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Cover Photograph: A Biotite gneiss sample from Sri Lanka is being sheared inside a confined thick concrete cylinder by the 5000 MT Universal Testing Machine in the Civil Highbay at University of Wollongong, NSW, Australia, an experiment crucial to optimize pile designs in Sri Lanka.

Cover design & Photo credit:
Eng. Udara Bulathsinhala

Message from Editor of the Journal Incorporated Engineer

We take pride in the continuous publication of the journal INCORPORATED ENGINEER, with valuable articles from our members and invited authors. This journal increasingly serves as an avenue for our members to publish the findings of their research in many different fields of engineering and engineering technology. Most manuscripts received are on contemporary technologies with a focus on applications, as well as on applied research such as the story featured on the cover page of this issue. Further, we receive manuscripts reviewing existing applications of the engineering industries, along with comparative analyses of global developments and the local context, highlighting opportunities for the growth of our local engineering industries and the way forward for Sri Lanka. We are pleased to bring to you another issue of our journal covering a wide variety of subjects that are of great value to our readers.

Dr. Bhadranie Thoradeniya, FIIESL

Review Panel

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SECTION I

A Review of Railways Development: Way Forward for Sri Lanka

Eng. K.S.E.D. Kodikara

Abstract: The railways have been tremendously developed from their origin over a period of a century. The developments are in many different aspects of railways from the rail tracks to modern electric trains. Even though the Railway system in Sri Lanka has a history of around 150 years, we are far behind the modern developments. Hence this paper attempts to describe some key global developments in the sector shedding light to way forward for Sri Lankan railways.

Key Words: High speed trains, Railway Technology, Locomotive, Level crossing, Permanent way

1.0 Introduction

Different Railway systems are being adopted in the world, depending upon the topography of the area.

(a) Surface railway - Railways located over the ground surface.
(b) Tube railways - Railways located at depths varying from 26 m to 50 m from ground level.
(c) Underground railways - Railways located just below the ground level.
(d) Elevated railways - Railways located above the ground surface. (Saxena & Arro, 1981)

There are other railway classifications that exist. Classification based on track gauge is one such example. The Shanghai Maglev in China, which is the fastest train in the world today, runs on a standard gauge track (Figure 1).

Figure 1: Shanghai Maglev

Shanghai Maglev, also known as the Shanghai Trans Rapid, tops others with its maximum operating speed of 460 km/h and average speed of 251 km/h. The Maglev train is not a conventional high-speed model. Instead, it utilizes electromagnetic force to levitate above the track, eliminating friction and allowing for incredibly smooth and quiet travel.

Under this backdrop the aim of this paper is to present global railway modernization initiatives, inclusive of Sri Lanka.

2.0 Evolvement of Sri Lanka Railways

Bamunusinghe Aarachhige Don Rampala (14th Nov 1910 – 20th June 1994), popularly known as B. D. Rampala was the first native Sri Lankan to hold the post of Chief Mechanical Engineer at Sri Lanka Railways (SLR), who later became the General Manager of Sri Lanka Railways. Engineer B.D. Rampala, achieved many firsts in the buildup of local shunting locomotives at the Ratmalana workshops, including the introduction of color light signaling with centralized traffic control to ease the congestion at peak hours in the suburbs of Colombo and the installation of a network of radio transverse receivers. Those were the best examples of railway innovations in terms of Sri Lanka. In 1956, the Institution of Locomotive Engineers in London recognized Rampala as the finest diesel engineer in Asia at the time (Fgure2).

Figure 2: Mr Rampala in a M1 locomotive

Dieselization of the steam engines and introduction of long distance fast express trains were some of Eng. Rampala's other pioneering efforts.

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Dieselization, in other words, changing traction from steam to diesel was a leap forward for any railway in the globe at that time (Wikipedia, 2013). The next fire up is the electrification of railways and Sri Lanka railway is too looking forward to transforming its diesel traction into electric traction. Sri Lanka Railway's electrification project is to be implemented by the Department of Railways with loan assistance from the Asian Development Bank under the supervision of the Ministry of Transport and Civil Aviation. Preliminary studies of this project have been completed by now and preparation of the detailed plans has been initiated.

2. 1 Preparation of electrification project plans

Preparation of a project for electrification of railways consists of a few stages:

- Preparing the detailed designs required for renovation of existing railway lines and construction of the new parallel railway lines with the objective of driving the electric trains in the future and determining the land belts belonging to the rail routes accordingly.
- Conducting a survey on the social and economic status and exiting properties of all the residents living in the area, which are affected by the project.
- Preparing a plan for the resettlement and granting compensations to the project victims.
- Conducting environmental evaluations in the area belonging to the project.

As railway electrification is still unfamiliar in Sri Lanka the terminology given in Table 1 will be helpful to understand some general features of it.

Table 1 Terminology of Electrification of railways

Term	Description
Railway electrification	Use of electric power for the propulsion of rail transport
Propeller	Electric locomotive, Electric multiple unit
Electric railway type 1	Possessing own dedicated power generating stations
Electric railway type 2	Purchasing power from electric utility
Power conductor type 1	Overhead line
Power conductor type 2	3rd rail

The advantages of electrification over diesel traction are that they are quieter, more powerful, more responsive, more reliable, and urban friendly.

The disadvantages of electrification over diesel traction are high capital cost, relative lack of flexibility, vulnerability to power interruptions. Global share of railway electrification is one third of total tracks.

SLR has taken some initiatives to modernize the railway system and some of them are listed below.

1) Rehabilitation of coastal railway line.
2) Rehabilitation of northern railway line.
3) Rehabilitation of Talaimanar railway line.
4) Construction of Railway line from Matara to Belliatta with modern Long Welded Rails (LWR).
5) Rehabilitation of signaling and telecommunication system in the Northern and the Thalaimanar line.
6) Replacing the centralized traffic control system in the coastal line.
7) Rehabilitation of signaling and telecommunication system in Mainline.
8) Electronic payments.
9) Mobile seat reservation.
10) Train ticketing and operating information system.
11) Dueling project between Kalutara South and Payagala South with modern Short Welded Rails (SWR) track structure.

Rehabilitation of the Costal line (from Colombo to Beliatta) was an initial project raised by SLR. With a view to providing a safer and speedier train service to the south, upgrading of the coastal line from Kalutara to Matara had become a matter of paramount importance. SLR had upgraded/rehabilitated the coastal track from Colombo to Kalutara, prior to the above project with welded rail panels and concrete sleepers.

A good understanding of the modern railway revolutions in the world by the relevant professionals may help SLR, where there exist several railway modernization projects. It is cheerful news to know that several projects will be implemented by the SLR in the future too. However, due to prevailing financial crises it might take some time in a vacuum.

Proposed main line development is one such example. Under this project an additional rail track will be introduced to both Colombo-Ragama and Ragama-Veyangoda rail track corridors. A few issues that will demand the attention of the project team when implementing this project are:

- Encroachments in the railway reservation.
- Curves In the existing railway line.

- Intersections and parallel sections of central highway.
- Removal of level crossing at Hunupitiya.
- Level crossings.

The design of Sri Lanka main line railway was carried out based on two studies which were conducted during recent years under the Colombo Suburban Rail (CSR) project (CSRP, 2016).

1. Pre-feasibility study conducted by M/s. Egis international of France.
2. Main line Feasibility Study conducted by M/s Dohwa Engineering jv of Korea.

3.0 Modern Trends in World Railways

Technological advances in many spheres have resulted in excellent services for better, more economical and efficient world railways.

3.1 Track Vehicles

In railway engineering terminology rail track vehicles are commonly referred to as rolling stocks. These include both powered and unpowered vehicles. Locomotives, freight cars (wagons), passenger cars (coaches) and non-revenue train vehicles are some key instances for rolling stocks. Passenger vehicles can be unpowered or self-propelled, single or multiple units. A connected series of railway vehicles is a train. Key technologies used in high-speed train rolling stock include tilting train tests, aerodynamic designs (to reduce drag, lift and noise), air brakes, regenerative braking, engine technology and dynamic weight shifting. Notable high speed train manufactures include Alstom, Hitacchi, Kawasaki, Seimens, Stadler Rail and CRRC. Nonetheless, where railway modernization is concerned, high speed railway is not the only matter at hand. Metro trains, commuter trains, freight and intercity trains along with others must be considered.

3.2 Motive Power

Railway traction can be diesel, steam or electric power. The traction system can be broadly classified as non-electric and electric traction systems.

Non-electric high-powered locomotives - Although commonly called "diesels", those locomotives are actually electrically driven. The diesel engines drive an alternator, which produces electricity to run electric motors mounted on the locomotive's axle. Nonetheless, traction of the diesel locomotive is not electric but diesel because it is fueled by diesel. This is confusing context. In order to clarify, firstly one has to understand the basic types of railway tractions. SLR uses two main types of tractions.

(1) Steam traction
(2) Diesel traction

Diesel traction is again branded as Diesel hydraulic and Diesel Electric. Steam traction and diesel hydraulic traction are not dealt with electricity. Those locomotives are hauled by fuels called steam and diesel respectively. Diesel electric locomotives need electricity to rotate axels because axels mounted motors work if only generators are active. Generators activate by not external electricity supply from an overhead wire or 3rd rail which is the practice of electrified locomotive. As such there is a huge difference between diesel electric locomotive and electric locomotive.

Electric locomotives: When studying world railways, the best examples of locomotives which bring superior performance to relevant countries embodying their railway modernization process are mentioned below.

(1) 2ES 10S locomotive: This is a twin section electric locomotive manufactured from 2010 by Ural locomotives. Russian railway (RZD) ordered 221 units in 2010. Ukrainian railway ordered 50 units in 2013. These locomotives are primarily used to pull freight trains.
(2) WAG 11: The Indian locomotive class WAG 11 is a class of twin section 25 KV AC electric locomotives that was developed in 2018 by Banaras Locomotives Works (BLW), Varanasi for Indian railways. This freight engine has been designed for 105 km/hour and weighs 252 tons.
(3) 060EA: Wheel arrangement of this electric locomotive is Co-Co. Locomotive is owned by Romanian railways and numerous private railways in Romania and Hungry. There are three chains of these locomotives.
(4) 2-10—10-2: Under the Whyte notation for the classification of steam locomotive wheel arrangements a 2-10—10-2 is a locomotive with 2 leading wheels, 2 sets of 10 driving wheels, and a pair of trailing wheels. All these 2-10—10-2 locomotives have been articulated locomotives of the Mallet type. This wheel arrangement is rare. Only two classes of 2-10—10-2 locomotives have been built for Virginian railways.

For gaining high power only electric traction is more fruitful than steam traction. Diesel electric locomotives too perform in this field but not up to electric locomotives. Union pacific railway's 'The centennials' locomotive is the best example for high

powered Diesel electric locomotive, with 6600 horsepower.

3.3 Infrastructure (Track)

The key feature of the modernization of the rail track is the mechanized maintenance. Under this type of track maintenance, the following steps are to be taken.

- Deep screening of the ballast below joints.
- Packing the joint sleepers and shoulder sleepers thoroughly.
- Providing proper drainage at joints.
- Tightening the loose fittings.
- Providing 1-meter-long fish plates at joints.
- Adjusting the creep.

The mechanized maintenance of tracks normally involves the use of track machines. There are many machines and one of the most prominent examples is the mechanical tamper. These machines are used to tamp or pack the ballast. There are two broad types of mechanical tampers as 'Off-track tamper' and 'On-track tamper'.

'Off-track tamping machines' are a type of hand tool driven by compressed air, electricity or petrol engine. 'On-track tampers' are self-propelled machines, where the tamping of sleepers is done automatically through controls provided near the operator's seat. On-track tamping machines are again categorized into two types. They are the 'Light on-track tamping machines' and 'Heavy on-track tamping machines'. The 'Light on track tamping machines' usually consists of two tamping units mounted on a common motorized trolley. These machines are light (1000 kg to 1200 kg) and can be taken off track without much difficulty, while the 'Heavy on-track tamping machines' weigh 15,000 kg and above.

The earlier machines were able to do tamping only, but the latest models can do lifting, leveling, tamping and lining of track automatically. Mechanized track maintenance, particularly with previously mentioned 'Heavy on-track tamping machines', has been able to overcome most of the limitations enumerated in beater packing and measured shovel packing (MSP). Its superiority lies in the following:

(1) Its capability to maintain modern LWR track laid with concrete sleepers to close tolerances, as required for high-speed traffic.
(2) Its marked reduction on human effort, most of track maintenance being done automatically.
(3) Its high speed of operation, which is particularly beneficial for the restoration of track geometry after deep screening or relaying in the shortest possible time.

In the Indian railways, mechanized track maintenance is being increasingly adopted for the maintenance of high-speed routes and for quicker restoration of track after relaying. Its present fleet of machines consists of more than 120 on-track tamping machines. In addition, there are few points and crossings tampers, crib and shoulder compacters, ballast regulators and ballast cleaning machines working in the Indian railways. In addition to above straight track maintenance machines, all mechanized railways, inclusive of Indian railway, utilize following self-propelled machines for various intentions in rail track management (Mundrey, 2009).

a) Rail track laying machine
b) Rail cranes
c) Rail material transport cars
d) Rail track inspection cars

Rail track inspection is another crucial aspect. As a whole detecting track errors, in modern railways could be observable in several modes as below.

- Track inspection vehicles
- Track measurement systems
- Track imaging systems
- Autonomous inspection systems
- Track inspection tools

***Track inspection vehicles*:** The different types of vehicles are described below.

- Self-propelled vehicle: That serves as a track inspection platform, carrying work crew too.
- Towed coaches: Cost effective solutions that improve the capacity of the rail network. Can be towed on revenue trains or behind dedicated locomotives and configured for high speed and long-haul track inspection operations.
- Hi rail vehicles: Designed and constructed specialized equipment to meet the customer's inspection and testing needs for light, medium, or heavy-duty trucks to address a full range of inspection and operational requirements.

***Track measurement systems*:** For ensuring safety of the track, increasing productivity and efficiency and reducing operating cost automated measurement technologies, modular and scalable, built into a new customized vehicle or retrofitted into existing vehicles are used.

- Track geometry measurement system (TGMS)
- Rail profile measuring system

- Third rail measuring system (TRMS)
- Deployable gauge restraint measurement system
- Ride Quality measurement system
- Rail corrugation measurement system
- Overhead wire measurement system

***Track imaging systems*:** High resolution camera systems and advanced image processing algorithms that can be operated during day or night, deliver comprehensive track inspection and evaluation.

- Joint bar imaging system
- Track component imaging system
- Rail surface imaging system
- Driver view imaging system
- Overhead wires (catenaries) imaging system
- Tunnel wall imaging system
- Thermal imaging system

***Autonomous inspection system*:** Operate uninterrupted, more frequent and without on-board operators on passenger and freight cars in revenue service for cost effective maintenance, planning and railway standards compliance.

- Vehicle/ track interaction (V/TI) Monitor: Real time monitoring of track and vehicle conditions without impacting revenue service. Risk alerts transmitted via cellular network, received as email alerts.
- Autonomous Track Geometry Measurement System (ATGM): Measures and creates reports that track geometry exceptions, including gauge, cross level, warp, twist, surface and alignment to meet FRA safety standards.
- Overhead Wire (catenaries) Measurement System.

***Track inspection tools*:** Accurately know the location and condition of the track assets from the condition of track to location of train for efficient maintenance, safer operations and cost savings through reliable data management.

- Portable Track Loading Fixture (PTLF): Easy to use, manually operated track inspection tool measures gauge strength to AREMA and FRA standards.
- Digital Track Notebook®3.0 (DTN): Mobile, web-based track inspection tool automates management of inspection schedules, maintenance, defect identification and follow up records in performance reports to ensure regulatory compliance.

In addition to those hi-tech devices today, the rail industry brings into play with many portable machines replacing manual tools. The incessant problems of vacancies of gang men and their continuously increasing age profile is leading to reduction in efficiency of manual maintenance of track. The track structure has become heavier. The deployment of small track machines has become inevitable. Now there is no other way except introducing small track machines in day-to-day maintenance. Output of those is more than the manually achieved work. In the modern scenario if time is saved it will increase wagon turnaround, and more time for traffic; hence earning of railway is also increased.

Using the small track machines, railways can achieve the best quality of work. The rail track can be maintained to closer tolerances as required. Those portable machines are suitable for concrete sleepers and modern CWR track (Figure 3). Use of small track machines is always economical. Nevertheless, rail track construction is more difficult than its maintenance practice. For this, railways need many types of intricate rail track machines which are bigger than those small track machines.

Figure 3: Modern CWR rail track structure

3.4 Container Transport Services

In many countries the rail cum road container transport services have been introduced to check the diversion of high rated freight traffic from rail transport to road transport. The containers used in this intermodal transport are in the form of closed or open boxes of varying dimensions and designs which are made of steel, stainless steel, aluminum etc. These are suitable for mechanical handling and can be transferred rapidly from and to rail wagons, to and from road trucks, ships and even the aero planes. This rail cum road container transport services combines the advantages of low cost of long hauls in railways and of door-to-door collection and delivery service possible in case of highways. Although most railway container wagons are 5-ton capacity, 20-ton and 40-ton capacity wagons conform to international standards for promoting export and import cargo program with

other countries. There are many examples of products which can be hauled using rail cargo containers. In the modern railway industry logistics experts are available to find the right transport solution for any other industry. Years of experience make intra model transport employees as customer reliable partner when it comes to efficient, high frequency, combined and networked end to end logistics.

3.5 Miscellaneous Development

Two other major developments are discussed here.

a) ***Improved level crossing safety***: Enhancing the level crossing safety is an important matter because even in a very cautious environment there remains opportunity for human error to occur, for users to be distracted and deliberate misuse to take place. It may be interesting to note one creative method adopted by Belgian National Railways. Experiments are in progress to improve safety at level crossings by providing barriers made of transparent plastic material and reinforced with glass fibers. This type of barrier will give greater safety at nighttime during adverse weather conditions such as poor visibility in foggy weather. Modern concept, when enhancing level crossing safety can be basically classified as below.
   - preventing averted collisions
   - preventing collisions
   - Minimizing damages due to collisions

b) ***Refrigeration trains*** (Figure 4) - These trains with mechanical cooling arrangements have been introduced by Russian railway to carry food stuffs and other perishable goods. Today United Kingdom is one of the key countries using this type of rolling stock. Due to the shorter distance to be travelled in UK, the need for refrigeration was limited to specialized goods, which could be in express train format – mostly run overnight to avoid delays from passenger traffic – transported in suitable time scales of less than a day from the area of production to processing, or onwards to the point of consumer consumption. A refrigerator car (or reefer) is a refrigerated box car piece of railroad rolling stock designed to carry perishable freight at specific temperatures. Refrigerated cars differ from simple insulated box cars and ventilated box cars (commonly used for transporting fruits, neither of which are fitted with cooling apparatus.) Reefers can be ice cooled, come equipped with any one of a variation of mechanical refrigeration systems or utilize carbon dioxide (either as dry ice or in liquid form) as a cooling agent. Milk cars (and other types of express reefers) may or may not include a cooling system but are arrayed with high-speed trucks and other modifications that allow them to travel with passenger trains.

Figure 4: Refrigerator train

4.0 Railway Advancements

Studies reveal that in the development of railways, the technological emphasis has shifted following advancements.

4.1 Faster Operations

The faster operation of railway is not the mere high speed. All following items too should be in a faster mode: Scheduling trains; Train dispatching and rail traffic control; Train crew management; Maintenance of infrastructure; Maintenance of rolling stocks; Railway safety; Customer service; Fare enforcement.

4.2 Facilities for Passengers

Some facilities available for passengers of Indian express trains departing from major cities such as Delhi, Kalka, Howrah and Mumbai, are Escalators, Lifts, Reservations, Second class bookings, Train enquiry sections, Pilgrim guide, Tourist assistance, VIP lounge, Fully air conditioned hotels with a shopping lounge, Multi cuisine restaurants, Cloak rooms, Waiting halls, Book stalls, Tea stalls, Toilet blocks, Catering area, and Huge parking places.

Nonetheless, Indian railways is not an advanced railway in the world, though it is a very magical rail network and the 4th largest in the world. Not only its technology but also its passenger amnesties give good lessons to countries like ours. Further, it is worth noting that specific features and facilities of world railways may vary from station to station, depending on their location, size and level of development. Modern railway stations aim to create a pleasant and efficient travel experience for passengers while catering to their diverse needs.

4.3 Larger and More Specialized Freight Cars

A rail freight car is a rolling stock used for carrying goods. A freight train can be in one rail wagon or can even be arranged in an entire train depending on goods and needs and other railway operation conditions. Advantages of rail freight transport are as follows.

- Ability to transport large volumes of freight
- Reliable transit time
- Reliable transit schedules
- Environmentally friendly
- Fuel efficient

Rail freight is important to economic development because of its comparative economic advantages in serving certain forms and flows of freight. Countries with well-functioning freight railways are more competitive and reap wider benefits of balanced transport systems in which the right freight moves in the right mode. The economic benefits of freight transport occur when it allows producers from developing countries the affordability to access inputs of raw materials, intermediate goods and other resources and to consign their final products to markets. Well run railways provide the capacity and services required by heavy industries, thus facilitating trade, economic specialization and economic growth. In some regions of Central Asia, Eastern Europe, South Africa, Southeast Asia and Sub-Saharan Africa characterized by groupings of many small countries, rail freight can increase economic integration by providing access to international and regional markets and connecting land locked countries (Wikipedia, 2023)

One of the key technology concepts of freight wagon modernization is the use of composite panels. A 3D documentation was prepared for the process of modeling and computer aided analysis of the freight wagon type 1415 A3 and dumper 418V wagons, which are widely used In Poland railway, by Silesian University of Technology.

5.0 Conclusion

The Sri Lanaka Railways (SLR) has a great and long history. However, many of the modern, relevant developments taking place in the world, have yet to be implemented at SLR. In this paper the author attempted to mainly discuss the modern developments in motive power, infrastructure and other special operations. Technical advancements in other miscellaneous items are also briefly discussed. It is expected that readers, especially those who are interested in Railways, will be motivated to further enhance their knowledge. It is anticipated that engineering and other professionals in Sri Lanka Railways will be stimulated to better plan and implement Railway modernization at the SLR.

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Optimization of the Usage of Weathered Rocks Found in Sri Lankan Rock Quarries

Eng. A.U.V.B. Bulathsinhala, Eng. M.M.P.D. Samarasekara and W.M.D. Priyankara

Abstract: The weathered rock found in most of the rock quarries in Sri Lanka are underutilized. Since the weathered rocks show some discolouration, quarry owners treat them as waste material and either dump them or use them as land filling material mostly at the quarry sites itself. This study was carried out to determine how rock waste is utilized and/or disposed at different rock quarries in Sri Lanka by using a questionnaire survey and to ascertain strength properties of rock waste by conducting laboratory experiments. The data obtained from 30 rock quarries distributed in many parts of Sri Lanka, it was found that nearly 40% of quarries treat weathered rocks as waste material. The strength tests conducted as part of this study indicated that slightly weathered and moderately weathered rocks have acceptable strength properties suitable to be used as highway and building construction materials. Hence this study concludes that usage of weathered rocks can be optimized by means of judgements based on experimental results rather than using conventional visual observations which leads to a considerable wastage of rock materials and economical loss.

Key Words: Metamorphic rocks, Optimization, Rock Quarries, Weathered rocks.

1.0 Introduction

Sri Lanka's physiography consists of a central mountainous mass enclosed by a low, flat plain on all sides and extending up to the sea (Jayewardene, 2018). According to previous studies, 90% of Sri Lankan Geology is made of high-grade metamorphic rocks of Precambrian age which are older than 570million years (Cooray, 1984). It belongs to South Indian shield which is one of the oldest and stable parts of the earth crust. The common Precambrian metamorphic rock types in Sri Lanka are Charnockitic gneiss or Charnockitic, Quartzite, Marble, Dolomite, Granulite, Migmatite, Gneisses (Garnet Sillimanite Graphite Gneiss, Hornblende Biotite Gneiss, Biotite Gneiss, Calc Gneiss, Cordierite, Wollastonite-scapolite Gneiss and Granitic Gneiss) and Amphibolite (Jayewardene, 2018).

Currently, there are large amount of rock quarries that are being operated in the country and they produce a large quantity of crushed rocks for the industry to fulfil various construction requirements (GSMB, 2011). The current study has revealed that there is a high demand for fresh rocks rather than weathered rocks since the weathered rocks show some discoloration in surface texture. Therefore, most of the quarry owners and engineers have decided to treat this material as waste without checking their properties experimentally. Consequently, in considerable number of quarry sites, weathered rocks are considered as waste material and used for filling the quarry ground itself or dump in some suitable locations which ultimately ends up with an economical loss.

This study has shown that some weathered rocks such as slightly weathered and moderately weathered rocks also possess strength properties adequate for construction work. Therefore, results of laboratory testing carried out on the weathered rock samples to determine engineering properties can be used to check their suitability as construction material. Thus, this study aims to make recommendations on optimizing the use of rock waste as construction materials and reduce the wastage at quarries by using experimental results.

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2.0 Classification of Rock Weathering

The term weathering highlights the previous changes caused by the interaction of six factors: type and structure of parent rock, climate, groundwater, time, topography and organism (Dearman, 1974). Accordingly, the weathering may not have finished completely and may be at different stages when the time factor is considered. Therefore, classification of the extent that the particular rock has undergone in the weathering process is required to identify the stage of weathering. Moye, (1955) has used a weathered rock classification which was adopted to classify the weathering grades for granite of Snowy Mountains scheme. Originally it had 6 classified weathering grades (WG) and later a few modifications were made to it. One such modification was done by Little (1967) by sub dividing weathering Grade-I into two categories: Grade-IA, Grade-IB. Grade-IB was introduced to consider the major discontinuities such as faults. Later in 1970 Knit et.al (1970), suggested a weathering classification for logging rock cores based on Moye's classification and generalized it for all rock types.

For this study, weathering classification shown in Table 1 (Ulusay and Hudson, 2007) was considered and an identical rock weathering classification was used by the mining engineers of the selected quarry sites to identify the weathering grades of rock types.

2.1 Association between the weathering grades of metamorphic rocks and their engineering properties

There is a limited number of literature available on the weathering grades and their properties of metamorphic rocks encountered in Sri Lanka. One such study was carried out in 2017 to evaluate geomechanical and geochemical properties of metamorphic rocks of different weathering grades found at Samanalawewa hydropower project. Their objective was to evaluate the effect of weathering on engineering properties of Metamorphic rocks present at subtropical regions. Further, they have used the Metamorphic rock type, Garnet Sillimanite Gneiss for their study from 4 different weathering grades: II, III, IV, V. From that study, they found that the properties such as uniaxial compressive strength (UCS) gradually reduces with increasing weathering grade. Further, results of point load strength (PLS) confirmed a similar reduction in strength for a higher number of weathering grades (Udagedara, 2017).

2.2 Engineering properties of rocks suitable for road and building constructions

Unconfined Compressive Strength (UCS) value is a very important property of intact rocks when it is used as foundation material. The UCS value of a rock sample can be measured using the unconfined compressive test

Weathering Grade	Category	Description
I	Fresh (F)	No visible sign of matrix weathering; some rock discoloration may be present along main discontinuities.
II	Slightly weathered (SW)	Discoloration of rock indicates beginning of rock matrix weathering and along discontinuities surfaces. All rock matrices can be discolored by weathering and can be slightly softer externally than in sound condition
III	Moderately weathered (MW)	Lower than half of rock matrix is decomposed or disintegrated to soil condition. Sound or discolored rock is present forming discontinue zones or as core stones.
IV	Highly weathered (HW)	More than half of rock matrix is decomposed or disintegrated to soil condition. Sound or discolored rock is present forming discontinue zones or as core stones.
V	Completely weathered (CW)	All rock matrices are decomposed or disintegrated to soil condition. Original structure of rock mass is commonly preserved
VI	Residual Soil (RS)	All rocks are transformed into soil. The geological structure of rock mass is destroyed. There is a great volume variation, but no soil significant soil transport is present.

Table 1: Weathered rock Classification

The durability, hardness and strength of rocks are some important properties when rocks are used as road and building construction material. Hence, the slake durability, Los Angelis Abrasion Value (LAAV), Aggregate Impact Value (AIV), and Aggregate Crushing Value (ACV) are significant parameters which are checked for building and road construction works (ICTAD, 2009).

3.0 Rock Quarry Sites in Sri Lanka

By July 2023, 1227 number of rock quarries were registered and operated in almost all the districts of Sri Lanka under the industrial mining license; grade A, grade B and grade C issued by Geological survey and Mining Bureau, Sri Lanka (2023).

When issuing a mining license for rock quarries, following documents are required; deed and plan of the land, initial site investigation report, approval reports from Urban Development Authority, Central Environmental Authority & Archaeological Department, Economical Viable Report (EVR) and Environmental Impact Assessment (EIA) report (GSMB).

Table 2 – Locations of selected quarries

Number	Quarry Location	Grade	Coordinates
1	Thudugala	A	6°34'5.02"N, 80° 3'48.97"E
2	Horana	A	6°44'18.2''N, 80°08'29.4'' E
3	Mawathagama	A	7°27'26.29"N, 80°24'27.55"E
4	Uva karandagolla	A	6°46'52.17"N, 81° 6'1.45"E
5	Neboda, Thudugala	A	6°34'42.33"N, 80° 5'13.74"E
6	Central Highway Pothuhera.	A	7°24'11.04"N, 80°16'13.50"E
7	Kuda Imbula, Paragasthota, Millaniya	A	6°39'55.55"N, 80° 0'21.41"E
8	Korathota, Kaduwela	A	6°54'53.25"N, 80° 0'17.58"E
9	Madola, Avissawella	A	6°55'35.37"N, 80°13'37.60"E
10	Walallawita	B	6°21'53.73"N, 80°13'3.43"E
11	Meepe	C	6°51'51.63"N, 80° 6'3.96"E
12	Maruthamadu A	B	8°52'52.32"N, 80°27'52.16"E
13	Maruthamadu B	B	8°52'26.97"N, 80°27'32.29"E
14	Rabawewa, anamaduwa	B	7°36'51.46"N, 80°12'15.02"E
15	Anguruwathota,Kaluthara	A	6°39'25.67"N, 80° 5'24.15"E
16	Beliatte	A	6° 5'16.33"N, 80°45'9.62"E
17	Thalagala,Horana	A	6°47'6.48"N, 80° 1'49.77"E
18	Kosgama	B	6°56'45.11"N, 80° 9'14.69"E
19	Ampara	A	7°14'54.32"N, 81°38'44.99"E
20	Padukka	A	6°51'35.04"N, 80° 5'57.89"E
21	Avissawella	B	7° 0'48.82"N, 80°12'6.78"E
22	Kaluthara	A	6°38'9.06"N, 80° 1'33.08"E
23	Poruwadanda	C	6°43'17.70"N, 80° 8'31.24"E
24	Mahiyanganaya	A	7°20'43.12"N, 81° 2'17.07"E
25	Dombemada, Rambukkana	C	7°23'9.39"N, 80°21'6.66"E
26	Elugoda, Kandy	A	7°15'7.94"N, 80°34'32.88"E
27	Haragama, Kandy	C	7°15'22.64"N, 80°43'17.06"E
28	Aladeniya, Kandy	A	7°19'55.81"N, 80°34'17.26"E
29	Manikhinna, Kandy	A	7°18'48.83"N, 80°43'20.28"E
30	Dawulagala, Kandy	A	7°13'48.31"N, 80°34'35.88"E

3.1 Study Locations

Thirty study locations covering many districts were selected out of currently operational quarries which are officially registered in the Geological Survey and Mining Bureau, Sri Lanka. These selected quarry sites are shown in Table 2. Most of the quarry sites selected are in Kandy and Kalutara districts.

4.0 Objectives of the Research and Methodology

Objectives of this research is to study how the weathered rocks are disposed in different quarries in Sri Lanka and to evaluate the engineering properties of these rocks using experiments to check their suitability as construction materials. To meet the objectives, an exploratory research framework was designed consisting of two main components: a quarry site survey and testing of rock samples for selected engineering properties. Brief descriptions of both components together with methods of data analyses are presented in the sub-sections below.

4.1 Quarry Site Survey

A questionnaire survey was carried out among 30 quarry sites selected from the list of registered quarries in Sri Lanka. Mining Engineers of the grade A rock quarries and the owners of the grade B and C rock quarries were interviewed to collect 16 important facts related to lithology of quarried rocks, encountered weathering grades and their usage, and waste management.

4.2 Tests on Engineering Properties of Rock

Twenty-two rock samples were collected from 11 quarry sites of 3 different weathering grades.

- Weathering grade 1- 3 rock samples
- Weathering grade 11- 11 rock samples
- Weathering grade 111– 8 rock samples

Collected samples were tested for UCS, AIV & ACV values using unconfined compression test, aggregate impact value test and aggregate crushing value test.

4.3 Method of data analyses

Statistical analyses were used for analyzing the data collected through the questionnaire survey. Simple percentages, pie charts and bar charts were used for descriptive analyses of the individual questions. Further, the hypothesis tests were carried out to obtain a general conclusion on all the rock quarries using binomial distributions, since the sample size is greater than or equal to 30.

5.0 Results and Data Analysis

Out of 30 rock quarries selected, there were 19 grade A quarries, 6 grade B quarries and 5 grade C quarries. Out of those, the oldest quarry had started the work in 1986.

5.1 Rock types and their weathering grades encountered in quarry sites used for the samples

Thirty quarry sites were selected covering most parts in Sri Lanka to obtain required data. Major rock types encountered in those selected quarry sites are shown in Figure 1.

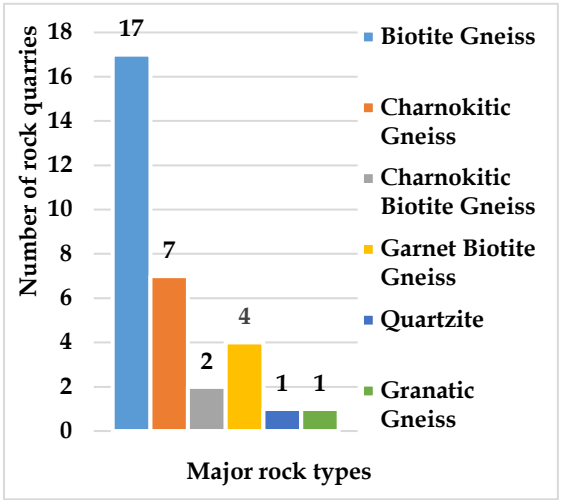

Figure 1 – Major rock types encountered in selected quarry sites

Accordingly, Biotite Gneiss is the predominant rock type encountered in many of the quarry sites used for this study. This result was rearranged in such a way that there is a dichotomous response for answer. Accordingly, 17 quarry sites have Biotite Gneiss as the major rock type while 13 quarry sites have other rock types as major rock type. The following hypothesis was framed to infer the major rock type encountered in quarry sites in Sri Lanka.
H0: Biotite Gneiss is encountered as major rock type in at least 50% of the rock quarries registered in Sri Lanka.

H1: Biotite Gneiss is encountered as major rock type in not more than 50% of the rock quarries encountered in Sri Lanka.

The responses are binomially distributed. The hypothesis test performed on the distribution accepts the null hypothesis at 95% of confidence level. Therefore, it can be deduced that more than 50% of the rock quarries registered in Sri Lanka have Biotite Gneiss as the major rock type.

The minor rock types encountered in those quarry sites are shown in Figure 2.

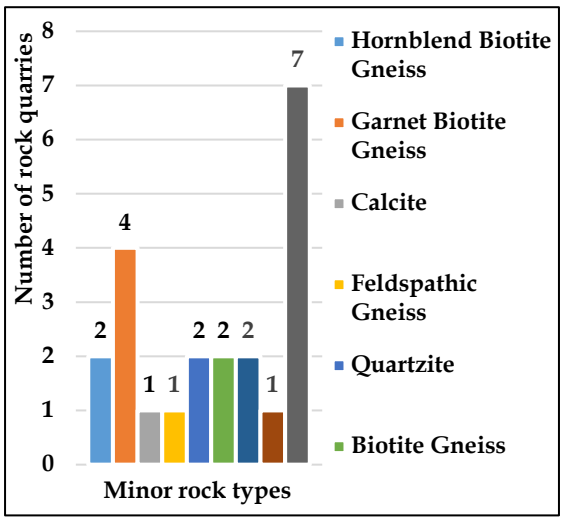

Figure 2 – Minor rock types encountered in selected quarry sites

As shown in Figure 2, Garnet Charnokitic Gneiss is the predominant minor rock type found in 7 out of 30 selected quarry sites used for this study. Also, Feldsphathic Gneiss is present in 4 quarry sites as minor rock type.

Weathered rocks are present in most of the quarry sites in the selected quarry sample. Their distribution among the 6 weathering grades as specified in Table 1 is present in the bar chart shown in Figure 3.

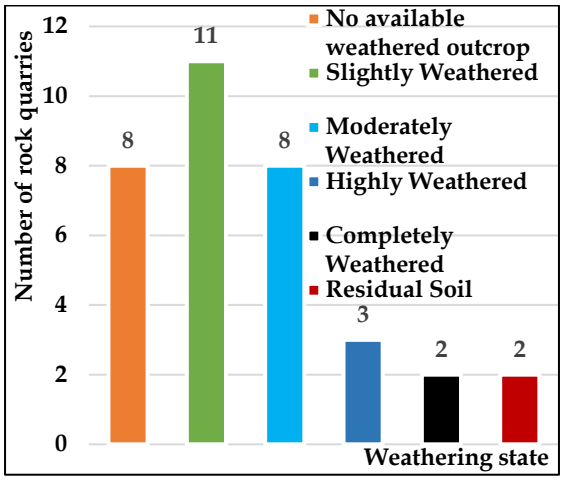

Figure 3 – Distribution of weathering grades

Accordingly, 8 quarry sites have only fresh rocks while 11 quarry sites have slightly weathered rocks, and 8 quarry sites have moderately weathered rocks. Further, very few number of sites have highly weathered, completely weathered and residual soil out crop that cannot be used for any construction purpose.

Most of these weathered rocks (quarry waste) are sold for several purposes by quarry owners. Figure 4 shows the usage of quarry waste by the quarry owners who participated for this study.

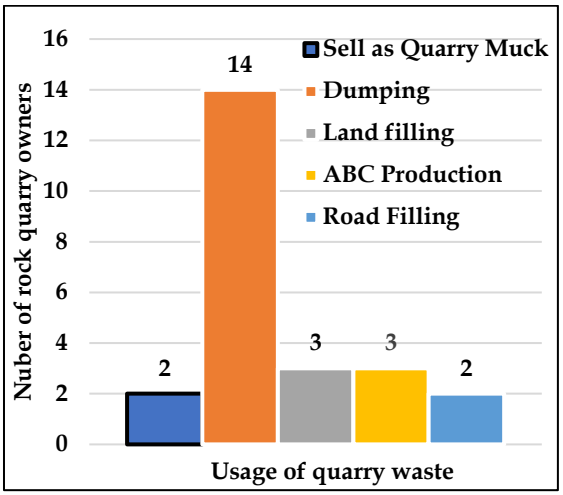

Figure 4 – Usage of weathered rocks

Accordingly, 14 out of 24 owners dump quarry waste while 3 owners use the quarry waste for land filling. Quarry waste is used for ABC production by 3 owners while 2 owners sell the weathered rocks as quarry muck and another 2 owners for road filling.

The following hypothesis was framed to infer the major rock usage type encountered in quarry sites in Sri Lanka.

H0: Dumping of weathered rocks happens in at least 40% of the rock quarries registered in Sri Lanka.
H1: Dumping of weathered rocks happens in not more than 40% of the rock quarries registered in Sri Lanka.

The responses are binomially distributed. The hypothesis test performed on the distribution accepts the null hypothesis at 95% of confidence level. Therefore, it can be deduced that more than 40% of the rock quarries registered in Sri Lanka dump the weathered rocks without using for any purpose.

Table 3: Properties of rock samples and their usages

Location	Rock Type	WG	UCS (MPa)	ACV (%)	AIV (%)	Main Usage
Meepe	Garnet Biotite Gneiss	I	197.0	13.2	13.7	Road construction
		II	87.6	25.5	22.2	Road and building construction
		III	11.4	40.3	43.7	Dumping
Elugoda	Biotite Gneiss	I	213.5	12.0	12.9	Road and building construction
		II	143.2	18.2	17.1	Road construction
		III	34.1	35.1	32.2	Dumping
Haragama	Biotite Gneiss	II	118.0	21.2	19.1	Road and building construction
Aladeniya	Biotite Gneiss	II	84.7	24.9	22.6	Building construction
Korathota, Kaduwela	Feldspathic Gneiss	I	276.4	8.2	10.1	Road and building construction
		II	176.2	15.0	14.9	Road construction
		III	19.7	36.3	37.9	Dumping
Mahiyanganaya	Biotite Gneiss	II	57.9	30.5	26.6	Land filling
		III	9.7	40.7	45.4	Land filling
Poruwadanda	Charnokitic Gneiss	II	114.8	21.6	19.4	Road construction
		III	42.0	33.5	30.0	Road construction
Madola, Avissawella	Garnet Biotite Gneiss	II	171.9	15.4	15.1	Road and building construction
		III	35.8	34.8	31.6	Road and building construction
Ampara	Biotite Gneiss	II	87.9	25.4	22.2	Road and building construction
		III	45.9	32.7	29.0	Road construction
Marathamadu (A)	Charnokitic Gneiss	II	113.4	21.8	19.5	Road construction
		III	77.6	27.1	23.5	Road and building construction
Thalagala	Biotite Gneiss	II	98.0	23.9	21.1	Road and building construction

5.2 Results of laboratory tests carried on collected samples

Laboratory tests were carried out on 22 samples collected from quarries operating in Colombo, Kalutara, Kandy and Ampara districts. These samples are from weathering grades 1,11 and 111. The results of UCS, AIV and ACV tests carried out on these samples are shown in table 3. Test results show that weathering grade 1 or fresh rock samples from Meepe, Elugoda and Korathota quarries have high UCS values and low AIV and ACV values which make them very good building and road construction materials. The UCS values of weathering grade 11 rock samples from Eludoda, Korathota and Madola quarries are comparatively higher than same weathering grade rock samples from other 7 quarries.

ACV and AIV values of weathering grade 11 rock samples tested from all 11 rock quarries are within the range 0-30%. Also, the AIV and ACV values of weathering grade 111 rock samples from the rock quarry at Marathamadu are less than 30%. According to ICTAD guidelines on Construction and Maintenance of Roads and Bridges (ICTAD, 2009) AIV and ACV values less than 30% can be used to construct the wearing course of a flexible road pavement. The test results show that AIV and ACV values of weathering grade 111 rock samples of all 11 quarries are less than 45%. According to ICTAD guidelines rocks having AIV and ACV values less than 40% can be used to construct Water Bound Macadam (WBM) base courses and if these values are less than 45% those rocks can be used to construct cement concrete base courses.

This study reveals that the quarries at Elugoda and Korathota dump the weathering grade 111 rocks in excavated areas of the same quarry sites. But according to the test results AIV and ACV values of the above-mentioned quarries are 32.2%, 37.9% and 35.1%, 36.3% respectively. As per the ICTAD guidelines (2009) they are suitable to be used in a Bitumen Bound Macadam base course and Water Bound Macadam base with bitumen surfacing. Further, the selected quarry at Mahiyanganaya use their quarried rock of weathering grades 11 and 111 for land filling. However, the weathering grade 11 rocks of this quarry have favourable properties as the AIV is 26.6% and ACV is 30.5%. Therefore, it is a good rock suitable for several applications: wearing course, bituminous surface dressing, penetration macadam, bituminous concrete and cement concrete. Weathering grade 111 rocks with AIV and ACV values 40.7% and 45.4% can be used in cement concrete base courses.

6.0 Discussion

Discussions with the quarry owners during the site visits gave additional information with regards to the production of waste and its management in quarry sites. During the visits to the quarry sites, it was found that most of the quarry sites didn't have qualified personnel such as a geologist who can make decisions based on visual observations without laboratory test results. Some small sites have used the service of a consultant geologist once a week or once a month. Due to this reason most of the naturally jointed rocks were identified as weathering grade 11 rocks by the quarry owners. Slight brownish discolouration which occurred over the exposed surfaces of the jointed rock blocks made them think that they were weathered rock. Most of these brownish stains were spread only up to a few centimetres and could have been easily chipped off to use the remaining rock mass. Therefore, one reason for this wastage can be identified as the lack of qualified personnel to make proper decisions.

Among the quarry sites participated in this survey, 60% of the quarry sites possessed grade A mining licenses and 20% of the quarry sites possessed grade B mining licenses. Grade A and B licensed quarry owners have their own crushers while none of the grade C mining licensed quarry owners have their own crushers at their sites. Further it was identified that the quarry sites having their own crushers fully utilized their quarried rocks and they maintain their wastage at minimum level. Also, they can optimize their usage by testing the rock materials in recognized laboratories. Conversely, it was also said that quarry sites which do not have their own crushers face wastage problems as they do not have the financial strength to transport all the waste materials from the sites. The other problem faced by the quarry owners of those sites is the rejection of the slightly discoloured and more whitish rock material by the transporters who visit quarry sites. They only tend to buy or transport visually pleasing materials for crushing purposes while the technically sound materials remained in the site just because of their colour. Therefore, non-availability of crushes and financial constraints which restrict the transportation of waste from the sites and misconceptions leading to wrong identification of weathered rock are also reasons for accumulation of waste at quarry sites.

Quantification of waste was not possible in this study due to the small number of quarries considered. Further, it was not possible to do any financial analysis since some of the quarry owners did not have any idea about the quantities they dump and use for land filling.

7.0 Conclusion

From this study it can be concluded statistically that 40% of quarry owners dump the weathered materials without using it for any construction purpose.

The test results concluded that engineering properties of tested weathered rock materials have technically acceptable properties irrespective to their observed weathering grades. Therefore, they can be effectively utilized as building and highway construction materials.

This study also concludes that dumping and land filling should be the final options.

Hence this study recommends using more laboratory test results to check the suitability of rock materials rather than using visual observations.

Acknowledgement

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SECTION II

The Impacts of Work-Life Balance and Job Satisfaction on Turnover Intention of Supervisory Level Employees in Construction Industry: A Case Study

Eng. D. M. Nishamalee Dassanayake

Abstract: This study was carried out to identify the impacts of work-life balance and job satisfaction on turnover intention of supervisory level employees in construction industry and examine the relationship between the turnover intention and each impacting factor. The study was carried out among supervisory level staff of a selected construction company in Colombo District. A comprehensive literature review led to identifying several factors that could contribute to employee turnover. This was followed up by developing a questionnaire with 28 questions using different standard questions on each impacting factor. The findings revealed a strong indication (more than 50%) of turnover intention among 15 employees that were involved in the study and plausible reasons for such a decision. There are two main conclusions that stem from this study. First, that there is a definitive indication that the employers of this company should take measures with further investigation to increase employee job satisfaction and to reduce the turnover intention of the employees within the company. Second, it is recommended that further studies with larger samples representing multiple construction organizations are a necessity to establish more accurate status about the employee turnover intention in the current Sri Lankan construction industry.

Key Words: Work-life Balance, Job Satisfaction, Turnover intention

1.0 Introduction

The construction industry in Sri Lanka is growing aftermath of the Covid19 pandemic and the recent economic turmoil. There are some ongoing building, road and water projects all around Sri Lanka under local and foreign funding. Within the above three categories of construction, most of the building projects are underway in Colombo District.

Employees are the most important resource in the building construction industry. They possess different educational levels and contribute to the industry in different ways. Considering their education level and responsibilities, they can be divided into three groups as labor category, supervisory category and managerial category. This research study is focused on supervisory level employees only.

On the one hand, usually it is difficult to find the required employees within the proximity of a construction site. As a solution to the labor shortage within the locality, companies are providing accommodation and recruiting workers from other areas. On the other hand, the general practice in the Sri Lankan construction industry is to operate not only during the office hours but also outside the normal working hours. With an urgent need for completion, the sites operate overtime on weekdays as well as weekends for which the employees are entitled to three to five holidays per month. This is considered as the main reason that affects the employees' work-life balance.

Organizations that do not work to achieve the work-life balance of their employees will find it increasingly difficult to attract and retain more talented and motivated employees (Robinson & Judge, 2013, p.21). In defining work-life balance, it reflects the combination of work-family balance, which leads to important outcomes such as job satisfaction, family satisfaction, family performance, and family functioning (Tavassoli & Sune, 2015). Researchers have shown that many organizations' work-life balance efforts are focused on managerial level employees only. Insufficient attention paid to this issue by the employers seriously impacts the supervisory level employee turnover in the building construction industry.

The Human Resource (HR) contribution in the construction sector is high compared to many other sectors. At present employee turnover is a serious problem in the construction sector which leads to regular recruitment of new employees and a shortage of mature employees. Therefore, time management of projects becomes difficult and productivity decreases. In other words, recruiting new employees and providing regular training costs both time and money. The performance and productivity of many organizations have deteriorated due to the high turnover rate (Sheppard, 2016).

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Among construction workers, especially those working in the sites and site office, the main reason for the reduced work-life balance is the long and inflexible working hours. Many employees today seek to focus on social and family lives, not just on wages and economic benefits. Research found flexible work arrangements allow employees to improve work-life balance (Berber et al., 2022).

Meanwhile, some researchers believe that the impact of work-life balance on employees and organizations has not yet been identified (Fayyazi & Aslani, 2015). Therefore, it is vital to find how work-life balance and job satisfaction impact turnover intention and to propose implementable strategies for better HR management. Thus, this research particularly focuses on assessing how supervisory-level employee work-life balance and job satisfaction affects their turnover intention using a sample of employees randomly selected from one construction company.

2.0 Review of Literature

This section presents the previous research findings and arguments built on 'work-life balance' and 'turnover intention'.

2.1 Work-life Balance

In traditional systems, workplaces operate only for eight to nine hours on weekdays. However, with the emergence of the global organization, the world never sleeps (Robbins & judge, 2013); many organizations have had to abandon traditional procedures due to call-based operations and operations on urgent basis. Under this scenario, HR professionals always strive to utilize employees efficiently and effectively through retaining experienced employees. Accordingly, maintaining 'work-life balance' plays a vital role.

Since there is no clear definition of work-life balance, many researchers define work-life balance as the satisfaction of an employee's professional and personal life. Kalliath & Brough (2008) explained six common work-life balance definitions as, "Multiple roles", "Equity across multiple roles", "Satisfaction between multiple roles", "Fulfillment of role salience between multiple roles", "Relationship between conflict and facilitation", "Perceived control between multiple roles".

Greenhaus et al., (2002) describe work-life balance as time balancing, involvement balancing and satisfaction balancing for both work and family. Accordingly, it is recommended that equal consideration should be given to both work and family in relation to the above three components. Delecta (2011, extracted Felstead et al., 2002) defines the 'work-life balance' as the relationship between institutional and cultural time and workspaces and non-workspaces in societies where income is generated and distributed through the labour market. Sirgy and Lee (2018), introduced two main dimensions of work-life balance as engagement in work-life and non-work-life and minimal conflict between social roles in work and non-work-life. According to Gragnano et al., (2020) work-life balance is described as having equal concern for work, health and family. According to Muthukumar et al. (2014), work-life balance means perfect integration between work and life both not interfering with each other. The researchers explain that there are many factors which affect the 'work-life balance' such as attitudes, psychological factors, behaviors, financial standings, family structure, life stage, social life, etc.

Through the analysis of all the above literatures, work-life balance can be defined as a desire to balance professional life as well as personal life and personal well-being, which varies according to each individual's life stage, lifestyle, family background, social life, attitudes, behavior, educational level, economic level and many more external factors.

2.2 Turnover Intention

Employee turnover has a huge negative impact on the organization. It has become a major problem faced by HR professionals today. Due to the high turnover rate, the HR professional must continuously carry out the HR functional process of recruitment, selection, hiring and training which is a costly process for the organization.

A study of the existing literature on turnover intensity reveals similar definitions with minor variations. Oloyede and Soyemi (2022) define turnover intention as an employee's thought and willful plan to resign from their current job in the near future. Suifan et al. (2016, extracted by Kerlinger, 1973) define turnover intention as an employee's estimated probability that intends to leave the job permanently in the near future. According to the Belete (2018), turnover intention can be described as the prerequisite to leave one's job or organization.

By analyzing the above literature, a simple definition for 'turnover intentions' can be proposed as 'employee's willingness to leave their current job'. However, the researchers point out that not everyone with turnover intensity will leave the organization. Instead, the researchers explain that turnover intensity negatively impacts the efficiency, effectiveness and performance of an organization, while it positively impacts the employee's mental health.

2.3 Job Satisfaction

Job satisfaction is one of the most important aspects affecting the employee sector as well as the organizational sector. Many research studies around the world have discussed in depth about the employee's job satisfaction in different ways and have implemented the conclusions. Nonetheless, the construction sector has gaps in job satisfaction related to research and its applications.

Schneider & Snyder (1975) define job satisfaction as personal evaluation of conditions present in the job, or outcomes that arise because of having a job. It concerns self-perception and evaluation of their job. Jusmin et al. (2016) explain that the Job satisfaction is basically an individual characteristic, and every individual has different levels of satisfaction according to his value system. Pawirosumarto et al. (2020, extracted from Hasibuan, 2008) state that job satisfaction is an emotional attitude that is fun and loves his job, where this attitude is reflected in work morale, discipline, and work performance. Nonetheless the researcher added additional factors and offered a more detailed definition of job satisfaction as the pleasure and positive emotions gained from individual work experience in the past.

By reviewing previous literature, it is argued that 'job satisfaction' can be described as the enthusiasm given to work in the current conditions in the job role as well as in the workplace.

3.0 Research Methodology

This research is a case study of 'test case' nature (Tan, 2018). The target group was supervisory level employees working in a construction organization of a purposively selected private sector institution. The initial step was to identify the factors that would contribute to employee turnover intention through a literature review. Thereafter, a structured questionnaire with 28 questions was developed to collect relevant data. This was distributed among 15 employees of the institution. The surveyed group included of both male and female employees as well as both married and unmarried employees. At the end of the survey, the respondents were informally interviewed for any clarifications needed and such clarifications received were recorded. The analyses included both statistical methods such as percentage calculations and qualitative analysis.

The literature review clearly identified the 'turnover intention' as a variable that depends on several independent variable factors. However, since the number of data obtained was small (< 30) no statistical tests were used to test the relationship that may exists between the independent variables such as, 'work-life balance' and 'job satisfaction'. Instead, analyses were carried out on different aspects that could contribute to the dependent variable (turnover intention) from the responses received for the questionnaire.

4.0 Data Analysis and Results

The total positive turnover intention responses were 8 (53%), negative turnover intentions were 2 (13%) while 5 (33%) were indecisive. The positive, negative as well as indecisive responses further analyzed for gender, marital status and age of respondents are given in Tables 1, 2 and 3 as percentages of each category.

Table 1 – Turnover Vs Gender, Age and marital status

Turnover intention	Yes	Indecisive	No	Total
Male	6 (67%)	2 (22%)	1(11%)	9
Female	2 (33%)	3 (50%)	1(17%)	6

Table 2 – Turnover Vs marital status

Turnover intention	Yes	Indecisive	No	Total
Unmarried	2(100%)	0 (0%)	0 (0%)	2
Married	6 (46%)	5 (39%)	2(15%)	13

Table 3 – Turnover Vs Age

Turnover intention	Yes	Indecisive	No	Total
20-29 years	1(50%)	0 (0%)	1(50%)	2
30-39 years	6(67%)	3 (33%)	0(0%)	9
40-49ears	1(50%)	1 (50%)	1(50%)	2
> 50 years	0(0%)	2(100%)	0(0%)	2

The above analysis indicates that majority of males and employees of age between 30-39 years have accepted the turnover intention. It is also noteworthy that 46% of married employees agree with turnover intention, while both unmarried employees also agree with turnover intention. Out of the total group only 2 (13%), one male and one female and agreed that they have no turnover intention. They are both married and in the age group 20-29 years and the other in the age group 40-49 years. More in-depth studies are needed to find out the reasons behind their decision.

Family oriented matters: Out of the 15 respondents 13 were married and 6 had children. All with children had agreed with turnover intention. Further inquiry revealed that none of the respondents had agreed to the statement "I have enough time to stay with my family and friends", while 50% of the respondents with children have directly disagreed with the statement. One of the reasons for this situation could be that all respondents (6) with children have accepted that they

engage in office activities during the holidays and non-working hours.

Personal life: Large majority (67%) of respondents were neutral in their response to the statement "I can manage my personal life when I work with this organization". At the same time 53% of respondents agreed that they prioritize their personal life over work-life.

Institutional support: 47% of respondents definitively agreed that they are able to obtain leave for personal needs without any inconvenience while 33% of respondents definitely disagreed with this statement. However, none of the respondents were satisfied with the salary they earn where 60% of respondents were directly indicating their dissatisfaction. Similarly, 67% of respondents were dissatisfied with the other benefits provided by the organization and 60% felt that their work is not properly valued by the organization. However, all respondents agreed that the staff provide good support for their work and personal matters.

Personal Feelings: While 47% of respondents agreed that they "do not mind being busy because they love their job", the rest (53%) disagreed to the same. However, only 13% of respondents stated that they are happy with their jobs. Supporting this statement, 1 (7%) employee stated that the job motivated her while 60% of respondents stated that their jobs do not motivate them. Further, 73% of respondents did not believe that their job is secure. Only 2 (13%) respondents agree to continue to stay in the company, while 12 (80%) said that they would not choose this organization, if they have a chance to choose again. Finally, 87% agreed that they are seeking new better jobs.

The above percentage analyses of the reasons that could have contributed to turnover intention among employees led to a few important findings.

a) While 53% were sure of their turnover intention, there are 87% seeking new, better employment.
b) The majority are happy with the job they do and the support they get from the others around them, even though they are unsatisfied with the remunerations given by the organization.
c) A work-life balance is difficult to all married employees with children and a main reason agreed is the lack of time as they have to work on holidays and non-working hours.

5.0 Conclusions

It is expected that there should be a delicate balancing act which employees carry out in their personal life and work-life. The reviewed literature clearly articulates that organizational policies which respond to common personal and family requirements are essential to keep up positive emotions among employees, because every employee should have a family life and a social life as well other than his/her work-life. It is the responsibility of top management to enable the men under for proper work-life balance practice.

There are two main conclusions that stem from this study. First, there is a definitive indication that the employers of this company should take measures with further investigation to increase employee job satisfaction and to reduce the employee turnover intention within the company. It is essential for the employer to pay more attention when deploying employees on duties to create a flexible work environment within the Organization. Cultural and religious leave and compassionate leave for one's essential or important family requirement (e.g. Birthday of a kid, Wedding or a funeral of a close relation), organizing family oriented cooperate events such as family get-togethers, cultural and religious functions are very important in this regard. When there is a delicate balancing act which employees carry out between their personal life and work-life, it will be a vital factor which improves their job satisfaction and reduces the employees' intention to turnover as well.

Second, since the results of the current study are presented as percentages that are only relevant to the selected organization, they do not contribute to strengthening the general acceptance of the influence of individual variables as proven by many previous studies in the literature. Therefore, further studies with larger samples involving multiple organizations are recommended.

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Building Information Modeling (BIM) in Construction Industry

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Abstract: Building Information Modeling (BIM) has emerged as a transformative force in the construction industry, revolutionizing how we design and build infrastructure and buildings. This paper provides an overview of BIM's evolution, its current applications, and the benefits it offers to the developer, including improved project efficiency, reduced costs, and enhanced collaboration. The integration of BIM and Artificial Intelligence (AI) is also discussed, highlighting the potential for a more efficient, sustainable, and innovative future through the combined use of these technologies. BIM, a collaborative platform based on cloud technology, assists project teams in data collection, storage, and management, leading to improved processes and reduced costs. Furthermore, the paper explores how BIM can enhance various disciplines within the construction industry, outlining quantitative and qualitative benefits. By utilizing Building Information Modeling (BIM), the architecture, engineering, construction (AEC), and facility management sectors can streamline communication, improve collaboration, and achieve cost savings throughout the project lifecycle.

Key Words: Building Information Modeling, artificial intelligence, cloud technology, virtual design, collaborative platform.

1.0 Introduction

In the early 1980s, professionals in the construction industry, notably designers, foresaw the leadership of advanced Building Information Models (BIM) in the development of infrastructure and buildings. In the 1990s, acclaimed architect Frank Gehry utilized building modeling software from Dassault's CAITA to create his distinctive ribbon-like buildings in Bilbao, Spain (Figure 1), Los Angeles, and various global cities, thus establishing a lasting legacy (Builtworlds- 2023). This trend persisted, prompting designers in the building industry to progress building modeling software. Towards the latter part of the 1990s, the adoption of BIM became popular among large-scale developers.

Figure 1 Iconic ribbon-like buildings in Bilbao, Spain

In the early 2000s, contractors were making strides in using BIM. They combined advanced digital models across building disciplines with traditional project planning and management techniques to build a project digitally before it was built physically, a process referred to as "virtual design and construction." However, these process improvements were short-lived. Developing and using related software had become excessively expensive, limiting its use to large-scale contracts and complex projects. This was a significant drawback, as it hindered the widespread adoption of BIM in the industry.

Fast forward to today, and BIM is a transformative force in the building industry. It unites people and technology, streamlining time and cost and significantly improving efficiency in the construction of skyscrapers, apartment complexes, and infrastructure projects. Its evolution has been nothing short of remarkable, and its potential is yet to be fully realized. BIM is not just a tool but a game-changer in the construction industry, revolutionizing how we design and build.

2.0 Integration of BIM and Artificial Intelligence (AI)

The built world can anticipate a more efficient, sustainable, and innovative future by integrating artificial intelligence (AI) and adopting it as an

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additional technique to optimize BIM further. The resulting system becomes enhanced with extraordinary technological capabilities, allowing its end-users to maximize the use of BIM in their projects. The designers, contractors, project managers and the maintenance teams of building projects gain valuable insights as AI, which analyzes the data contained within the BIM model more efficiently when integrated with BIM. However, in this article, the writer will not explore how AI will enhance the use of BIM in the industry, which will help clients by providing real-time project examples. Instead, the writer will discuss BIM in general, giving a basic knowledge of BIM for the reader's benefit.

Professionals in the current construction industry use BIM basically to save time and money on construction projects. BIM is a collaborative platform based on cloud technology.

It also initially assists the project team members in collecting and saving related data and information with its support design of 3D models and manages, analyzes, and improves the data, maximizing the construction process from its planning stage through design, operation, construction, and maintenance period. It reduces errors and rework, saves cost, improves timelines and upgrades the entire process. This process allows all the stakeholders simultaneous and real-time access to the system.

The design process of Architecture, Engineering, and Construction (AEC) is complex. It includes a lot of iterative work and involves multidisciplinary design work that can be done sequentially, concurrently, or in parallel. Project changes are inevitable and can occur from multiple sources at any time and have extensive impact. Accordingly, ensuring the accuracy and consistency of data after sharing and emerging is significant, which raises the requirement for the detection of design changes. Suitably tailored BIM can manage all these issues.

BIM can improve various business practices in the construction industry. The AEC and facility management sectors can benefit throughout the project's lifecycle (Eastman et al., 2011). It provides the opportunity for better collaboration between the design, construction, and maintenance teams, reducing errors and rework, saving costs, improving timelines, and upgrading the entire process.

BIM applications are mainly used for visualization, drawing production, fabrication, forensic analysis, code reviews, cost estimating, space planning and facilities management in the building lifecycle (Azhar, Hein, and Sketo, 2008).

BIM benefits are divided into quantitative and qualitative benefits according to the type of objectives. Quantitative benefits are numerically measurable benefits (resulting in a measurable quantity), and qualitative benefits are disciplines or behavioural benefits (Deutsch, 2011).

Alliance for Construction Excellence (2008) attributed the main benefit of utilizing BIM influence in the design and construction phase. According to Eastman et al. (2011), BIM benefits are identified in several sections: preconstruction benefits to the owner, design benefits, construction and fabrication benefits, and postconstruction benefits. These benefits are explored further in detail below.

Pre-construction benefits:

- Feasibility, concept and design benefits
- Increase in building quality and performance.
- intergraded project delivery collaboration

Design benefits:

- More accurate and early visualization of the design
- Earlier collaboration platform of multiple design disciplines
- Easy verification and corrections of design intent
- Cost estimation is extracted during the design stage.
- Improved energy efficiency and sustainability

Construction and fabrication benefits:

- Design models are used to fabricate components.
- Identification of design errors before construction
- Design and construction planning synchronization
- Lean construction technologies application

Post-construction benefits:

- Hand over facility management information and improve commissioning.
- Improve the facilities management and operation.

3.0 BIM Model Development

Projects with large scopes, long durations, complex interfaces, significant management requirements, and complicated coordination and cooperation use BIM technology to avoid complexity and improve construction management. If the BIM manager and the participants who handle BIM model

development are in different office locations, a centralized platform is needed to share the latest real-time BIM model development with the related participants. Such project managers must collaborate with all the participants to ensure an effective and successful BIM development.

3.1 Model Development Methodology

Model development level is associated with selected model element breakdown structure and model's needs. Working groups can benefit from the following through each element and visualization of the element (The Computer Integrated Construction Research Program, 2012). Model development is divided into different categories and levels of development (LOD) for BIM model components. The development of a model is a complicated process that has challenges in integrating repeated themes of poor data between BIM and the management systems of existing information. It needs to clarify the gap in the knowledge on how to formulate a BIM model, enabling it to maximize its use in the operational and maintenance (O&M) phase.

3.2 Model Development Categories

Model categories are established with a minimum level of BIM model development for each project. The State of Ohio BIM Protocol (2010) categorized four model development categories, I, II, III and IV, described as follows:

Category I: This model supports project planning, volume illustration and site positioning.

Category II: This model reflects an increased level of development involving supported documentation, clash detection and coordination, system review and as-built formats.

Category III: This model incorporates all benefits and model requirements. In addition, it contains additional details for occupancy and facility management of the building.

Category IV: In addition to incorporating the benefits of Category III above, further highly detailed logistical, estimation efforts, and scheduling are also included in the development of this model.

3.3 Level of Development

Level of development (LOD) is established with model content criteria and described in five specific development levels, as shown in Figure 2 (AIA document E202, 2008).

3.4 BIM in Project Execution

The project execution process is defined after BIM uses are identified. According to the goals and uses of BIM, the project team can be developed during the implementation process throughout the project life cycle. This execution process accomplishes well-developed processes, defining information exchange within multiple participating disciplines. The process maps were developed to portray information deliverables to multiple parties utilizing BIM. The process maps are divided into two stages: BIM 'Overview Map' and 'Detailed BIM Use Process Map', for clear identification and performance implementation

3.5 BIM Overview Mapping Procedure

The BIM overview mapping procedure consists of potential BIM users, project sequences, and information exchanges. Aouad et al. (1998) posited that the process mapping procedure supports and encourages integration and better coordination between various disciplines within a construction project. Potential BIM uses are identified and listed in the first stage according to the priority level. Once the team has identified BIM users, the process can be mapped by adding each use or process to the map. In addition, it's important to understand BIM uses in several process locations often connect and influence the project life cycle (The Computer Integrated Construction Research Program, 2010).

After the project team establishes the BIM process, deliverables have to be coordinated with the project sequence throughout the project. In this stage, the focus will be on the BIM users within the planning, designing, construction, and operation phases to implement the process team, which will include a BIM deliverable schedule aligned with BIM disciplines.

Level of Development	Description
LOD 100 **Schematic Design Model**	Overall building massing indicative of area, height, volume, location, and orientation may be modeled in three dimensions or represented by other data.
LOD 200 **Design Development Model**	Model Elements are modeled as generalized systems or assemblies with approximate quantities, size, shape, location, and orientation. Non-geometric information may also be attached to Model Elements
LOD 300 **Construction Documentation Model**	Model Elements are modeled as specific assemblies accurate in terms of quantity, size, shape, location, and orientation. Non-geometric information may also be attached to the Model Elements.
LOD 400 **Construction Model**	Model Elements are modeled as specific assemblies that are accurate in terms of size, shape, location, quantity, and orientation with complete fabrication, assembly, and detailing information. Non-geometric information may also be attached to Model Elements.
LOD 500 **Record Model**	Model Elements are modeled as constructed assemblies actual and accurate in terms of size, shape, location, quantity, and orientation. Non-geometric information may also be attached to modeled elements.

Figure 2: Level of Development (Source: The Computer Integrated Construction Research Program, 2012)

In the next stage, the project team will identify the responsible parties for each process. The most important aspect of this stage is selecting team members to successfully complete the task. Information exchange is the most critical aspect of this process. Reflecting on the clear process flow from one party to another is the most important thing.

3.6 Information Exchange Methods

BIM project information exchange methods are most important for project implementation. To define the information exchange between each party, the project team must understand that the required information must be delivered to each BIM user. It is important to define which model components are necessary for implementation.

Required Information for Each Exchange Activity: Basically, each information exchange, model receiver, and model file type need to be included for better communication. The model receiver's identification is given to identify the receiver and the information. Every project team member must update information inputs and outputs for future BIM users. Generally, the project model designer or the architect shall give output exchanges.

The model file type is explained within specific software applications to develop the model. It further highlights the interoperability between exchanges between each party.

Information levels are highly important for BIM implementation. This information can be structured and the project team has to consider input versus output in the information exchanges regularly. Once the information requirements of processes are defined, it is necessary to discuss the information inputs and outputs requested. If any discrepancy in the information exchange is identified by the project team, corrective actions have to be taken to overcome the inadequacy.

3.7 Training for Successful BIM Implementation Procedures

Most BIM implementation trainings relate to a specific software system or process. Training strategies are established to include the following:

- Objective of the training
- Who needs what training?
- What training methods are most suitable?

Firstly, the necessary training subjects are listed to identify the software system or process that is most required. Secondly, identify who needs software training and training on BIM processes. Generally, upper management only needs to understand the process of BIM. Middle management needs extensive education and induction training on different software packages. The implementers need extensive process and software training to maximize the system's use. However, the organization must identify the specific

requirements to use the BIM designed for them to manage within their budgets. Software vendors often train BIM users based on their training needs, which vary and depend on the organization's size and the scope of BIM adoption (The Computer Integrated Construction Research Program, 2012).

4.0 Conclusion

Building Information Modeling (BIM) provides substantial opportunities to improve the quality and efficiency of the construction industry. The future of construction will be more collaborative and digital, with BIM evolving to include 4D, 5D, and 6D capabilities. This will allow for real-time cost estimation and data simulation throughout the design, construction, and operational stages. Ultimately, BIM will enhance construction methods and their overall value.

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