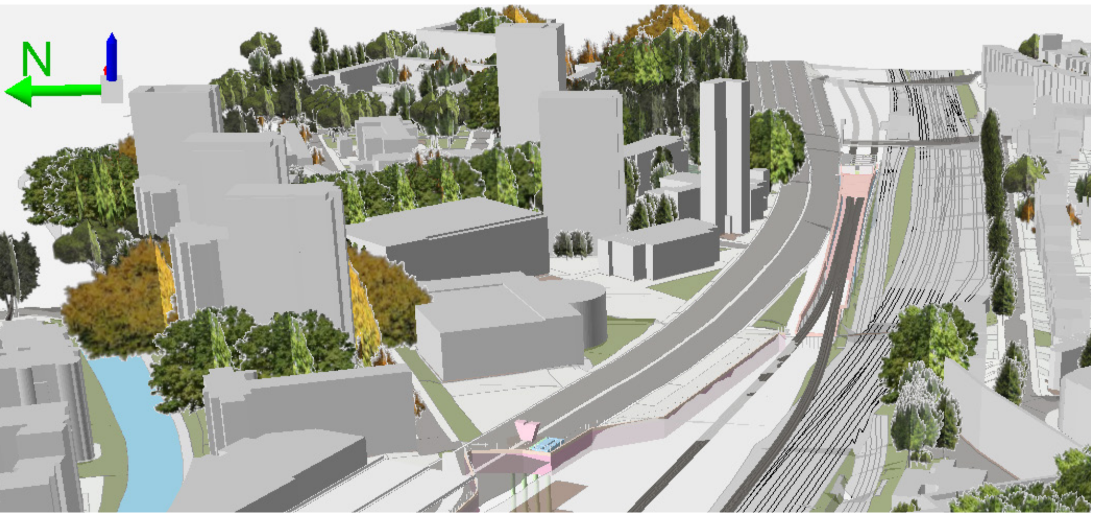
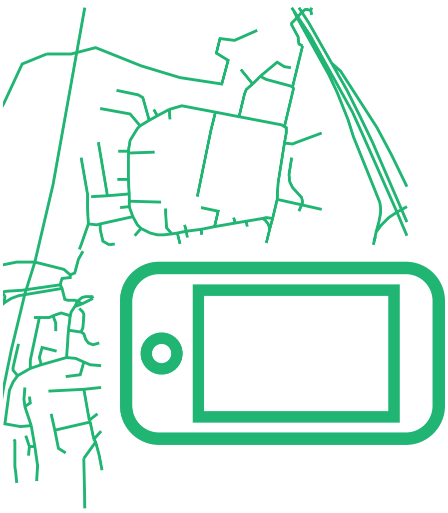


Figure 1: Location in Railways

What is BIM?

BIM (Building Information Modelling) is the use of defined processes, supported and enabled by technology, to manage an information model collected about objects in the built environment throughout their lifespan, from planning and design through operation to decommissioning or disposal.

BIM & GIS



The fields of BIM and GIS are inextricably linked, and have been so ever since the early days of BIM. GIS provides the tools and processes to geographically enable BIM so that, throughout the lifecycle of assets, an understanding of the contextual surroundings in which that asset exists can be included.

But it goes further than that. GIS has been at the forefront of technological evolution for many years now and long gone are the days of storing data in files to be viewed on desktop PCs. GIS applications and the information they contain are now typically provided through a web based interface, sourcing data from web-enabled services that are hosted on Relational Databases Management Systems (RDBMS) or other mass storage architectures. This allows data to be stored and managed in far more effective ways than traditional BIM technologies which still typically rely on desktop access to files.

The BIM movement should take note of what GIS has achieved in the last 20 years, particularly the adoption of international standards on the storage and sharing of geographic data, which has allowed for true interoperability. In essence, data has become separated from the tool which uses it; allowing users to directly access data from anywhere and vendors to focus on how the tool uses the data, rather than what tools can even use such data.

What Benefits Can GIS Bring?

This section is divided into a number of sub-sections, each focusing on a different part of the lifecycle of the railway. Each of these sub-sections discusses how and what benefits location enabled data and the GIS that consume it can provide to the rail industry. This covers the benefits and practical applications that can be addressed by infrastructure managers throughout the lifecycle (Figure 2) (Steen, 2009), from planning and design through to operations and maintenance. This will then be followed by a sub-section focusing on the practical applications and benefits of GIS as used within spatial analytics and reporting realms, citing specific examples of where this has already been achieved. A final sub-section focuses on how GIS can be utilised as an Information Management system to connect and manage this information and the benefits that location aware data can bring.

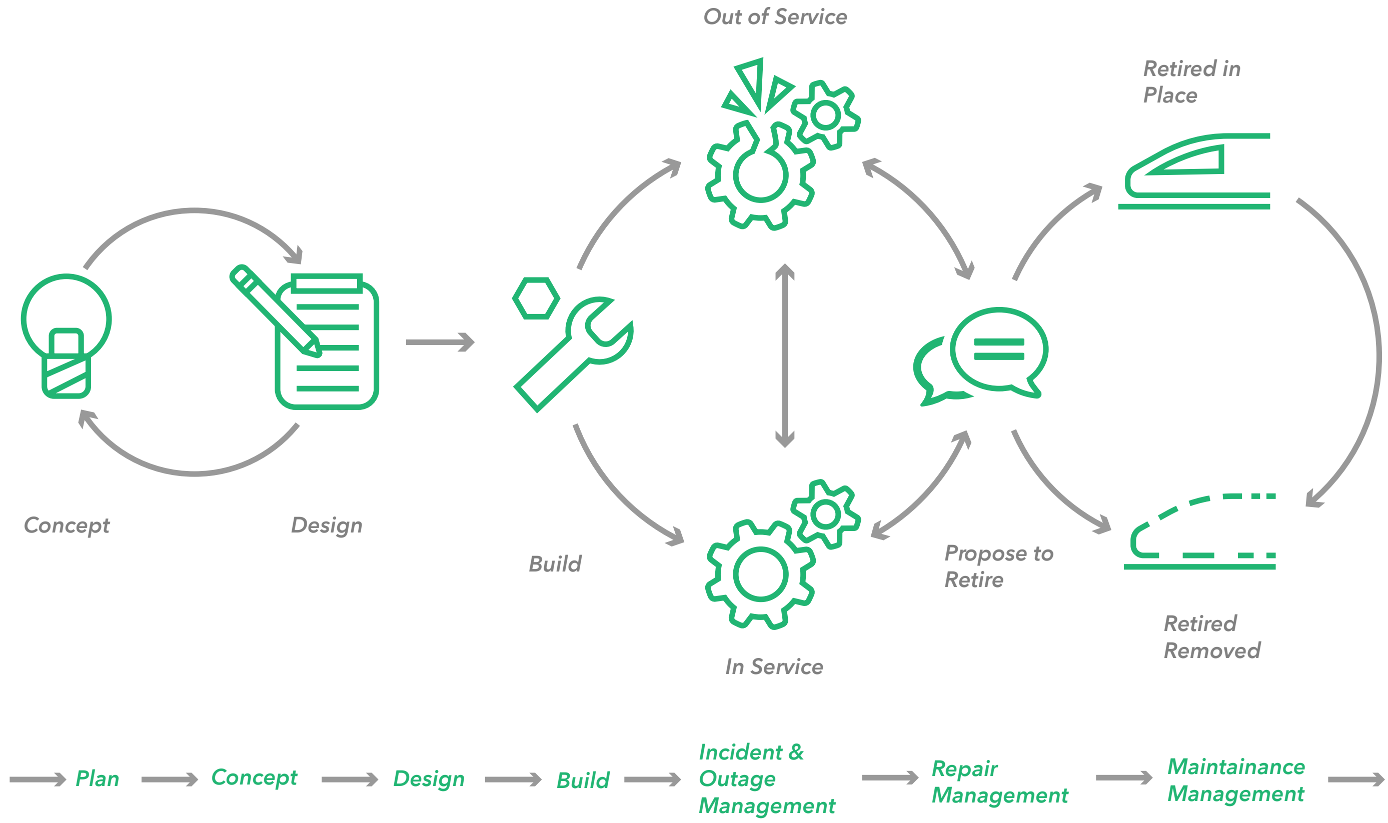


Figure 2: Typical Asset Lifecycle within Railways

Planning & Design

GIS has always been a primary tool for planners to assess the options for development, whether that be new construction, redesign of a station layout, creation of new access or egress points, or working with third party developers who might be building on adjacent land. The ability to visualise and analyse not just the proposal itself but also the impact on its surroundings is vital to a successful design, and GIS has a proven track record of enabling this.

GIS can also be used to assess the land requirements, both in terms of acquisition (if necessary) and occupation, of the project at this stage.

Other uses of GIS at this stage include:

- Ground Investigations (Geotechnical surveys)
- Surveying (tied in with CAD / Point Cloud)
- Track Design (including determination of settlement for sub-surface construction)
- Flood Risk Assessments
- Third party structure / infrastructure assessments, including defect surveys through field data collection
- Travel Time modelling (see below) to assess the effect of a project on the travel times for commuters, presenting both a before and after picture
- Pedestrian flow modelling to assess the effect of design on the flow of commuters through the facility
- Use of multi-discipline geospatial data sources to calculate optimal site selection

Specific benefits from using GIS that have been identified at this stage within rail organisations include:

- Proximity Analysis (see Analytics & Reporting, below) to determine properties affected by construction works, saving 5,000 person hours per year (Crossrail, Crossrail 2)
- Reduction in time taken to find information, based on the intuitive, efficient and accessible GIS interfaces (Crossrail, Skanska, Crossrail 2)
- Reduction in time taken to carry out site work and reduction in loss of productivity through collaborative tooling (Skanska)
- More decisive planning decisions based on better quality information as well as using GIS as an audit trail and assurance of work completion (Skanska)
- Line-of-Sight analysis (see Analytics & Reporting, below) to establish the optimum placement position of signalling equipment (Network Rail)
- More efficient and cost-effective Information Management of Safeguarding by mastering information in GIS (Crossrail 2)
- Semi-automated environmental impact options appraisals for proposed worksites using GIS (Mott Macdonald)

Construction

Once design is at a suitably agreed state construction can begin, and this opens GIS to a new field of use. As construction proceeds, GIS can be used to track the progression of works, as well as act as focal point for information to be accessed from the project. Elements of this include:

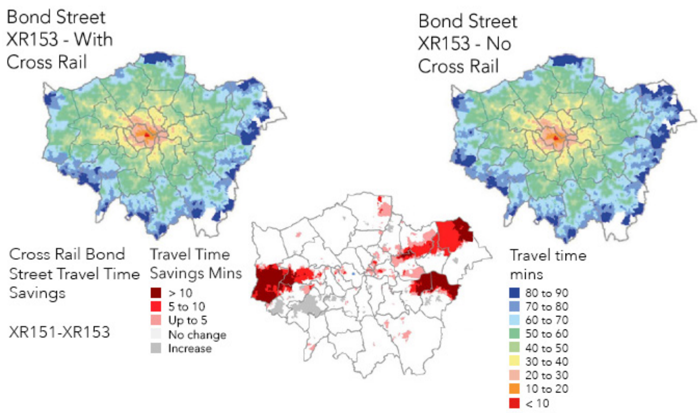
- Mobile GIS capability for site workers to carry out location-based activities and tied into project planning and management software to provide real-time updates on progress
- Spatio-Temporal (4D) analysis (see Analytics & Reporting, below) to track and provide updates on progress to construction activities
- Use of proximity analysis (see Analytics & Reporting, below) to advise of activities that are taking place outside their designated area
- Integrate BIM and GIS data to provide greater certainty over the state of project through construction sequencing
- Development of Asset Information Model (AIM) in line with client requirements, linking asset modelling to asset information

Planning Case Study: Skanska

Skanska are using mobile GIS to enable site workers to carry out ground investigations, providing real-time updates on progress and enabling collaboration with associated teams that need access to a given site. This is shared across multiple disciplines and provides progress estimates to streamline handover of sites between disciplines. This data also acts as an audit trail and provides both assurance and reporting capabilities to senior management that deadlines are being met.

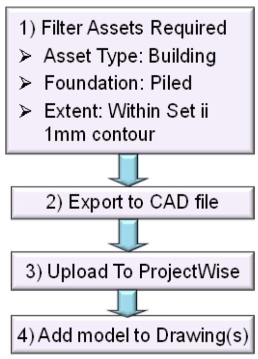
Planning Case Study: Transport for London

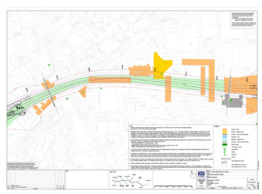
Crossrail and Transport for London (TfL) collaborated early in the project to assess the impact of the new railway on the journey times of commuters across London and the South-East. Using geographical origins (output areas) against a single destination (Bond Street in the example below), they were able to model the delta in journey times depending on a number of design scenarios. This assisted TfL in proving the business case for Crossrail and allowing the project to proceed.



Design Case Study: Crossrail

Crossrail used GIS extensively to assess ground conditions and record information about potential obstructions to the tunnel construction. This included identification and monitoring of all structures that were at risk from settlement resulting from engineering activities, and this information was linked to CAD, Document Control and reporting applications to provide outputs to stakeholders on the project. Engineers could select the structures they wish to view and export these into a CAD model.



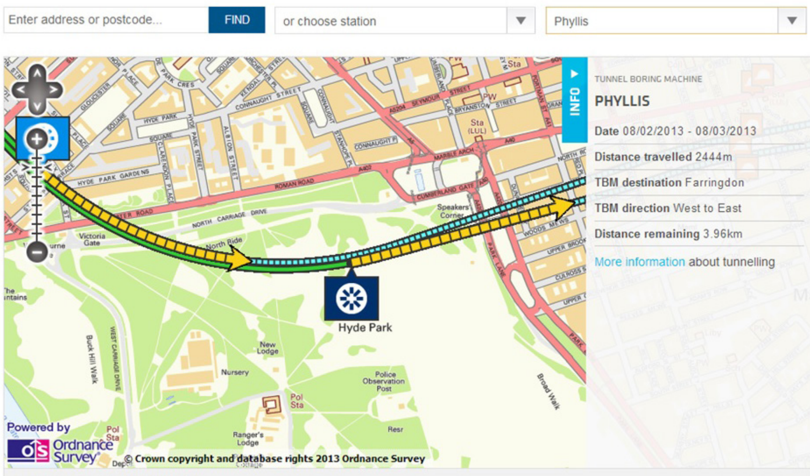


Specific benefits from using GIS that have been identified at this stage within rail organisations include:

- Proximity Analysis and Reporting (see Analytics & Reporting below) on progress of utilities investigation and non-destructive testing and implementation of remediation / mitigation measures against TBM progress to identify at risk activities (Crossrail)
- Spatial monitoring of noise, vibration and other hazards to prevent excess disturbance during construction works (Crossrail)
- Semi-automated reporting on claims of damage or disruption during bored tunnel construction, based on spatial and temporal extents to establish validity of claim, with an estimated saving of £120,000 (Crossrail)
- Geospatial Management of land occupation by contractors during construction, resulting in an estimated saving of £90,000 per year (Crossrail)

Construction Case Study: Crossrail

During the course of the tunnelling for Crossrail, data on progress was fed back directly from the Tunnel Boring Machines (TBMs) to Crossrail. This enabled map-based reporting of the progress of the TBMs to be made available to both internal project staff as well the public. This resulted in transparency of the progress of Crossrail works to all parties which led to better decisions being made about associated construction that needed to be carried out within the facilities.



Operations & Maintainence

Once the construction is complete and the infrastructure moves into the operational domain, the use of location-based data shifts once again to fulfil a different set of requirements from preceding phases. However data can be handed over from the planning, design and construction phases to support operational activities, as long as they have been built with operations in mind and are relevant to the activities that this part of the lifecycle entails.

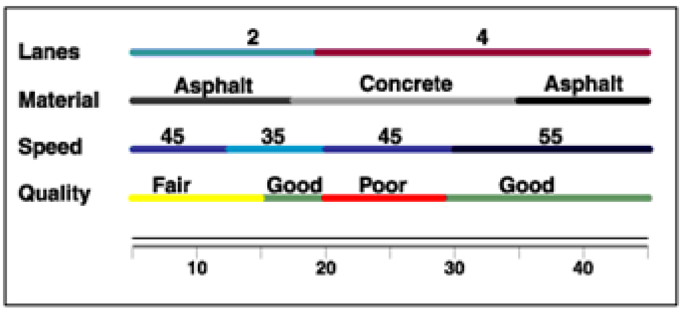
From an operational perspective knowledge of the location of both static and dynamic assets can be critical to the successful running of a railway. This might include real-time positioning of rolling stock to monitor reliability of the service, or knowledge of the location of facility staff to be able to optimise staff positioning during different times of the day (for coping with peak demand etc.).

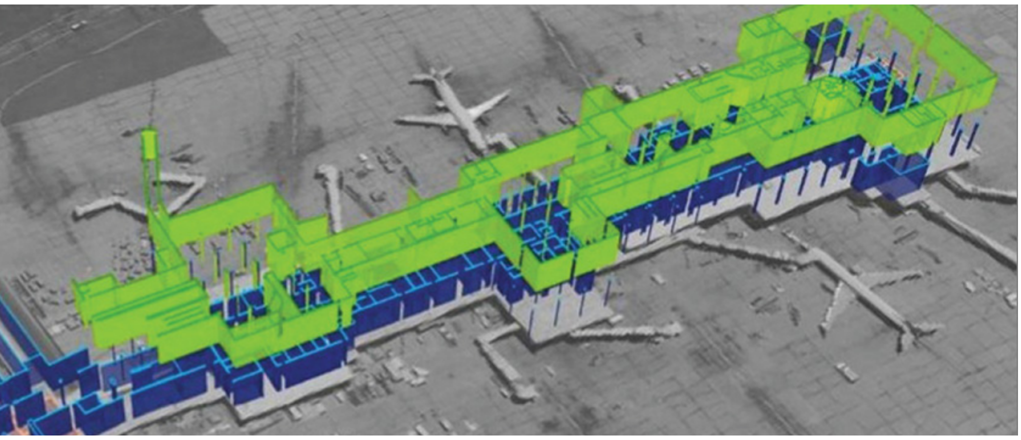
In addition to the daily running of a facility, GIS can be used to analyse and aid the efficiency of a station. This includes:

- Pedestrian Flow Modelling to assess the capacity to respond to station overcrowding
- Assisting in the design and implementation of emergency evacuation routes and locating emergency or safety critical equipment in an emergency situation, including locating points of access and egress for emergency services.
- Making available routing capabilities to assist the public in navigating through the facility (Figure 3)
- Use with Access Management software to provide location, route and obstacles to accessing locations, including hazardous materials, locked or restricted areas
- Use of location based events alerts to warn station staff when they are in dangerous or hazardous areas, outside of the remit of their maintenance activities or when other tracked items or people are likely to come into contact
- Using of linear referencing and routing technology to generate patrol routes, maintenance routes and other navigable directions (including distance and time) for maintenance crews

What is Linear Referencing?

Locating specific places on long linear features such as rail track can be a difficult task, particularly if such track is underground or in a remote location. Linear Referencing is often used to describe the position of an asset, activity or problem in such locations. This uses a simple distance measurement from a known location along the track, sometimes with an offset to indicate how far from the track whether to the left or right the event or object resides.





Lastly GIS can also be used to analyse other spatially diverse information about activities across the railway. An example of this is spatial analysis of crime, where locations of criminal activities can be analysed to identify geographic hotspots which in turn allows managers to prioritise the use of the law enforcement or other measures to reduce crime in those areas.

Figure 3: GIS used to Create Emergency Routes at an Airport

Specific benefits from using GIS that have been identified at this stage within rail organisations include:

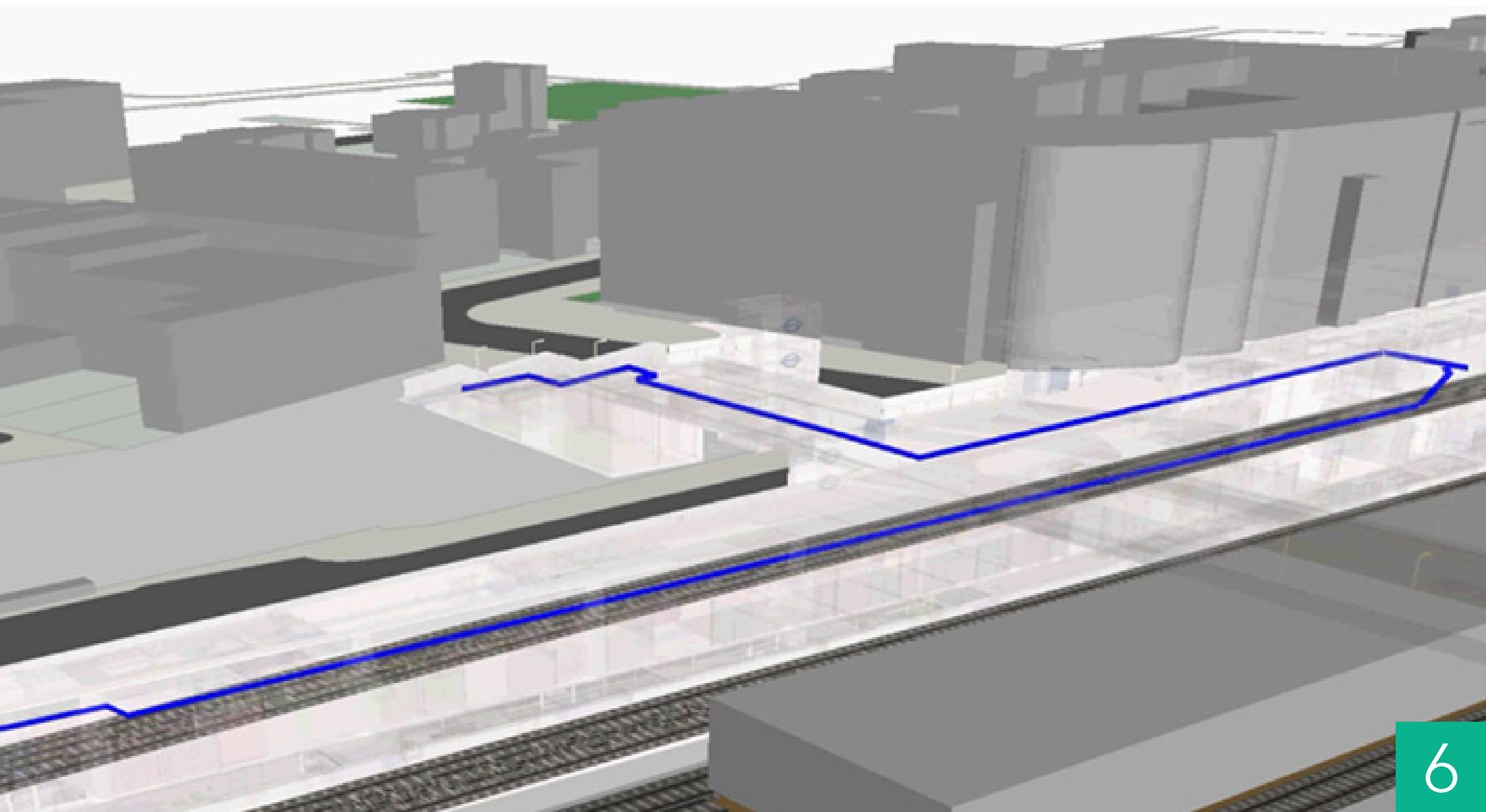
- Finding information based on a geographic incident, for example a bridge strike, such as structural drawings, maintenance inspections or risk assessments (London Underground)
- Use of maps to guide operation staff to O&M Manuals and other documentation based on location (London Underground)
- Location-based decision making for level crossing mothballing and decommissioning (Network Rail)
- Generation of timetabling information from location (London Underground)

From a maintenance perspective, this is an ongoing expenditure to the organisation. Inspecting, cleaning and repairing (or replacing) assets are typical maintenance operations that would be carried out, and for each of these GIS can be used to streamline such activities. Knowledge of the location of the asset is a first step, but understanding of how to get there through routing, optimisation of inspections route and work orders through network analysis, and collaboration and prioritisation of activities based on their location are just three examples of how GIS might be used to help.

This includes the optimisation of planned interventions or preventative maintenance. Simple geographic visualisation of such activities can quickly and easily highlight where conflicting or overlapping activities are taking place, making it easier to coordinate and collaborate between teams so as to reduce the time taken and the risk involved. It would even be possible to have reports or alerts generated based on works carried out in close proximity.

Use of mobile GIS technology can also assist with these processes, allowing maintenance crews to access their work orders and other activities from the field, and provide real-time updates on their status. This would also allow managers to track the progression of activities, be kept up to date on any delays, or alert them to activities which may cause safety concerns such as staff straying into areas that they are not supposed to enter.

Figure 4: Optimised Routing for a Maintainer at a Railway Station



Specific benefits from using GIS that have been identified at this stage within rail organisations include:

- Fault clustering to enable location-based root causes to be identified and remedied (JNP)
- Recording of track faults using locational identification from specialised train using on-board equipment (JNP, London Underground)
- Visualisation and analysis of asset performance (London Underground)
- Reduction in time and cost to locate assets and produce maps and diagrams to assist staff in carrying out maintenance activities (London Underground)
- Spatial Analysis of track geometry, curvature and condition to identify where track modifications can made to improve line speeds (London Underground)

Health & Safety

Throughout the full lifecycle mentioned in the previous sections, location based information can also be used to track, analyse and improve health and safety within the industry. From construction sites to operational railways, observations, near misses and incidents always have a locational component, and these can be interrogated by incident management teams to understand potential root causes of such occurrence's related to location; and subsequently help to implement solutions to ensure that lessons are learnt and that incidents do not occur again there or elsewhere. When such locational information is connected with other information such as location of materials, hazards or known works, this can grant health and safety teams' greater insights and understanding and improve the health and safety performance of an organisation.

Use of GIS to help with Health & Safety can additionally confer the following benefits:

- Track, report and identify areas of threat posed to personnel
- Reduce the time spent by staff on site, particularly within hazardous areas, by optimising works and overlapping activities
- HSE decision-maker can use overlay analysis to combine demographic data, such as the number of households, showing the average number of school age children, with the region accident data showing members of the public related accidents. This can be done in order to derive risk factors for the total number of members of the public-related accidents relative to the total number of school age children region thus for members of the public-to-school safety analysis (Manase, Heeson, Oloke, Proverbs, Young, & Luckhurst, 2011)
- Inclusion of the effect of spatial aspect of hazards on overall risk analysis methodologies (Atay, Ergen, & Toz, 2010)

Operations & Maintainance Case Study: JNP Work Orders Management

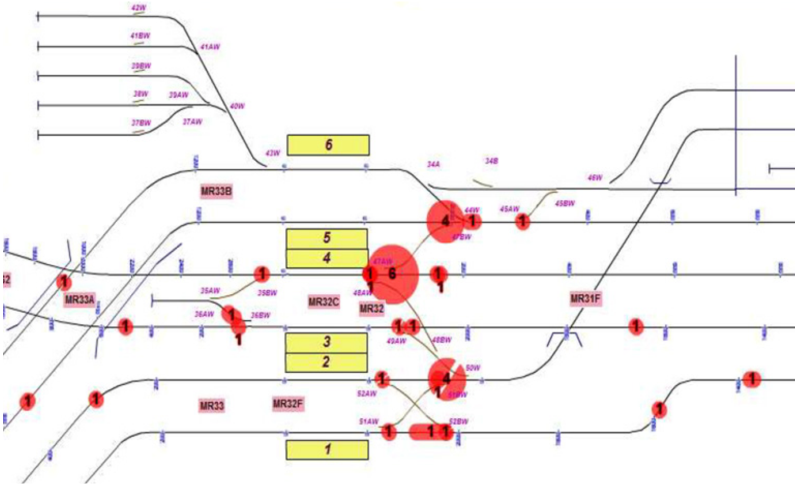


Figure 5: Cluster Analysis of Work Orders on Operational Railway

JNP have linked their GIS to their EAMS system, allowing intuitive visualisation of work orders and assets. This has led to managers being able to coordinate work activities on site to reduce duplication of work at a given location, as well as highlight specific locations that are suffering from repeated problems, prioritising where deeper root cause analysis needs to be undertaken.

Analytics and Reporting

One of the most underused components of GIS within the rail industry is its capability as an analytics and reporting engine. Geospatial analysis is one of the most powerful capabilities of a GIS, helping infrastructure and facility managers to answer important questions that are otherwise difficult to address. Many of the examples shown in earlier sections used spatial analysis to provide the answers to questions, many of which are used without realising by the end user. This draws on the implicit spatial relationships that was described earlier in this document (see Information Management), and a variety of these analytical methods are briefly described below (Rich & Davis, 2010):

- Buffer – How many things are within x distance of a location?
  - How many signals are within x distance of a crossover, station or other signals?
- Overlay - What things are within the boundaries of a specified area?
  - What is the line speed of the area through which the train is currently travelling?
- Proximity - What are the nearest x things to this location?
  - What are the nearest 10 open work orders to this asset?
- Geocoding - Provide a location that corresponds to a given address
  - Where is room 1/230?
  - Where is the escalator control room at station x?
- Density - Show the density of things typically per square unit
  - Where is the highest concentration of commuters along the route at peak travel times?
- Route - Display the fastest or shortest distance between two points along a transportation network
  - What is most direct route to get from room x to room y if I require step-free access?
- Spatial selection - Select the objects in layer A that are within the boundaries of a feature in layer B
  - Select all of the fire extinguishers at a facility and schedule them for inspection
- Drive time - Show me all the things or areas that can be aggregated within a specified drive time of location x
  - How many employees of facility x live within 30 minutes' drive time of public transportation?
- Temporal - Show the geographic relationship between things over time.
  - Display energy consumption per square meter for each building across my portfolio by month
- Line of Sight - What can I see from location x (3D)?
  - What is the coverage of security cameras at a specific location?

Each of these provides a unique ability to understand information in the context of where but also provides a means of visualising that output in a way that can be intuitively understood by the target audience. It is reported that organisations that utilise analytics as part of their toolbox outperform those that do not by 83% (IBM, 2010)

Analytics and Reporting Case Study: London Underground

London Underground used GIS to model flood risk, highlighting facilities which were at greater risk of flooding events, allowing prioritisation of flood defence measure improvements. This is now a business as usual tool, and is starting to incorporate real-time weather data from the Met Office, allowing near-term predictive analysis of flood risk based on actual events rather than forecast models.

Figure 6: Spatial Modelling of Flooding in London

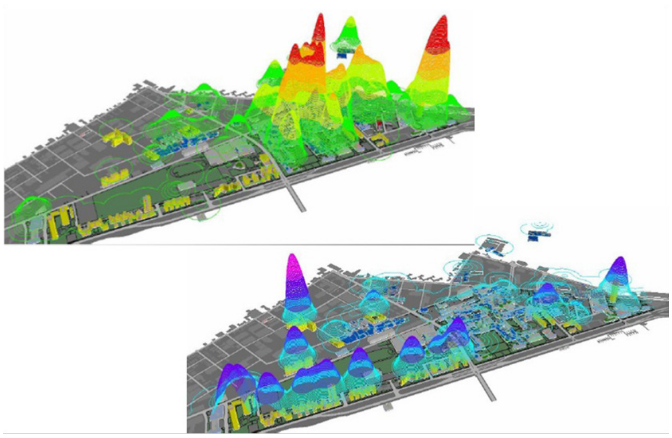


Figure 7: Analysis and Visualistion of Footfall within a Facility

As a final example GIS can be used to undertake volumetric spatial analysis, allowing the planner or analyst to calculate the volume of air in the station, which in turn can assist with design or air filtration and cooling systems or calculate speed and direction of spread of fire or other hazardous incidents.

Specific benefits from using GIS that have been identified at this stage of the rail lifecycle include:

- Proximity Analysis to determine properties affected by construction works, saving 5,000 person hours per year (Crossrail, Crossrail 2)
- Line-of-Sight analysis to establish the optimum placement position of signalling equipment (Network Rail)
- Spatio-Temporal (4D) analysis to track and provide updates on progress to construction activities (Crossrail)
- Use of proximity analysis to advise of activities that are taking place outside their designated area

Information Management

Typically any two non-spatial datasets that have a relationship between them must have that relationship explicitly defined in order for said relationship to exist (Codd, 1990). For example, the relationship between books in a library and the customers who borrow them must be defined between who the customer is and what the book is. Without this, one cannot know which customers have borrowed what books.

Geospatial data on the contrary does not exist within such a sphere of implicit isolation. All geospatial data is intrinsically related to all other geospatial data by its very nature, that of location and therefore no relationships between geospatial data sources need to be explicitly defined. It does not matter where the geospatial data source is; each geospatial entity intuitively understands where every other piece of geospatial data exists in relation to itself. There may be multiple business systems within a single organisation; using federated information model architecture to allow these to exist independently whilst retaining a connection between them.

For non-spatial data this would require definition of relationships between those systems, which can be technically complicated, but using the inherent spatial relationship between objects creates an instant connection between systems without having to explicitly define such relationships. Additional explicit relationships can then be used to refine connections between systems, depending on the level of precision to which locational data is collected.

For example a building footprint in one system already knows which buildings are next to it, but also which roads are nearby, which traffic lights are within 50m, what utilities intersect the property and so on. This makes spatially enabled data ideal not only for visualisation, but also for managing the relationships between disparate data sources.

Another example of this is the use of floorplans or spaces within a facility. Historically these are represented by Computer Aided Design (CAD)

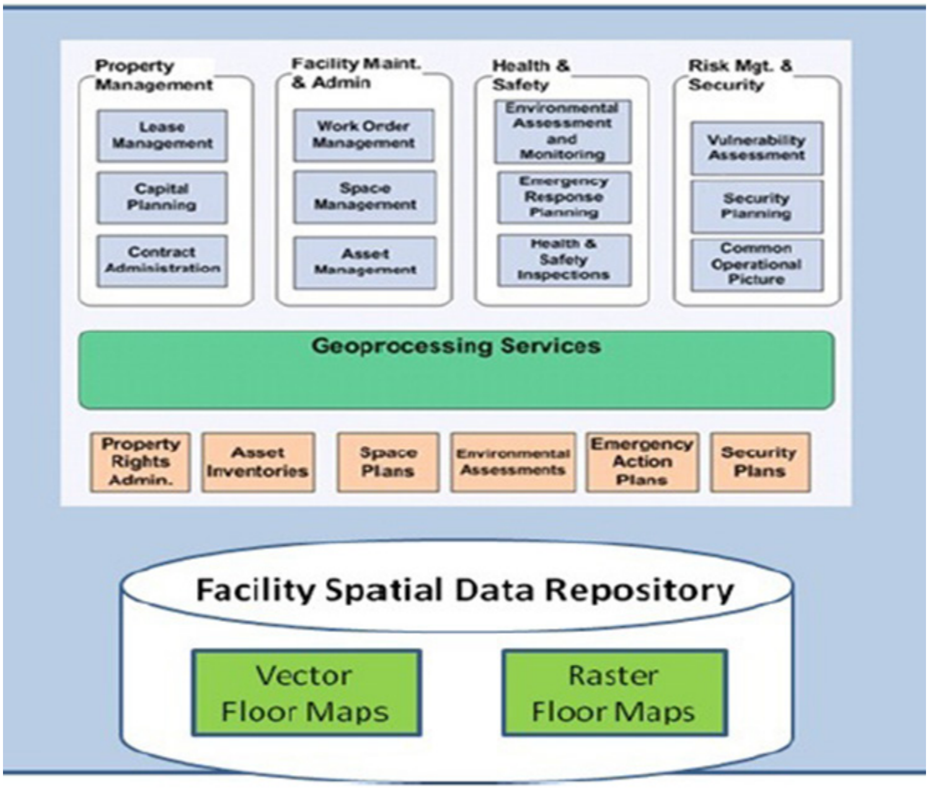


Figure 8: Typical Geospatial Information Architecture

drawings and associated room data spreadsheets which are loaded into an asset information or Enterprise Asset Management System (EAMS).

However because these data sources are disconnected this can quickly lead to discontinuity between the two data sources. Storing them within a GIS by comparison allows both sets of data to reside in a single location as a master data set, to which other datasets (such as assets) can additio nally be incorporated.

Some of the additional benefits of using location as an information management tool include:

- Connecting disparate information systems together such as CAD, Document Management, Asset Management, Work Order Systems, Access Management Systems etc. (Crossrail, London Underground)
- Acting as a centralised portal to allow users to pass between different and distinct systems
- Creation of intelligent maps that reflect change without requiring recreation of map (Crossrail 2, London Underground)

Some of the additional benefits of using location as an information management tool include:

Federated Models

Federating data across a collection of systems as required by the function of the organisation allows individual data models to fit their specific purpose whilst retaining linkage between those disparate systems. Such systems can include CAD, EDMS, GIS and EAMS, but these systems link to each other through the use of a master data model (see below), which means that this data can be related to each other.

Master Data Model

A master data model allows an organisation to centralise its core information requirements, ensuring that changes to such information are managed centrally and then pushed out to federated systems (see above). This leads to an increase in data consistency and minimises duplication and loss of data within those systems

Information Management Case Study: Geospatial Portal

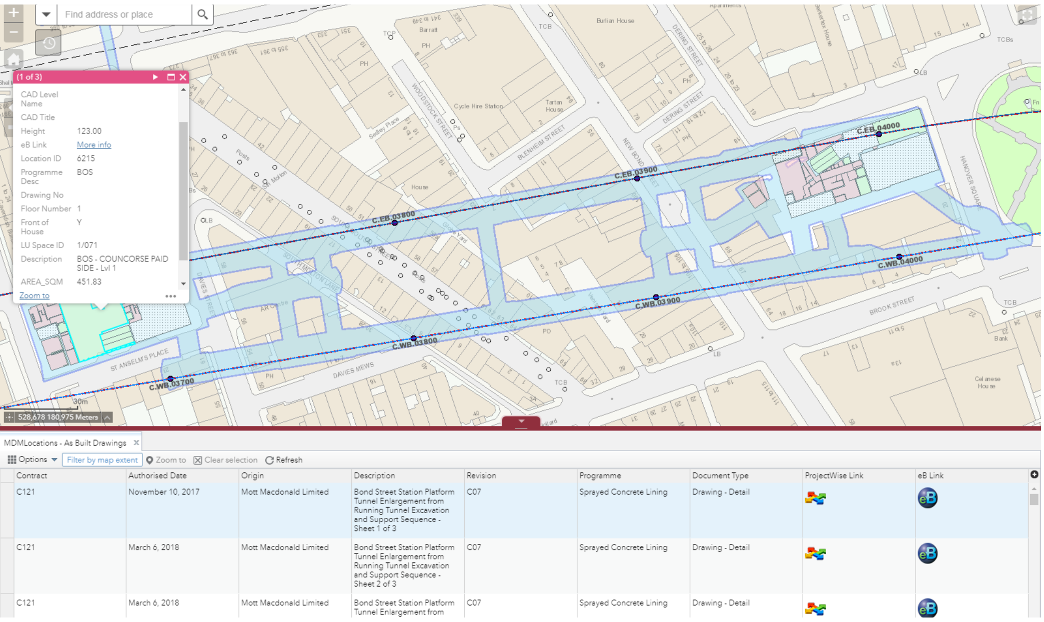


Figure 9: Interacting with the Crossrail Geospatial Portal

Crossrail use a single portal on the project to allow multiple users from different disciplines to access information from a variety of data sources. This is achieved by interacting with an intuitive map interface to select a location, which will then provide a list of attributes and accessible data sources from a pop-up. Sources include CAD drawings, documents, spreadsheets, images, street view visualisations and data from other systems such as the Master Data Model, Estates Management System and Asset Information System.

The Geo-Centric Railway

Given all of the benefits shown above that location-based information can provide throughout the lifetime of assets, it can be seen that the use of GIS could provide a framework for better utilising and managing resources within the rail industry. However it is often the case that these activities are carried out in isolation of one another, using disparate systems that provide benefit only at the point of use.

If, however, geo-centric information was to be included as part of the model from the outset of a project, or was embedded within an operational information environment, this could improve the efficiency of an organisation whilst also driving down costs. Location, at its heart, is simply answering the question of where, but that answer can lead to other questions such as why and what? Why has something occurred at this location? What is nearby that is affected?

Herein lays a word of warning though. Like any data type, location should be as precise and as accurate as is required. Recording location at a coarse level (e.g. to ward or borough level) does not allow anyone to know where within that ward or borough the specific location is. Simplification of a precise data type is possible (e.g. rounding or aggregating), but making a value more precise once it is recorded is not easily achieved without additional sources of data to infer location. In addition, historically location has been restricted to two-dimensions as technology and data collection methodologies did not permit machine friendly three dimensional data. This is, however, evolving, with the advent of LIDAR, Orthomosaic, 3D Meshing and other desktop tools and processes enabling the rapid creation of accurate three dimensional data.

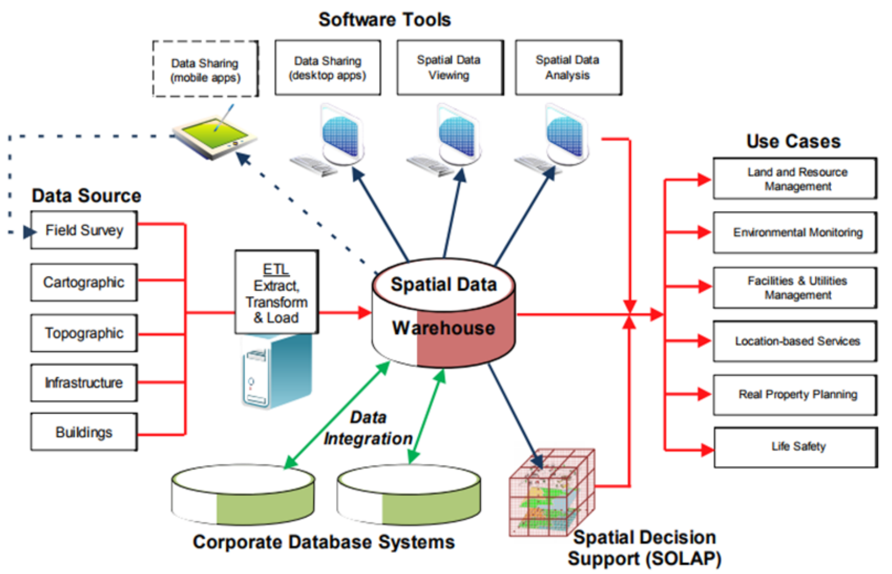


Figure 10: Potential Geo-Centric Data Warehouse

On the other hand, capturing extremely precise and accurate data increases the overhead on both the collection process and subsequent storage medium, and can lead to issues of performance and scalability.

Storing point cloud data a 1 million points per cubic metre, for example, would lead to terabyte size point clouds which are both unwieldy and slow to render on even modern computer technology. So the right balance must be struck between collecting and recording geospatial data at the precision and accuracy that is appropriate for the need that it is fulfilling.

Precision and accuracy can also have a direct impact on the spatial relationship described earlier. The more accurate and precise data is, the better the spatial relationship, but this degrades as accuracy and precision become worse.

Some of the additional potential uses of a geo-centric information model throughout the lifecycle include:

- Energy design compliance in which designers could check the compliance of building design with the urban development schema, and meanwhile urban planners could give feedback to the designers for further improvement of the energy performance of the buildings (S.Y. Niu, 2015)
- Perform geospatial analysis of the logistics delivery in a visualized construction supply chain management system developed for tracking supply chain status of materials and providing warning for materials delivery accident (J. Irizarry, 2013)
- Analysis of the fault patterns of an asset, identification of other assets that may be affected, and subsequent prioritisation of replacement or remedial measures to prevent such failures from re-occurring
- Optimisation of work bank planning, from collaboration on maintenance tasks through to route optimisation for inspections and other activities. This includes virtual walk-throughs of geographic areas such as railway lines, stations and even rolling stock
- Use of the spatial relationship between features to connect multiple data sources together with far greater ease than is currently possible.
- Real-time data feeds including pedestrian flow paths, weather profiles and even crowd-sourced data from sources such as Waze allowing greater insight into the performance of facilities, assets and staff
- Integration of building model as well as the road network information and location of fire brigade stations in GIS, allowing firefighters to calculate the shortest route from the fire brigade stations to the fire place before they set out (U. Isikdag, 2008)
- Develop an indoor emergency spatial model based on IFC with surrounding environment information from GIS databases to increase responders' perception of the indoor area, decrease indoor reaching times and optimize route finding in the emergency (H. Tashakkori, 2015)

Accuracy and Precision

Locational Accuracy, as opposed to precision is not how many decimal places you store a coordinate at, but rather how closely it matches the real world location. It doesn't matter if you store a coordinate to the nearest millimetre, if that coordinate is 5 metres from where the actual object exists in the real world, then it is not very accurately described.at the cost of storage and performance when analysing such precise information.

Precision of any data type is always present, and locational precision is no exception. Store geometry to the nearest kilometre and this is then the precision that one can expect when using it. Store it to the nearest millimetre on the other hand and you will have extremely precise data, but at the cost of storage and performance when analysing such precise.

In the example to the right (A) is both accurate and precise, (B) is precise but not accurate, (C) is accurate but not precise and (D) is neither precise not accurate.

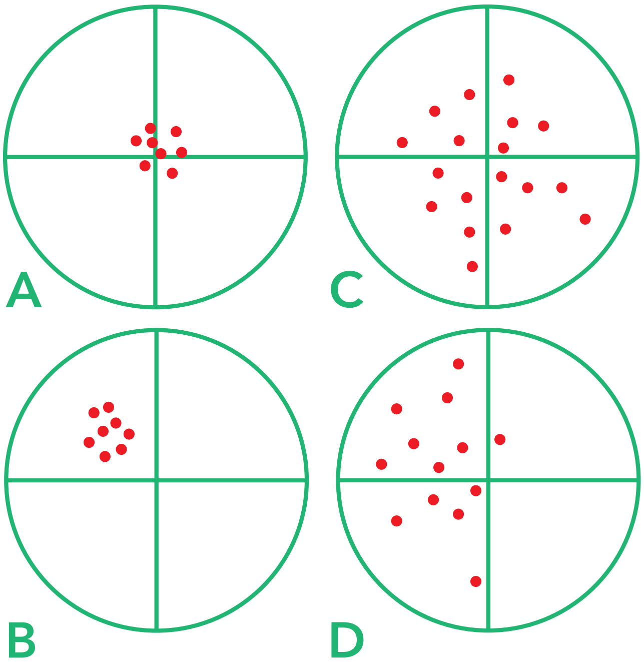


Figure 11: Accuracy vs Precision

Conclusion

This document has outlined the primary benefits of using GIS within a rail organisation. This includes examples at every stage of the asset lifecycle, but also how GIS can be used to improve the performance, reduce risk and add resilience to the railway. GIS has, and will, continue to expand its role in the rail sector, with the increased use of new and improved methods of collecting geospatial tagged data. From geo-tagged photos, point cloud surveys or other methods requiring mediums to manage, analyse and present such data and information, GIS and location-centric data provides the perfect solution to do this.

Add to this the increasing need to drive down cost whilst improving performance of the railway, and suddenly GIS presents rail infrastructure managers with tools and processes that can achieve this goal.

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