Automated management information systems to enhance decision-making abilities are becoming more important today. Funding and resources are scarce, but technological developments are making it possible to conduct sophisticated analyses that will enhance planning and prioritization: doing more with less. Centered around optimization and efficiency, the geographic information system (GIS) tools provided by Esri have been crucial in providing MAG (Mines Advisory Group) with decision-making software.

MAG has assisted affected communities in Southeast Asia (SEA) for more than twenty years. In Cambodia, Laos, and Vietnam (SEA), MAG employs more than 2,000 national staff—more than 30 percent of whom are women. Between 1965 and 1975, more than 7.5 million tons of bombs were dropped over Cambodia, Laos, and Vietnam, which is double the amount dropped on Europe and Asia during World War II. Despite the conflicts ending more than forty years ago, cluster munition and landmine contamination continue to kill, injure, and hinder development in the region.

To be able to make better operational decisions in SEA, MAG incorporated information from the Theater History of Operations Reports (THOR) database, which overlays bombing locations and related data over satellite images. THOR contains declassified records of the aerial bombing missions conducted by the United States from World War I to the present. In what remains the largest aerial bombardment in human history, more than 182,000 bombing missions were conducted during the Vietnam War using cluster munitions in Cambodia, Laos, and Vietnam. As a result, according to data from THOR, almost 1.6 billion submunitions were dispersed. The cluster munition contamination tool developed by MAG aims to accelerate the process of survey and clearance by informing stakeholders in advance to determine where there is a need for non-technical survey (NTS), technical survey (TS), or if an area should be cleared directly.
The first concept of a simple geospatial analysis was conducted in 1832 by geographer Charles Picquet, who created a map that showed cholera outbreaks across forty-eight Paris districts. His cholera outbreak map was an early version of a heat map represented by color gradient according to the percentage of deaths from cholera per 1,000 inhabitants. In 1854, a similar geospatial analysis model was used by Dr. John Snow who also mapped data from a cholera outbreak in London. His map allowed him to see a clear pattern that no one had noticed and to ultimately discover the source of the outbreak. His findings led to changes in the water and waste management systems of London and other cities resulting in improvements in general public health. The term GIS did not exist in the 19th century, but it allowed Picquet and Snow to ask questions based on data and helped them to solve problems, just like we do today with GIS.

Problem Statement

In 2005, the Geneva International Centre for Humanitarian Demining (GICHD) released its publication, A Study of Manual Mine Clearance. Many of the conclusions and recommendations in this publication are worth revisiting. The publication urged the mine action community and its stakeholders to urgently consider moving to a more explicit risk management approach. Systematically recording, e.g., the depth at which mines are located, would provide valuable information to support development of a professional risk management system. Furthermore, if confidence in the mine clearance industry is to be maintained, the study recommended that performance must be reported accurately and honestly to reinforce the principle that exaggerated clearance statistics are unacceptable. It also recommended that data collection should be standardized and improved to allow clearer oversight of cost-benefit issues related to mine clearance. This data should enable detailed analysis of the costs for the land that had been cleared. In short, this publication outlined the key elements for land release, which almost a decade later was acknowledged when the major amendment of land release was approved for the International Mine Action Standards (IMAS) in 2013. Land release was further strengthened by a new version of the IMAS covering quality management in 2016 and complemented by the new IMAS on risk management in 2019, and an updated IMAS on information management in 2020.

Moreover, in 2018, the Mine Action Review’s publication Clearing the Mines repeated some of the key issues identified in 2005:

For sure, mistakes in survey in the early days cost us all dearly, exaggerating hugely the extent of the problem and asserting the presence of contamination where it did not, in fact, exist. And, despite the best of intentions, poor survey and inadequate information management continues to plague our profession, sometimes leading to clearance resources being wasted on uncontaminated areas. Today, however, old surveys can no longer be an excuse for slow progress. The re-surveys conducted in several countries over the last few years, as well as those underway or planned, clearly evidence that high-quality survey can be achieved without excessive expenditure. An accurate baseline is, or should be, the starting point for all successful national mine action programmes.

Managing Big Data

Many sectors moved more quickly than others to embrace technological developments at the turn of the 21st century, including a broad range of new technical breakthroughs such as information technology and telecommunications. Yesterday’s powerful desktops are being transformed to sensory input and output devices, combining intelligent software and extensive connectivity. We become used to networks connecting to everything and we are adapting to “smart environments” that are changing how we work, what we consume, and how we interact with other people. In the past decade organizations have been increasingly storing, processing, and extracting value from data of all forms and sizes. Systems that support large volumes of structured and unstructured data will continue to rise. Organizations will continue to explore technology that fulfills the demand on platforms that help data custodians govern and secure big data while empowering end users to analyze that data. These systems will mature to operate well inside of enterprise IT systems and standards.
Geographic Information Systems (GIS) Made Simple

GIS is an extension of cartography, which can be summarized as the art and science of making maps that enable organizations and individuals to visualize, analyze, question, and interpret data. Realistically, there is no limit to the amount of data that can be added to an ArcGIS system for an organization working in mine action. Esri was founded as the Environmental Systems Research Institute in 1969 as a land-use consulting firm and is today a leading international supplier of GIS software, web-based GIS, and geodatabase management applications. Over the past decade, Esri has transformed its GIS into the power platform it is today—easy to set up and use “out of the box.”

Since 2013, MAG has explored and developed various information systems for mapping and reporting of survey and clearance activities. In 2015, MAG started exploring Esri tools in Cambodia. Research and development activities were conducted under an Operational Field Evaluation (OFE) project in Ratanakiri Province in northeast Cambodia. MAG’s OFE projects in Cambodia have been funded and supported by the U.S. Humanitarian Demining Research and Development (HD R&D) Program® for almost two decades, and have expanded to other global MAG programs in the Middle East, Europe, and SEA for mechanical and detection OFEs. HD R&D focuses on the rapid development, testing, demonstration, and validation of technologies that increase the efficiency and enhance the safety of humanitarian demining operations. In this mission, HD R&D may adapt commercial-off-the-shelf technologies, use mature technologies, or leverage existing military countermine technologies.

In 2018, MAG decided that it was of strategic importance to replace the paper-based system in use at the time with a “one time input” of data method via tablets used by field operators that would improve analysis and decision-making. The information system also needed to be compatible with IMSMA Core® that was being developed and rolled out to national mine action authorities by the GICHD in 2016. The strength of MAG’s information system is that
it has taken full advantage of the tools made available by Esri, especially when it comes to geospatial analysis and predictive analysis to inform and assist operational decision-making.

MAG’s information system was named the Operations Management Information System (OMIS) to separate it from other information systems being developed in MAG at the same time. In late 2018, funded by HD R&D, MAG purchased a license for Esri systems, and began setting up and implementing OMIS. HD R&D has continued to provide support for the development and rollout of OMIS. In 2020, the Dutch government also contributed toward the rollout of OMIS.

Development of a geospatial analytical tool. During the global pandemic in 2020, MAG’s Global OMIS team started work on exploring U.S. bombing data from the Vietnam War using datasets from THOR. MAG’s aim in developing the tool was to improve planning, prioritization, and evidence-based operational decisions in SEA.

Cluster munition contamination tool. The cluster munition contamination tool runs within MAG’s Esri Enterprise environment and OMIS, where it classifies priority areas for survey and clearance of cluster munition contaminated areas across SEA. To predict cluster munition contamination risk, the tool compares extracted data from bombing missions that only contain cluster munitions with recorded submunition evidence found during explosive ordnance disposal (EOD) response, survey, and clearance operations by MAG in SEA. Mapping relative risk of ground contamination provides insight for prioritizing survey and clearance operations. In certain cases where predictive risk is very high, the tool will identify areas where battle area clearance (BAC) teams can move directly to clearance operations without the need for TS.

U.S. bombing data. The U.S. bombing analysis uses target location data for Cambodia, Laos, and Vietnam from the THOR database that are mapped as points representing cluster munition target locations. Not all cluster munitions were successfully dropped on target, as indicated by battle damage assessment within the dataset. Despite spatial uncertainty, clear distribution patterns are detectable and useful for analysis, such as bombing missions along roads.

Evidence data. Submunition evidence was compiled from MAG’s survey and clearance operations in SEA. Norwegian People’s Aid (NPA) shared some of its data from Vietnam for comparative analysis. Maps of suspected hazardous areas (SHAs) and confirmed hazardous areas (CHAs), released land, and areas known to have no cluster munition contamination were used in the analysis for validation and refinement.

Elevation data. Thirty-meter grid elevation data from the United States Geological Survey (USGS) Shuttle Radar Topography Mission (SRTM) was used to create a 30-m slope grid. Terrain type, such as steep slope, gentle slope, and flat slope, provides further results segmentation to assist prioritization of contaminated areas.

Tool development. Using the Python programming language, Esri ArcPy, and numerical analysis libraries, the geospatial analytical tool runs locally on Esri ArcGIS Pro and is deployed over server-side geoprocessing services into web applications via Esri Enterprise ArcGIS Server. As data analysis takes place on a 30-m grid covering SEA, the tool creates a map of bomb risk by dispersing point-based cluster munition data onto this grid and creates a second grid for evidence-based risk using the density of items found on the ground. The two grids are weighted based on patterns within the data and summed to create an overall risk map. This is classified by priority for survey and clearance, using further ancillary datasets such as slope type. The tool enables selection of evidence data for model training and prediction. Countries and provinces are selected for iterative 30-m grid processing, and the results are converted back to seamless vector polygon mapping for reporting and visualization in Esri desktop and online products. Analysis is performed using Esri spatial grids and running mathematical functions on the same data converted into Python programming language data structures.

### Table 1. Weighted scoring table for classification.

<table>
<thead>
<tr>
<th>CLASSIFICATION</th>
<th>REASONING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical survey-low</td>
<td>Nearby cluster munition targets; no nearby submunition evidence recorded</td>
</tr>
<tr>
<td>Technical survey-high</td>
<td>High levels of nearby cluster munition targets; no nearby submunition evidence recorded</td>
</tr>
<tr>
<td>Clearance-low</td>
<td>Nearby submunition evidence recorded; no nearby cluster munition targets</td>
</tr>
<tr>
<td>Clearance-medium</td>
<td>Evidence of nearby cluster munition targets and nearby submunition evidence recorded, where either cluster munition targets are high with low submunition evidence recorded, or submunition evidence recorded is high with low cluster munition targets, or both cluster munition targets and submunition evidence recorded are both medium intensity</td>
</tr>
<tr>
<td>Clearance-high</td>
<td>Evidence of high levels of nearby cluster munition targets and high levels of submunition evidence recorded</td>
</tr>
</tbody>
</table>
Model Parameters

Several model-run parameters were set using a configuration file containing:

- Evidence data to be used for training and prediction
- Percentage evidence data covered by bombing dispersion zone
- Relative weighting applied to bombing and evidence risk
- Granularity of output classifications, i.e., number of output risk in the final risk map (high, medium, or low)
- Slope classification
- Countries and provinces to process

Determine dispersion distance from cluster munition drop target location.

An incremental distance search is performed from all cluster munition target locations until a required percentage of “training” evidence is found. The spatial relationship between bombing target locations data and evidence data is used to define a distance that ensures submunition data is dispersed to cover all areas of known evidence, with the exception of outliers.

Disperse submunition data into dispersion zones.

Estimates of submunition data at each cluster munition target location is calculated using the following formula:

\[ \text{submunition count} = \text{number of aircraft} \times \text{load} \times 650 \text{ as a starting point.} \]

Submunition counts are dispersed into a circular zone on the 30-m grid, defined by the dispersion distance and using distance weighting. Grid cells closer to the target location will receive a greater proportion of submunition count than those cells at the edge of the circular dispersion zone. The full submunition count at a target point is dispersed into the surrounding 30-m grid. In areas where cluster munition target points cluster, a grid cell may receive partial submunition counts from more than one nearby cluster munition target, which will accumulate. This process creates a submunition density map across SEA, where the sum of all submunition counts in 30-m grid cells equals the total amount of submunitions dropped.

Obtain submunition density profile for evidence locations and create a submunition risk grid.

Evidence points are overlaid onto the submunition density grid to calculate a density profile for known evidence. This is converted to percentile-based density ranges, where ranges are ordered from high to low density. The default analysis classifies each grid cell in the submunition density grid with a weighted score from eleven (low) to twenty (high) based on the low-to-high-density ranges overlapping known evidence. The specific number of ranges and weighted scores allocated to each is defined in tool configuration settings.

Create evidence-based risk grid.

Point locations of submunitions evidence are interpolated onto a 30-m grid using kernel density routines with a 1-km dispersion distance. Routines convert this grid to numerical Python arrays, and percentile density ranges are calculated based on cells with evidence densities greater than 0. Percentile ranges are classified with a weighted score from twenty-one (low) to thirty (high) based on the low-to-high-density ranges. Presence/absence evidence data is used to create the evidence-based risk grid.

Create cumulative risk map.

Submunition and evidence risk grids are relative rather than absolute. They are summed to create a grid cell range (i.e., low-medium-high). Evidence has higher relative weight. The cumulative grid result is re-classified into priority levels as indicated in Table 1 (previous page).

Output generation.

Quality control processes are included in the tool to resolve potential misalignment issues between different polygon datasets. For example, CHA extents are chopped using extents of clearance polygons to prevent overlap. Processes also resolve NTS issues. NTS field survey areas indicating no evidence of cluster munitions are subsequently removed from areas defined for TS or clearance priority.

To add reporting value to outputs, priority classifications are further refined by slope type (flat, gentle, or steep) and overlap status with CHA/clearance areas by combining with maps of slope classification and CHA/clearance polygon extents. Outputs are supplied as Esri raster grids and Esri file geodatabase feature classes ready for ingestion into Esri desktop and online products/services.

Figure 7. Priority TS and clearance areas with evidence points.

Figure 8. Priority areas with gentle and steep slopes with evidence points.

Figure 9. Predicted areas for clearance and high-priority TS areas with evidence points.
Conclusion

Easy access to interactive global networks together with machine learning (ML) can improve how we gather, analyze, monitor, and evaluate information. Mine action in particular benefits immensely, enabling the sector to move away from a traditional tiered command and control structure to horizontal networks and co-operative teams that continually enhance decision-making, monitoring, and evaluation abilities.

The cluster munition contamination tool will not be truly effective on its own. The more data that is entered, the better the system becomes. It requires stakeholder and operator feedback, sharing of data, and most importantly, use of the tool. Equipped with ML capabilities, this tool can assume control of manual and repetitive tasks to increase the speed of data analytics. This helps to eliminate manual data entry errors and data duplication, ensuring higher quality of work. Moreover, organizations do not need a developer to reprogram the system every time organizational workflows change inside the system. By learning from data continuously, the platform will be able to improve its performance and adjust work processes in the system with minimum human assistance.

Conclusively, access to information is key to inform decisions and actions determined by methods applied, to manage risk supported by a quality management system to ensure that acceptable risk is monitored and kept as low as possible. This should be a process driven by evidence and systematically sequenced for the control and continuous improvement of processes and products well known to many of us as the Deming Cycle: Plan, Do, Check and Act (PDCA). Consequently, location intelligence and data driven decision-making are key attributes for “doing the right things” and “doing things right.”

See endnotes page 150

Mikael Bold
MAG (Mines Advisory Group)
Technical Director

Mikael Bold joined MAG in March 2018 as the Technical Director to contribute to the delivery of MAG’s Strategic Plan through effective leadership of the Operations Development Team with the aim of ensuring high levels of safety, quality, innovation and continual improvement for MAG’s global operational implementation, and promoting the sharing of expertise, learning, and development inside MAG and within the mine action sector as a whole.

Before joining MAG, Bold worked for the Geneva International Centre for Humanitarian Demining (GICHD) from 2013 to 2018 as an advisor on mechanical and animal detection systems, standards, compliance, and legal efficiency. He also served briefly as the Secretary of the IMAS Review Board.

David Avenell
MAG (Mines Advisory Group)
Regional Information Systems Manager, SE Asia

David Avenell provided GIS consultancy to MAG in 2019, working on situational awareness mapping of the Syria conflict and techniques to increase efficiency of spatial data flows between online operational systems. He joined MAG in 2020 as Regional Information Systems Manager, SE Asia. He is responsible for management of MAG’s cloud-based Enterprise GIS platform and spatial analytics, with particular focus on automation and development of analytical tools.

Before joining MAG, Avenell worked in the United Kingdom implementing Esri Enterprise GIS capabilities and development of spatial tools across government, commercial, and military sectors.
Data Driven Decision Making in Southeast Asia
By Mikael Bold and David Avenell [MAG, Mines Advisory Group]