Tracking the Usage Patterns of Explosives Devices from Birth to Death: A Case of the Inspectorate Division of Minerals Commission, Ghana*

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Abstract

The Inspectorate Division of the Minerals Commission in Ghana plays a pivotal role in overseeing the safe and responsible usage of explosive devices within the Ghanaian mining industry. The proper management of explosives devices in the Ghanaian mining industry is a challenge. Lack of absolute control has caused several incidents and accidents in mining communities of Ghana. This study sought to develop a comprehensive tracking system, called Harmonised Explosive Management System (HEMS), for the usage patterns of explosive devices throughout their lifecycle within the jurisdiction of the Inspectorate Division of Ghana. The implementation of the robust tracking system will enhance regulatory oversight, ensure compliance with safety standards, and contribute to the sustainable and secure management of explosive materials in the mining sector. The procedure used involved a multi-faceted approach including data collection, analysis, stakeholder engagement and system design. Data was garnered from regulatory records, industry reports, and field inspections for developing the HEMS. A systematic software development approach was adopted to design and deploy the management system. The study investigated the complete lifecycle of explosive devices, starting from the point of acquisition by mining, quarrying, civil and oil and gas companies to their eventual disposal or demilitarization. Factors influencing usage patterns, such as geological conditions, mining practices, and regulatory compliance, were considered and analyzed to identify trends and potential areas for improvement. After deploying the software, the results revealed that, the proposed system was able to take inventory of all explosive devices imported or manufactured in the country, track their usage patterns, ensure compliance, and effectively extend the monitoring arm of the Inspectorate Division.

Keywords: Minerals Commission, Tracking Explosives, Explosive Devices, Hamonised Tracking and Management System.

1. Introduction

Explosive Devices (EDs), also known as explosives, refer to devices specifically designed to cause an explosion (Drzewiecki and Myszkowski, 2015). These devices contain explosive materials, often called pyrotechnics, that, when ignited, undergo a rapid chemical reaction, producing a large volume of gas and heat in a short period (Liu and Pond, 2016). The sudden release of energy creates a shockwave and generates destructive force, causing damage to structures, vehicles, and, most critically, human life (Chukwurah *et al.*, 2015). These energies are harnessed and controlled to effect blasting in the mining and allied industries. EDs come in various forms, including bombs, grenades, landmines, Improvised Explosive Devices (IEDs), and other similar weapons. They can be made using a variety of materials, including chemicals, metals, and plastics (Bilukha *et al.*, 2011). These devices have various applications, both in military and civilian contexts, and are unfortunately often used for harmful purposes, including terrorism, warfare, and criminal activities (Adusei, 2015). Due to the potential for causing significant harm and destruction (Afum and Opoku, 2018), the manufacture, possession, and usage of EDs are heavily regulated by law enforcement agencies and governments worldwide.

In the West African sub-region especially, countries with heavily endowed natural resources continue to invest greatly in the development of strategies to regularize the use of EDs throughout their life cycle. In Sacco *et al.* (2020), a law and a decree to regulate explosive substances and detonators have been passed in Cameroun. The decree details all the regulated chemical substances concerned by the law and further states that before the manufacture, storage, export, import, transport, destruction, transfer and purchase of explosive substances or detonators, the individual/company must be authorized by the Ministry of Mines. Violation of these regulations is punishable by "imprisonment from one month to one year" and/or by a "fine of two thousand to one hundred thousand

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francs. Reverberi *et al.* (2017) explained a monopolistic state structure, AFRIDEX, implemented in the Democratic Republic of Congo (DRC). AFRIDEX is in charge of the traceability and regulation of EDs in the country and delivers authorizations for importing, manufacturing, transporting, and storing explosives. The importation of ammunition and dual-use substances such as ammonium nitrate are subject to special authorization.

A similar view is shared by Laurent *et al.* (2021), where necessary authorizations are required in Gabon. In the case of unauthorized use of EDs, the punishment is by a "fine of five to twenty million CFA francs [approx. USD 32,550] and imprisonment for one to five years. The use of EDs is generally not allowed for artisanal miners. To strengthen the monitoring arm of the country's regulator against the illicit use of explosive substances, the General Direction is that the Territory Administration develops and applies texts on arms and ammunition, explosives, firecrackers and fireworks," and "verifies stocks of firearms, explosives and ammunition with importers and depot holders," and also "keeps a national register on firearms, ammunition, explosives, firecrackers and fireworks". In Congo, a law from 1962 and a decree of 1968 authorize the import, transport, produce, and store of explosives. Transportation and storage rules are also outlined in the decree (Figuli *et al.*, 2018).

In Ghana, the Minerals Commission is the Government agency with the primary responsibility of developing and coordinating mineral sector policies and monitoring their implementation (Afum and Opoku, 2018; Akpah *et al.*, 2023; Amegbey *et al.*, 2016; Anon., 2012). The Commission was established under the Minerals Commission Act, 1993, Act 450. Through the Inspectorate Division of the Commission, the Commission oversees and directs all activities concerning the use of EDs in Ghana. The division achieves its objectives by strictly adhering to the provisions set out in the Minerals and Mining (Explosives) Regulations, 2012 (L.I. 2177) (Anon., 2012). These regulations cover administration, certification, licensing and allocation of permits, packaging, reporting, manufacturing, transporting, destruction and storage of explosives as well as commercial and civil uses. The regulations also state techniques and requirements for using the explosives in different locations (e.g., underground, surface mines) and obligatory safety and environmental precautions. The legislation criminalises unlawful possession of explosives under regulation 200 and references the criminal code of Ghana, 1960 Act 29. The general penalty under Regulation 7 prescribes a summary conviction to a fine of not less than fifty penalty units or not more than one hundred penalty units or a term of imprisonment of not less than three months and not more than six months.

Even though these countries have implemented all these strategies to regularize and monitor the usage patterns of EDs, some terrorists and recalcitrant individuals/companies, operating within the illegal small-scale mining and quarry sectors continue to gain access to and use these dangerous devices illegally. To strengthen the monitoring arm of the Inspectorate Division of the Minerals Commission, the L.I. 2177 stipulates that all explosive companies operating within the country deploy systems that enable them to take inventory and track the movement of the explosive substances they deal in (ref. Regulations 45 and 46). Presently, as shown in Table 1, there are 36 ED companies (manufacturers, dealers, transporters and blasting services) operating in Ghana

Table 1 List of Explosive Companies in Ghana

SN	Company Name	Software Used
A. Explosives Manufacturing Companies		
1	AECI Mining Explosives (AECI)	SAP Software
2	Maxam Ghana Limited	Honeywell
3	Orica Ghana Mining Services	SAP Software
4	Solar Nitro Ghana Ltd	N/A
B. Explosives Dealers		
5	Shaanxi Mining (G H) Limited (EARL INT)	N/A
6	West Coast Construction Limited	N/A
7	Wileb Mining Supplies Limited	N/A
8	Akayet Mining services	N/A
9	Desnob Company Ltd	N/A
10	Aky Mining Services	N/A
11	Redrock Mining and Logistics	N/A
12	Auxin Mining Ghana and Tading Co. Limited	N/A
13	Absamel and Sons Mining Co. Ltd	N/A
14	Tanub Mining and Construction Ltd	N/A
15	Master Stone Thrower	N/A
16	Xamrock Mining	N/A
17	Premier Rock Blasting Limited	N/A
18	Schlumberger	N/A
19	Halliburton	N/A
20	Baker Hughes Oil	N/A

	Field	
21	Omnicad Ghana Ltd	N/A
22.	Western Industries Limited (WILLS)	N/A
23.	ETG Curechem (Gh) Ltd	N/A
24.	Bisbel n BartCompany Ltd	N/A
25.	Akos Dwomoh Company Ltd	N/A
26.	KCWCompany Ltd	N/A
27.	Nakoge Ghana Ltd	N/A
28.	Conombo Ghaa Ltd	N/A
29.	X-Logs Logistics	N/A
C. Explosives Transporters		
30.	Bajfreight Logistics	N/A
31	Jocyderk Logistics Ltd	N/A
32	Greenline Logistics Ltd	N/A
33	Portal logistics Ltd	N/A
Blasting Services Operators - Quarry		
34.	Master Stone Thrower	N/A
35.	Xamrock Mining	N/A
D. Blasting Services Operators –Oil and Gas		
36.	Schlumberger Ghana	N/A
37.	Haliburton International. Inc	N/A
38.	Baker Hughes Ghana Ltd	N/A
39.	Bajfreight Logistics	N/A

From Table 1, only three ED companies have deployed software systems to manage and monitor the day-to-day operations. Even though these standalone systems provide benefits to the companies that deployed them, the Inspectorate Division of the Minerals Commission is only made aware of the ED usage patterns only after the ED companies submit their monthly returns forms (Regulation 25(2) – Form I regulation 47(1) – Form Q). These challenges are further exacerbated by two main problems; (i) the lack of traceability techniques to track the entire lifespan of EDs from birth to death and (ii) the inability to monitor the usage patterns of EDs.

This paper sought to study the challenges that impede the efficient tracking of EDs and propose a Harmonized Explosive Management System (HEMS) to take inventory and track the usage patterns of EDs in Ghana. Objectives of the study are:

i. Develop a comprehensive database for recording and tracking EDs throughout their life cycle;
ii. Engage industry stakeholders, including mining companies and regulatory authorities, to gather insights and foster collaboration; and
iii. Propose recommendations for optimizing the tracking and management of EDs, with a focus on safety, sustainability, and regulatory compliance.

The findings of this research would provide accurate information on the usage patterns of EDs in Ghana and immediately prompt the Inspectorate Division of the Minerals Commission of breaches.

2. Resources and Methods Used

This section focused on the resources and methods adopted to achieve the objectives of this study.

2.1 Resources

2.1.1 Hardware Used

A Dell G5 15 laptop with Intel Core i7 (3.1 GHz base frequency, 6 cores) was used to develop and implement the program into a software. The laptop runs on Windows 11 Professional operating system. It features an NVIDIA GeForce RTX 1060 (10GB GDDR5 Dedicated) and 64GB RAM with a 128-bit interface.

2.1.2 Software Used

Different software was used to develop the front and back ends of the proposed HEMS.

i. Back-end: For server-side development
   - PHP (Hypertext Preprocessor) was the programming language used to develop the back end of the proposed HEMS. PHP is a widely used open-source general-purpose scripting language that carries the database required to run web applications (Vishesh *et al.*, 2017).

ii. Front-end: For client-side development
   - Hypertext Markup Language (HTML) which is a standardized system for tagging text files to achieve font, colour, graphic, and hyperlink effects on World Wide Web (WWW) pages was one of the programming languages used to design the front-end of the HEMS (Semil, 2022).
   - Cascading Style Sheets (CSS) is a style sheet language used for describing the look and formatting of a document written in HTML, XML, or other markup languages (Keller and Nussbaumer, 2009). CSS was used to control the layout, design, and presentation of the developed software.
   - JavaScript is mainly used for client-side scripting, enabling developers to create dynamic and interactive web applications which run directly in the user's browser, enhancing user experience without the

need for constant communication with the server (Ullah, 2020). JavaScript was employed to develop all modules that make up the proposed HEMS.

iii. Database: For database development.

- Structured Query Language (SQL) is a domain-specific language used for managing and manipulating relational databases (Khan *et al.*, 2023). SQL was used to create databases, specifying their structure, tables, and relationships between tables as well as to retrieve specific data from databases using queries, ensuring precise and efficient data retrieval.

2.2 Methods

Developing the HEMS to keep records, track and monitor the usage patterns of EDs required a systematic and multidisciplinary approach as shown in Fig. 1. Fig. 1 shows the detail methodology outlining the steps for designing the HEM system.

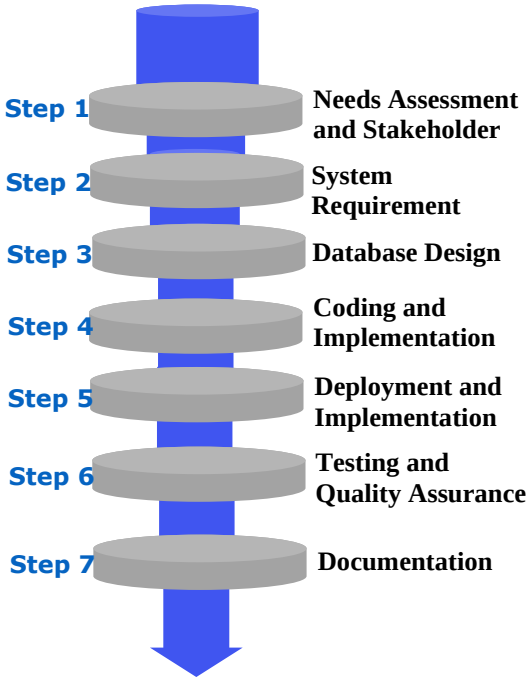

Fig. 1 HEMS Development Approach

2.2.1 Needs Assessment and Stakeholder Engagement

a) Identify Stakeholders: Key stakeholders involved, such as the Ghana Police Service, Ghana Armed Forces, National Intelligence Bureau, Ministry of the Interior, Conflict Armament Research (CAR), Ghana Ports and Harbours Authority, CSOs, and Inspectorate Division of the Minerals Commission were identified.

b) Gather Requirements: Interviews were conducted to gather specific requirements from each stakeholder as well as to understand their unique needs, data formats, and existing tracking systems.

2.2.2 Define System Requirements and Specifications:

a) The development of the HEMS was guided by a comprehensive set of system requirements and specifications that reflected the unique and critical needs of the software. These requirements encompassed various facets, including data security and compliance with local regulations, real-time tracking capabilities for explosives, user accessibility and personnel training, and integration with existing standalone software systems used by some explosive companies. Additionally, the HEMS specifications detailed the technology stack, infrastructure, and performance benchmarks to ensure optimal functionality. These rigorous system requirements and specifications not only serve as the blueprint for the development process but also underpinned the overarching goal of enhancing the safety and security of ED management in Ghana, thus, aligning the study with the crucial objectives of safeguarding public welfare and national security.

b) Functional and Non-Functional Requirements: The functional and non-functional requirements of the HEMS played a pivotal role in shaping the software's design and performance. Functionally, the system needed to support core features such as the recording and monitoring of ED inventory, including real-time tracking, historical tracking, and alert generation for any unusual activities. It also needed to facilitate user authentication, access control, and reporting functionalities for government agencies and authorized personnel. Non-functionally, the system had to prioritise aspects like data security, scalability to accommodate future needs, reliability, and disaster recovery mechanisms. It was imperative to ensure seamless integration with existing systems, adherence to strict regulatory and compliance standards, and high performance to guarantee quick response times for crucial tracking and reporting operations. These comprehensive functional and non-functional requirements were instrumental in moulding the software into a robust, secure, and efficient solution that met the specific demands of ED

management in Ghana while prioritizing both functionality and reliability.

2.2.3 Database Design

The database design process for the HEMS involved meticulous planning and structuring of the MySQL database to ensure efficient data storage and retrieval. The database schema comprised several interconnected tables, each designed to store specific types of information crucial to the system's operation. Key tables including those for tracking explosive materials, user profiles, incident reports, and access logs were carefully normalized to minimize redundancy and improve data integrity. Relationships between tables were established through foreign key constraints, ensuring data consistency and referential integrity. For instance, a user's unique identifier served as a foreign key in related tables to maintain associations with their corresponding records. Data types were carefully selected to accurately represent the nature of the information, with considerations for data size, performance optimization, and data validation. This approach facilitated the seamless storage, retrieval, and management of data while preserving the integrity and coherence of the database in the context of the system's comprehensive requirements.

2.2.4 Coding and Implementation

The coding process for the HEMS involved the adoption of structured and best-practice-driven PHP development. The PHP code was organized into modular components, adhering to the Model-View-Controller (MVC) architecture to separate data, presentation, and business logic. Object-Oriented Programming (OOP) principles were employed to enhance code reusability and maintainability. The coding standards and practices, including meaningful variable and function naming, code comments for documentation, and error handling to ensure robustness and reliability were rigorously followed. Additionally, security measures, such as input validation, authentication, and authorization checks, were integrated into the code to safeguard against potential vulnerabilities. This approach not only contributed to the software's stability but also facilitated collaboration among developers and the system's scalability in addressing challenges in ED management in Ghana.

The integration of PHP and MySQL was a fundamental step in the development of the HEMS. PHP was used to establish the server-side logic and dynamic content generation, enabling users to interact with the system's interface. MySQL, on the other hand, served as the relational database management system, responsible for storing, retrieving, and managing data related to explosive materials, users, incidents, and more. To connect these two technologies, MySQL extension was utlised to establish secure and efficient communication between the web application and the database. Queries were crafted in PHP to fetch and manipulate data from MySQL, while prepared statements and parameterized queries were employed to mitigate SQL injection risks. This seamless integration allowed for real-time data tracking, robust reporting, and secure data management, ensuring the successful implementation of the software's core functionalities.

2.2.5 Deployment and Implementation

The deployment process of the HEMS on a DigitalOcean Ubuntu Server VPS involved several key steps. First, the server was conFig.d by provisioning a suitable VPS instance, installing necessary software stacks (e.g., Apache, PHP, MySQL), and securing the server with firewalls and SSH key authentication. Next, the MySQL database setup included creating the database schema, user accounts, and permissions in line with the application's requirements. Data integrity was ensured during the migration process by transferring the database contents to the VPS and verifying data consistency. Subsequently, the PHP application was deployed by uploading the codebase and configuring the web server to host it. Once the application was live, rigorous testing was conducted to ensure it functioned correctly within the new environment. This systematic deployment process ensured that the HEMS was successfully up and running on the DigitalOcean Ubuntu Server VPS, ready to serve its intended purpose effectively and securely.

2.2.6 Testing and Quality Assurance:

The testing methodology for the HEMS was comprehensive, encompassing multiple phases to ensure that the software functioned as expected, was reliable, and user-friendly. Unit testing was carried out first, where individual components and functions were rigorously examined to verify their correctness. Integration testing followed, focusing on the interactions between different modules and their ability to work cohesively. During the user testing phase, a select group of end-users and stakeholders from various government and security agencies were actively involved. This phase evaluated the software's usability, alignment with user needs, and real-world performance. Continuous feedback loops were established, allowing us to address any identified issues promptly.

Overall, this three-tiered testing approach ensured that the system met technical standards, maintained integration integrity, and delivered a user experience that aligned with the diverse requirements of Ghana's explosive material management. To ensure the quality and reliability of the HEMS, a multifaceted approach was adopted. Initially, rigorous testing methodologies, as previously mentioned, were employed to identify and rectify any defects or inconsistencies at multiple stages of development. Beyond testing, code reviews were conducted regularly, allowing for peer evaluations of the codebase to catch and resolve issues early.

Furthermore, version control practices facilitated code traceability and rollback options in case of unforeseen problems. Continuous Integration and Continuous Deployment (CI/CD) pipelines were implemented to automate testing and deployment processes, assuring consistency and repeatability. Security measures such as input validation, data encryption, and access control mechanisms were tightly integrated to safeguard the software from vulnerabilities. In essence, the quality of the software and its reliability were systematically upheld through a blend of testing, peer scrutiny, and security measures, resulting in a robust and dependable solution for ED management in Ghana.

2.2.7 Documentation

Documentation for the HEMS included a systematic and comprehensive process. Code documentation followed inline comments and block annotations, clarifying the purpose and functionality of classes, functions, and methods. For the database schema, we created a detailed data dictionary outlining table structures, field descriptions, and relationships, aiding both developers and administrators in understanding the Database's architecture. User guides were crafted to provide step-by-step instructions for end-users, government agencies, and administrators, offering insights into system functionalities, best practices, and troubleshooting. This documentation not only served as a valuable resource for the development team but also ensured that users could effectively navigate the software, maintain it, and understand its operational intricacies, contributing to the system's transparency, maintainability, and usability.

2.3 Key Actors Involved in the Explosive Device Supply Chain

This section presents an overview of the various actors involved in the ED supply chain, both authorized and unauthorized as shown in Fig. 2.

2.3.1 Authorised Actors:

Authorised actors are such persons or companies that are legally registered with the Minerals Commission to engage in the business of importing, manufacturing and distribution of EDs.

Regulatory Agencies

The Minerals Commission is the main government agency responsible for overseeing and regulating the production, sale, and use of explosives. They set standards, issue licenses, and conduct inspections to ensure compliance with safety and security measures within the Ghanaian legislation.

Mining and Quarrying Companies

Entities in the mining and quarrying industry use explosives for activities like rock blasting to extract minerals. These companies typically adhere to strict safety and regulatory standards.

Construction and Industrial Companies

Construction companies may use explosives for controlled blasting during infrastructure projects.

2.3.2 Unauthorised Actors

Unauthorised actors are persons or companies that are not legally registered with the Minerals Commission to engage in the business of importing, manufacturing and distribution of EDs. Such persons or companies gain access to EDs from unscrupulous middlemen.

Illegal dealers

These actors can be authorized entities, which sell EDs to unauthorized persons. For instance, it can be an authorized importing company, which would sell explosives to the black market, or a dealer which would illegally sell explosives to small-scale miners.

Smugglers

Individuals or groups engaged in the illegal trade of commercial explosives, firearms, and ammunition. Several explosives trace-request sent by CAR to agencies in Ghana on explosives found in neighbouring countries of Ghanaian origin are numerous not forgetting internal seizures.

Thieves

These are individuals who steal explosive materials from authorized entities during transportation or

storage. Theft can be done by internal or external persons.

Separatist Non-State Armed Groups:

These are individuals or groups who gain access to EDs and use them for nefarious activities such as suicide bombing, etc. These groups are not active in Ghana, however, the need for prevention and protection cannot be over-emphasized.

Arms Traffickers

These are Individuals or networks involved in the illegal trade of arms that may traffic explosives and components as part of their operations.

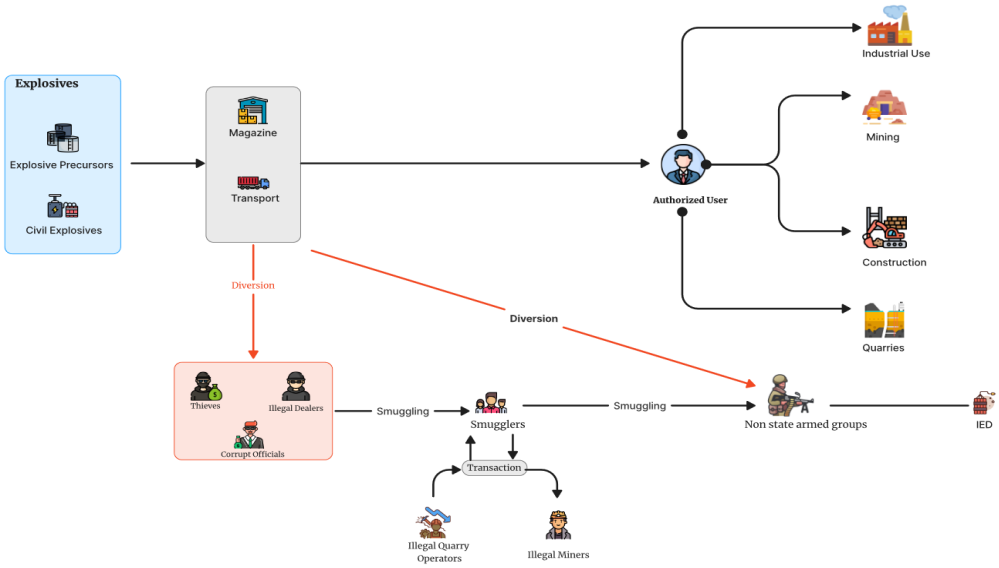

Fig. 2 Actors Involved in Explosive Devices Supply Chain

3 Results and Discussion

The results as presented in this section give a comprehensive overview of the HEMS that has been developed. Fig. 3 shows the login page of the HEMS. This was necessary to ensure that only authorized users gained access to the system. Access level privileges have been deployed in the system so that different user levels depict what exactly users can do in the system.

Fig. 3 Login Page of HEMS

3.1 HEMS Dashboard

Fig. 4 shows the dashboard of the developed HEMS. The dashboard shows the various modules that make up the entire system. The modules conform to the regulations set out in L.I. 2177. In total, the are 23 modules which have been integrated carefully to function effectively. These modules are discussed in the preceding sections.

3.1.1 Chief Inspector of Mines Module

The Chief Inspector of Mines (CIM) module as shown in Fig. 5 was developed to give the CIM an oversight of the operations of the ED carting companies without being on-site. Through the HEMS, the CIM can give approvals/decline applications where necessary. All these actions are carried out online and in real-time to conform with regulations 30-33, Form M, N, O and P of L.I. 2177.

3.1.2 Explosive Trucks Monitoring Module

Fig. 6 displays a map showing the locations of ED carting trucks across the country. This module is very crucial as it gives the personnel of the Inspectorate Division of the Minerals Commission a real-time view of the movement of the trucks across the country.

3.1.3 Law Enforcement Module

Fig. 7 displays the results from the law enforcement dashboard. On this dashboard, law enforcement officers can monitor the operations of ED companies in the country. The agencies can also approve/disapprove requests submitted by ED companies in accordance with Regulations 71(1c) and 95(1d) of L.I. 2177.

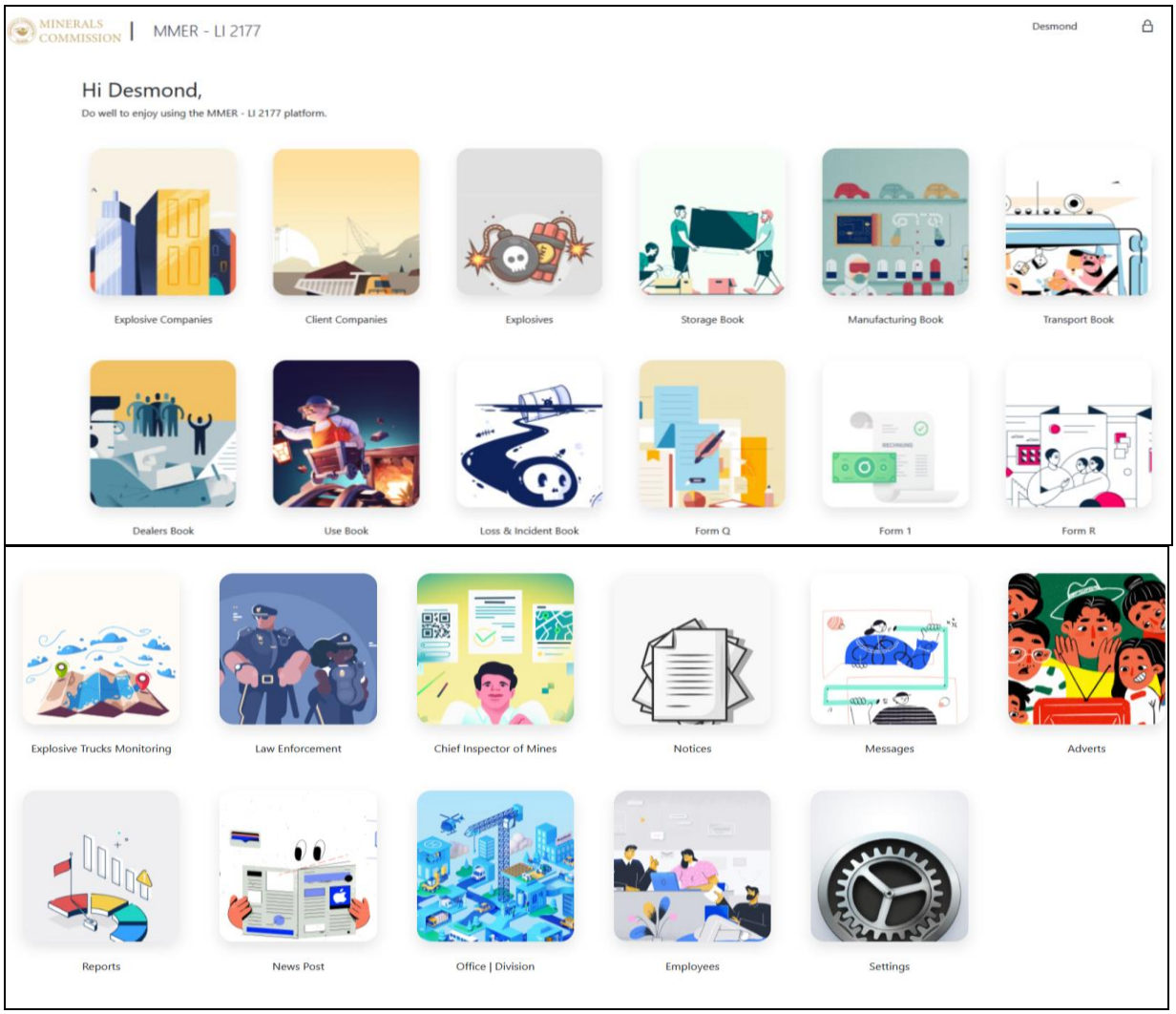

Fig. 4 Dashboard for Harmonised Explosive Management System

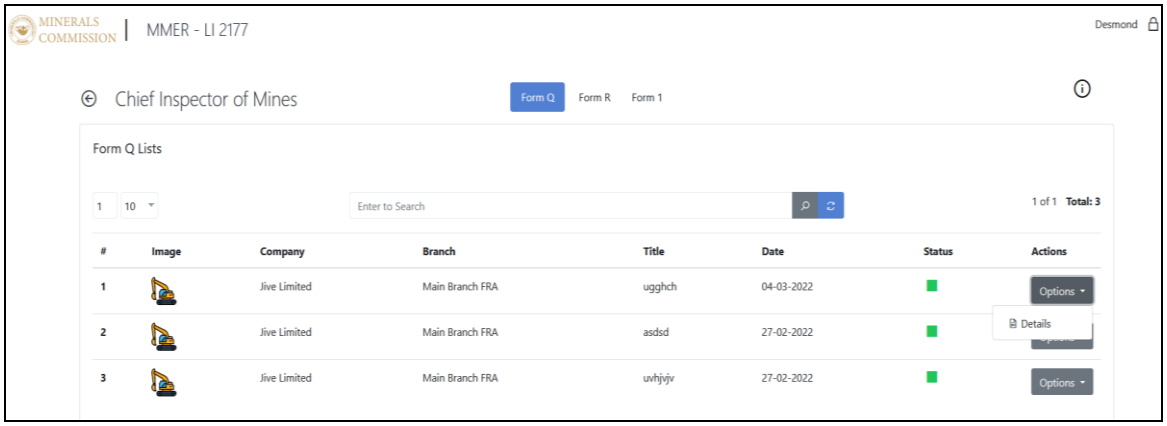

Fig. 5 Dashboard for the Chief Inspector of Mines

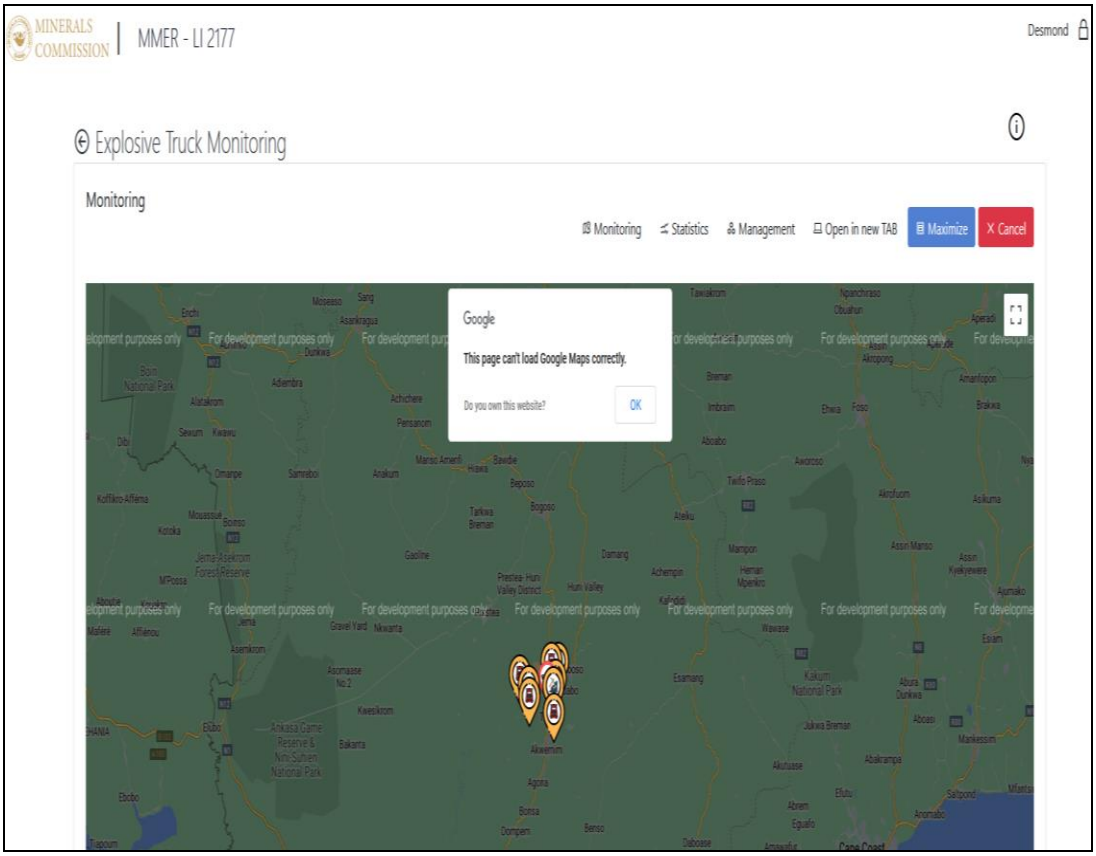

Fig. 6 Dashboard for Monitroing Explosive Carting Trucks

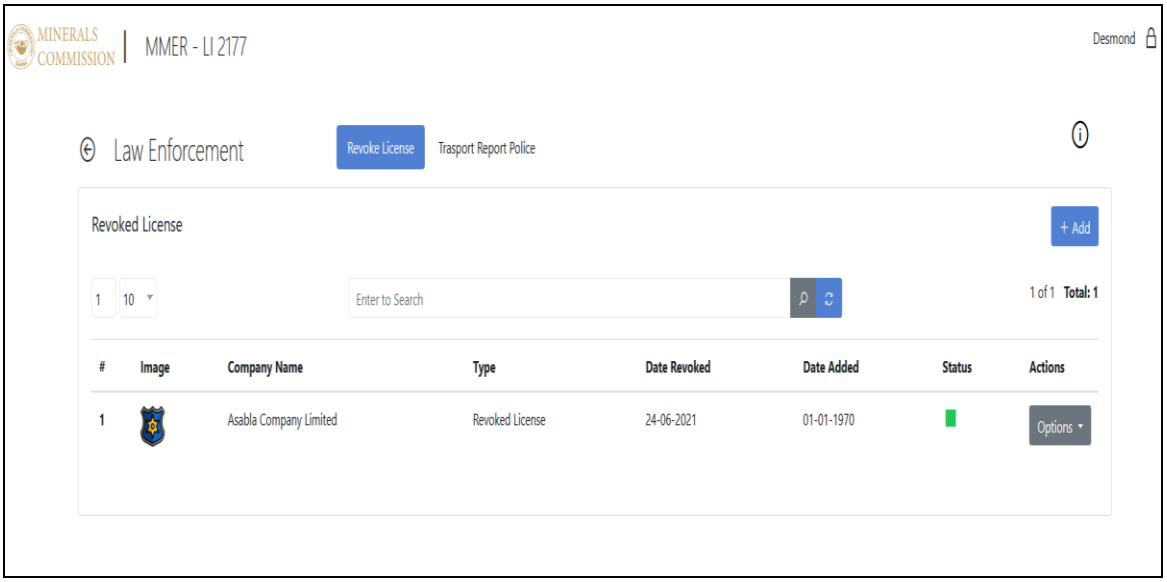

Fig. 7 Dashboard for the Chief Inspector of Mines Module

3.1.4 Loss and Incidence Book Module

Fig. 8 shows the results of the Loss and Incidence module. With this module, all ED companies are expected to input any form of ED loss or incidence into the HEMS in accordance with Regulation 4, 64(1c) and 110 of L.I. 2177.

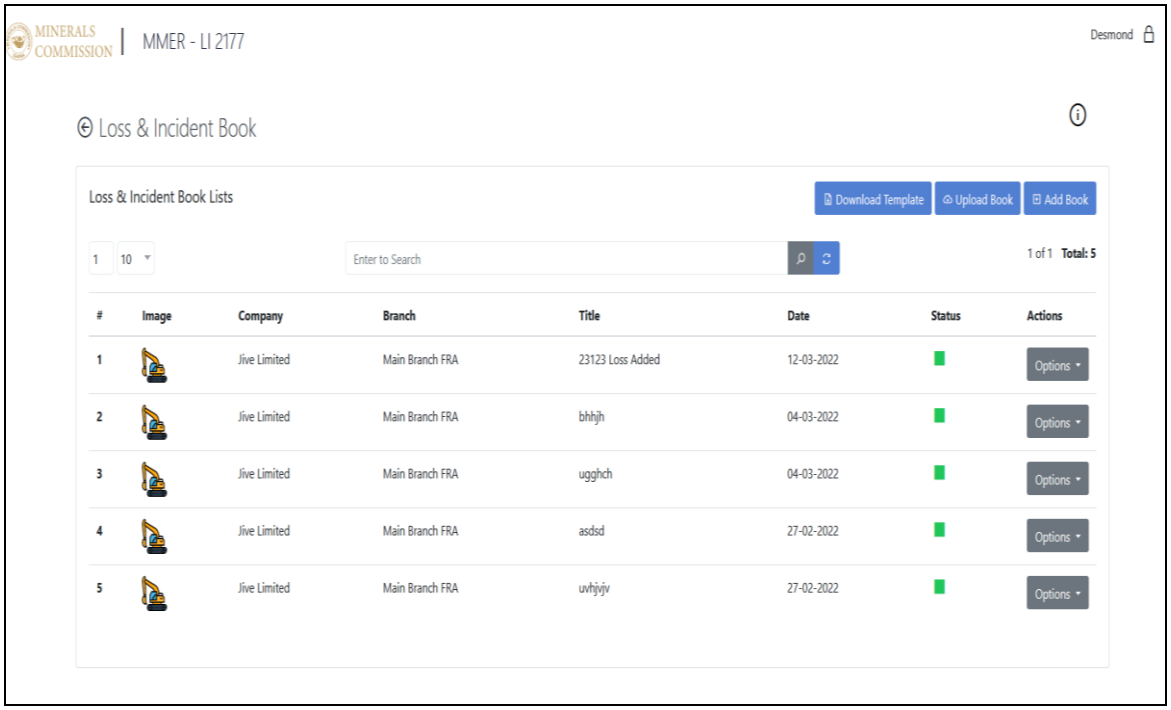

Fig. 8 Dashboard for the Loss & Incidence Module

3.1.5 Transport Module

Fig. 9 shows the results from the Transport module. This module tracks the movement of all ED carting trucks. To achieve this, explosives managers and drivers of ED carting trucks are expected to upload their travel itineraries on the HEMS. This module works directly with the Explosives Trucks Monitoring module. For compliance purposes, the movement of the vehicles will be monitored in real-time.

3.1.6 Use Book Module

To efficiently monitor the usage patterns of EDs in Ghana, this module as shown in Fig. 10 will enable ED companies to upload the records of explosives (as shown in Fig. 11) in their possession that will aid tracking and tracing.

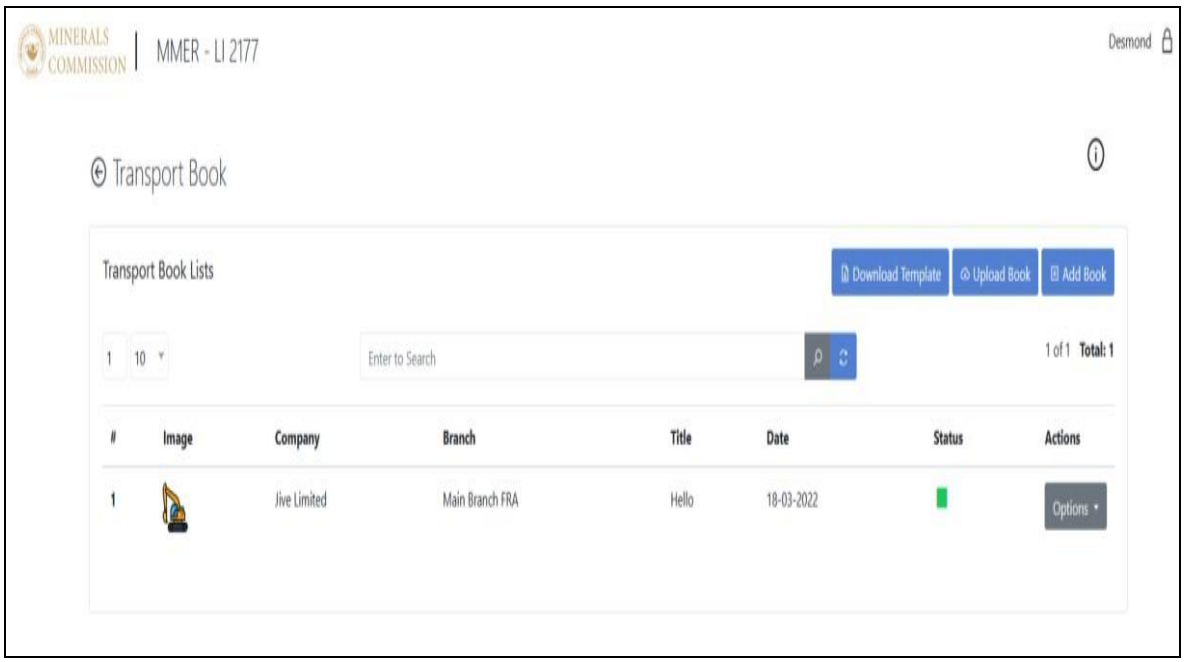

Fig. 9 Dashboard for the Transport Module

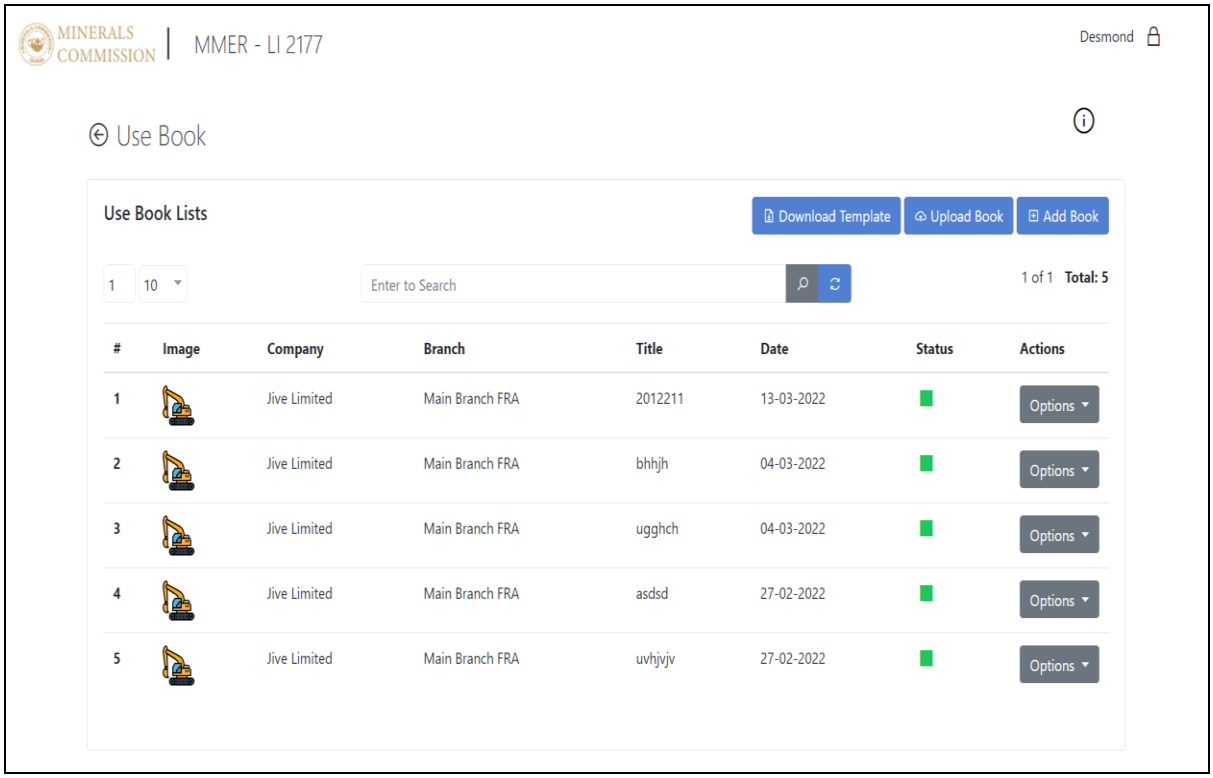

Fig. 10 Dashboard for the Use Book Module

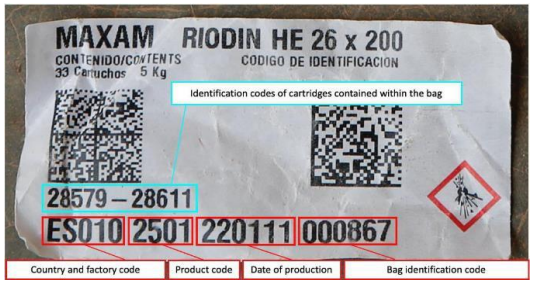

Fig. 11 :Sample of Labelling of Explosives with Traceability Number

3.1.7 Dealers Module

Fig. 12 shows the results of all dealers involved in ED activities in Ghana. The module takes inventory of all dealers, the types of EDs that they manufacture or deal in and the types of clients that they work with in accordance with Regulations 46(2d) of L.I. 2177.

3.1.8 Manufacturing Book Module

Fig. 13 shows the results of the Manufacturing Book module. This module gives detailed information on the types of EDs that are manufactured in Ghana, the manufacturing details such as type, quantity and the date on which the ED was manufactured, etc. in line with Rregulation 46(2b) of L.I. 2177.

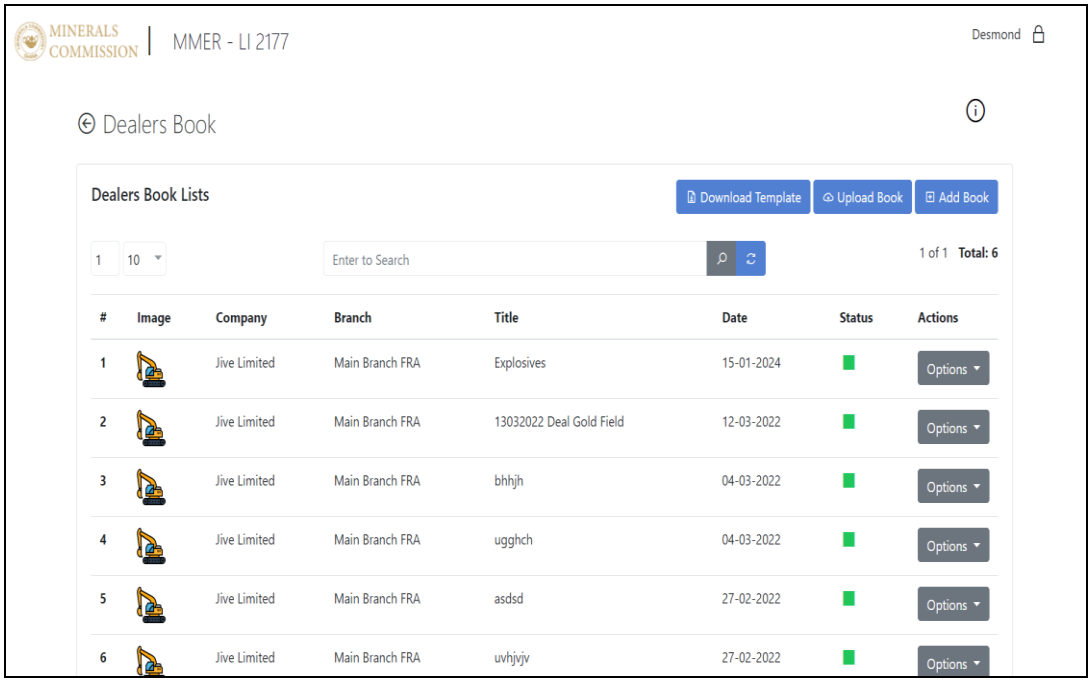

Fig. 12 Dashboard for the Dealers Book Module

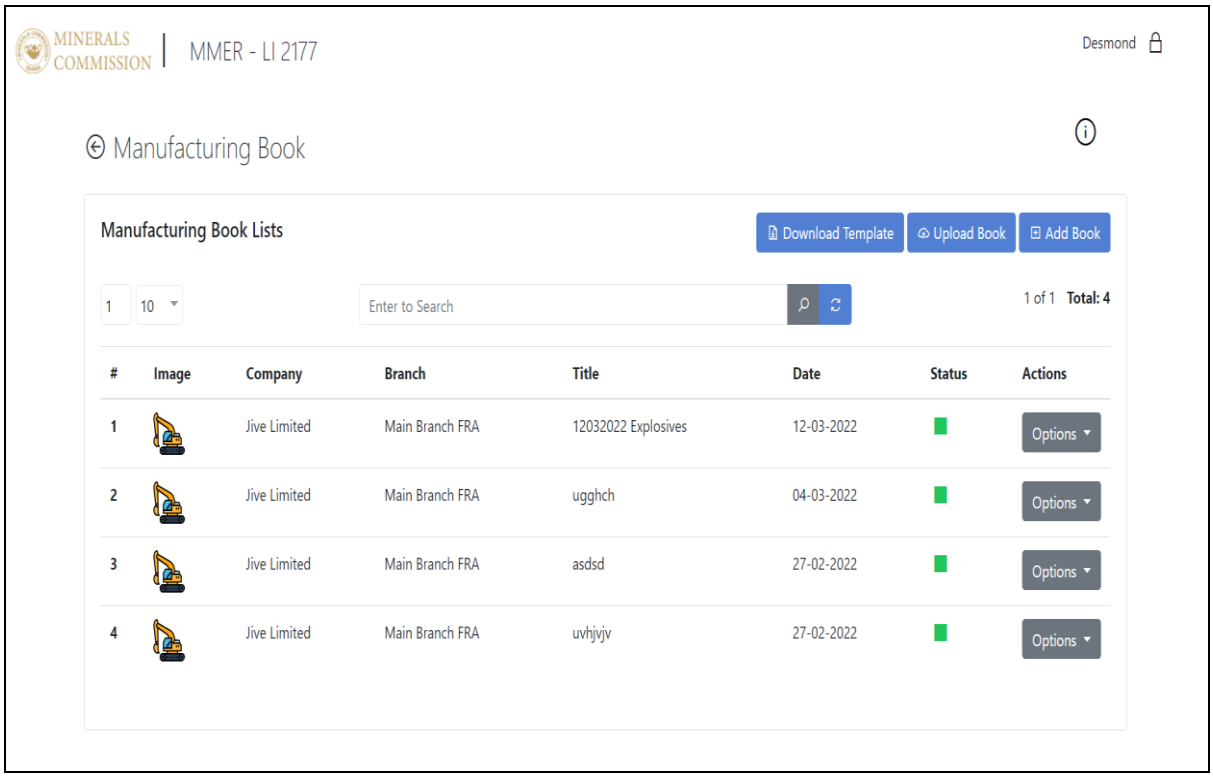

Fig. 13 Dashboard for the Manufacturing Book Module

4 Conclusions and Recommendations

4.1 Conclusions

From the research study, the following conclusions are drawn:

a) The HEMS is capable of taking inventory of all EDs that are imported and exported from the country;
b) The HEMS would track the movement of EDs throughout their life cycle;
c) The HEMS when implemented will provide real-time monitoring of the usage patterns of

EDs to the Inspectorate Division of the Minerals Commission of Ghana; and

d) The HEMS would fulfil the regulatory requirement of Regulation 45 of L.I. 2177 in the manufacturing of EDs.

4.2 Recommendations

From the study that has been carried out, the following are recommended:

a) The HEMS software should be implemented and its effectiveness and efficiency evaluated.
b) The software must be upgraded periodically;
c) Security patches for the HEMS must be installed periodically to ensure the system is up-to-date to withstand malicious attacks from hackers thus ensuring optimal functioning of the system at all times; and
d) The technical capabilities of personnel from the Inspectorate Division of the Minerals Commission must be frequently enhanced to enable effective utilization of this technology. With the advent of this technology, officers need to adapt to new ways of doing things including the use of software rather than the traditional paper-based rudimentaries.
e) Adopting the HEMS for use in Ghana to curtail illicit trade in EDs.

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