Initiative for Climate Action Transparency – ICAT

Digitalization of
Transport Sector MRV System in Sri Lanka

Deliverable 1: Report on System and Software Design for MRV System.

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ClimateSI, 2020

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Climate Smart Initiatives (Pvt) Ltd

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Climate Smart Initiatives (Pvt) Ltd.,

Sri Lanka.

List of Acronyms

AWS	Amazon Web Server
BAU	Business as Usual
BUR	Biennial Update Reports
CCS	Climate Change Secretariat
CDM	Clean Development Mechanism
CPSTL	Ceylon Petroleum Storage Terminals Limited
DMT	Department of Motor Traffic
EF	Emission Factor
GHG	Greenhouse Gas
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
JICA	Japan International Cooperation Agency (Prepared by Japan Weather Association)
LGC	Lanka Government Cloud
LGN	Lanka Government Network
LRT	Light Rail Terminals
MEWR	Ministry of Environment & Wildlife Resources
MoH	Ministry of Highways
MRV	Monitoring, Reporting, and Verification
MTSM	Ministry of Transport Service Management
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contribution
NTC	National Transport Commission
SLC	Sri Lanka Customs
SLR	Sri Lanka Railway
SLSEA	Sri Lanka Sustainable Energy Authority
SLT	Sri Lanka Telecom
SNC	Second National Communication

SRS	System Requirement Specification
UNFCCC	United Nations Framework Convention on Climate Change
VET	Vehicle Emission Testing

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Executive Summary

In 2016, Sri Lanka submitted its Nationally Determined Contributions (NDCs) to the Paris Agreement in order to support achieving the emission reduction objectives under the Agreement´s objectives.

Transport sector is a major source of GHG emissions in Sri Lanka, which contributes around 27% of the national GHG emissions (MoE, 2011). Sri Lankan NDCs submitted to UNFCCC in 2016 consists of 11 main NDCs for transport sector while it consists of 10 main NDCs as per the revised transport sector NDCs in 2019 under ICAT phase 1. There are sub NDCs under each main NDC.

Lack of transparency, inaccuracy and obsoleteness of information have historically been a problem in the country. An internationally acceptable Measurement, Reporting and Verification (MRV) system to track the emissions and their reductions is an important requirement for the transparency of mitigation actions aimed at achieving NDC goals. An MRV System was developed for the transport sector under the ICAT Phase 1 with the support from Initiative for Climate Action Transparency (ICAT) and UNEP DTU Partnership under the direct guidance of Climate Change Secretariat (CCS) under the Ministry of Environment & Wildlife Resources (MEWR) and Ministry of Transport Services Management (MTSM).

Requests for information can take days as they travel up and down the chain of commands, even in emergency situations. With digitalization, the information gathered is combined with real-time analytical tools to provide insights of what is happening at any given moment. Increased transparency also helps to increase reliability of the system and complies with article 13 of the Paris Agreement, which emphasizes the need for enhanced transparency framework “in order to build mutual trust and confidence and to promote effective implementation.”

Based on the requests of stakeholders for a digitalized system to reduce their administrative burden and save time and effort, ICAT phase 2 has formulated this project to digitalize the MRV system for the transport sector.

This report, which is the first deliverable of the current project, discusses the system and software design for the MRV system. It contains identified requirements with respect to system requirements, functional requirements, QA/QC process, user categories, user access levels, calculation engine, document management, analytics, language requirements, communications among users, system documents, solution hosting platforms, security aspects and post deployment warranty and support etc. The scope of the digitalized system will support five sub NDCs as per NDCs submitted in 2016 to the UNFCCC [1].

1. Introduce park & ride system (sub NDC 4.1)
2. Electrification of the railway system from Veyangoda to Panadura (sub NDC 5.1)
3. Purchase new rolling stock for Sri Lanka Railway (sub NDC 5.2)
4. Introduce other electrified vehicles such as cars (sub NDC 8.4)
5. Transport of heavy loads by railway (sub NDC 9.4)

The summary of this report is as follow:

- Under the proposed digitalized system, all data will be stored, and calculations would be performed on a web-based platform, which will be developed under this assignment. All users would access the system using their computers, laptops or tablets through the internet.
- The NDC unit at Ministry of Transport Services Management (MTSM) would operate and manage the software system, and also manage all users of the system by allocating appropriate access levels. The system would facilitate all steps proposed in the manual MRV system designed under ICAT phase 1, such as entry of project data and parameters, selection of calculation methodology, verification of data, validation of calculations and generation of reports.
- Facilities will be provided for the supervision of the system activities by the Climate Change Secretariat (CCS) of Ministry of Environment and Wildlife Resources (MEWR) and MRV expert committee, and an audit trail will be maintained in order to verify the usage of the system.

[1] The revised transport sector NDCs (2019) are expected to be submitted to UNFCCC in 2020. As per the revised NDC list, above 5 NDCs have been listed as NDC NDC 4.1, NDC 3, NDC 2.2, NDC 7.2 and NDC 1.2 (Annex 2).

- Interfaces will be provided to obtain help and report errors by users, to expedite resolution of problems.
- Provisions will be made to expand the system in future by the addition of Sinhala and Tamil language support, more NDCs and calculation methodologies.
- The system will enable backing-up of data on the cloud. An interface will be provided for MTSM to get a manual backup of the system to a designated location as and when required.
- The calculation methodologies used in the system will be validated by the MRV expert committee before the acceptance of the system.
- The system will be hosted on a cloud platform and maintained for a period of one year by the consultants. Thereafter, MTSM may continue the arrangement under an agreement with the consultants or make other arrangements.

1. Introduction

1.1 Background

Sri Lanka, as a signatory party to the United Nations Framework Convention on Climate Change (UNFCCC), has to submit its greenhouse gas (GHG) inventory as a part of National Communications (NCs) every four years, and Biennial Update Reports (BURs) every two years (UNFCCC, 2016). Article 13 of the Paris Agreement established an Enhanced Transparency Framework (ETF) for action and support in order to build mutual trust and confidence among the Parties and to promote the effective implementation of the Paris Agreement. Key elements of the ETF include National Communications (NCs), Biennial Update Reports (BURs), Biennial Transparency Reports (BTRs) and Nationally Determined Contributions (NDCs). Sri Lanka has experience with national level GHG Measurement, Reporting and Verification (MRV) due to the submission of First National Communication (INC) (UNFCCC, 2000) and Second National Communication (SNC) (UNFCCC, 2012) to the UNFCCC, and preparing the Third National Communication (TNC), which is expected to be submitted in 2020.

However, recognizing the need of taking immediate actions to mitigate climate change, Sri Lanka has submitted their Nationally Determined Contributions (NDCs) (MMDE, 2016) to UNFCCC in 2016 in order to support achieving the objectives of the Paris Agreement.

In order to manage the emissions from the transport sector and three other sectors (Waste, Industry and Forestry), Sri Lanka expects to reduce 10% of their GHG emissions by 2030 against BAU scenario. This 10% emission reduction will be 3% unconditional with the national capacity and 7% conditional with the external support. According to the NDCs submitted to UNFCCC in 2016, there were 11 main NDCs and 31 sub NDCs for transport sector (MMDE, 2016) which are annexed (Annex 1). Aligning with the requirements of the UNFCCC, Sri Lanka has revised its transport sector NDCs in 2019 with the support from ICAT and UNEP DTU Partnership under guidance and supervision of Climate Change Secretariat (CCS) of Ministry of Environment and Wildlife Resources (MEWR), and Ministry of Transport

Services Management (MTSM). The new set of NDCs include 10 main NDCs and 14 sub NDCs which are annexed (Annex 2). However, emission reduction target which is to reduce 10% (3% unconditionally, 7% conditionally) of emissions from transport, industry, forestry and waste sectors will remain the same.

These NDCs need to be tracked in order to a) meet the international reporting requirements; b) build mutual trust & confidence; c) promote effective implementation; and d) enhance the transparency of the progress of achieving the emission reductions for each NDC. Thus, the NDCs are required to be measured, reported and verified by a well-established MRV system.

Figure 1-1 shows the GHG emissions of 2000 in Sri Lanka by sector.

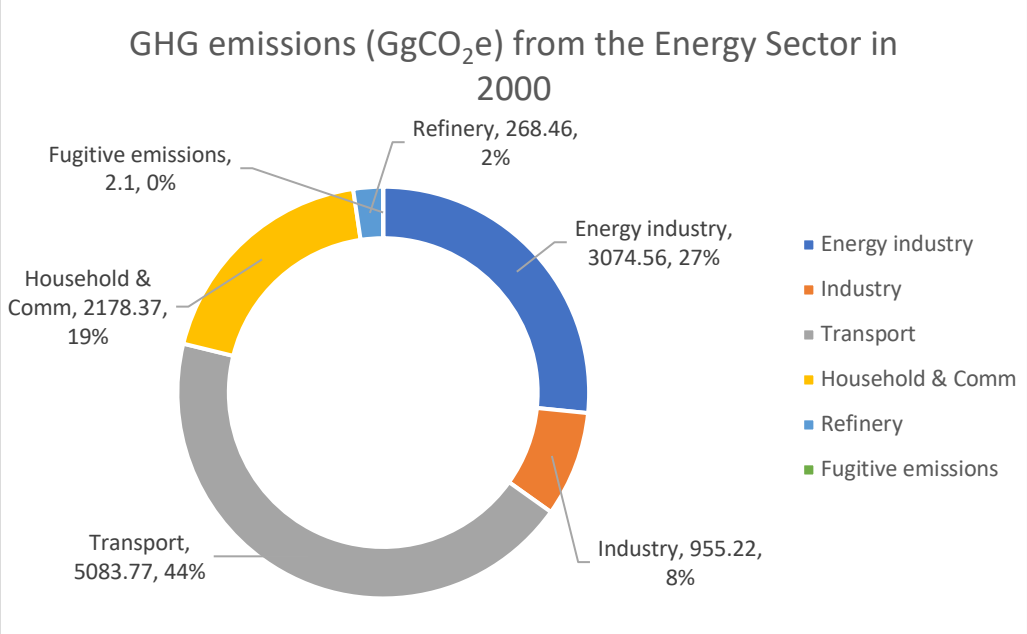

Figure 1-1:GHG emissions from the Energy sector

Source: MoE, 2011

According to the latest GHG inventory (SNC) submitted to UNFCCC in 2011, energy sector accounts for more than half (61.36%) of the country's GHG emissions (MoE, 2011). However, transport sector alone responsible for 44% of GHG emissions from the energy sector (MoE, 2011). Year 2000 has considered as the base year for the SNC.

The Measurement, Reporting and Verification (MRV) of GHG effects of policy and actions in Sri Lanka is limited mostly to energy sector. In addition, there are some ongoing MRV activities in energy sector under energy NAMAs (UNDP, 2020) coordinated by UNDP Sri Lanka. However, there aren't many MRV related activities in the transport sector, which represents the highest proportion of the energy sector emissions. The rapid growth of transport sector has made it contribute to the largest share of GHG emissions of the country. In order to address this rapid growth of transport sector emissions and to meet the international obligations on reporting the status of achieving transport sector NDCs, it is crucial to develop an effective national MRV system. As such, it was agreed among the Climate Change Secretariat (CCS) under the Ministry of Environment & Wildlife Resources (MEWR), Ministry of Transport Services Management (MTSM), and UNEP DTU Partnership to prioritize the development of an MRV system for the transport sector (ICAT phase 1).

ICAT Phase 1

The ICAT Phase 1 assessment is focused on: Reviewing existing MRV and institutional arrangement in the transport sector; identifying appropriate methodologies to measure GHG impacts of prioritized NDCs; designing a national MRV system including institutional arrangements, data management system, procedures, protocol and reporting templates for a robust national MRV system.

Due to the limited time and the budget of the ICAT phase 1, only prioritized NDCs were selected for the MRV system. NDCs were prioritized based on their financial feasibility, political preferences, effect on GHG reduction and availability of internationally accepted methodologies to measure the GHG effects. The selected NDCs include 6 sub NDCs namely,

1. Introduce park & ride system (sub NDC 4.1)
2. Electrification of the railway system from Veyangoda to Panadura (sub NDC 5.1)
3. Purchase new rolling stock for Sri Lanka Railway (sub NDC 5.2)

4. Introduce electric buses (sub NDC 8.3)
5. Introduce other electrified vehicles such as cars (sub NDC 8.4)
6. Transport of heavy loads by railway (sub NDC 9.4)

These 5 NDCs represents 4 main NDCs namely, Shift passengers from private to public transport modes (NDC 4), Enhance the efficiency and the quality of the transport system(NDC 5), Encourage and introduce low emission vehicles such as electric and hybrid (NDC 8), Reduce traffic congestion in order to reduce GHG emission (NDC 9) (Annex 1).

Measurement (M)

Methodologies were selected to measure the GHG effects of respective sub NDCs. While selecting the methodologies, priority was given to UNFCCC CDM methodologies to quantify the GHG effects of actions (projects) and ICAT methodologies to quantify the GHG effects of policies. When UNFCCC CDM or ICAT methodologies are not available to quantify GHG effects of policies and actions, other methodologies such as JICA methodologies were used. Data required to measure the GHG effects of each NDC are stipulated in the respective methodology. Based on this, responsible institutions for data provision were identified. Data management systems were developed indicating who, when and how data will be collected and whom to be reported. Data collection templates were also developed. Data collection template and data management systems were validated and approved by the relevant institutions indicating that they will be able to measure and provide these data in order to measure the GHG effects of the respective NDCs. Eleven (11) procedures including the designed data collection templates and other required information to measure the GHG effects are annexed (Annex 3).

In line with the NDCs, 2010 was selected as the base year. However, when the data are not available to develop the reference scenario using 2010 base year, the nearest year which has latest data for the concerned mitigation action has taken as the base year.

Reporting

Data management systems and institutional arrangement were developed to indicate how the data measured should be reported to the relevant users. These systems were mostly built upon the existing data collection and reporting practices and guidelines. In situations where there were no existing practices for data management, new systems were introduced in consultation with the relevant stakeholders. Data management system provides the process of data reporting which addresses the criteria of: who will measure, record and report the data and how often. As per the proposed institutional arrangement, data collected from each and every responsible agency will be reported to the "transport sector NDC unit", which will be established under MTSM. Processed information will be reported to the MRV coordination unit which will be established under the MEWR. Received information will be submitted to the MRV expert committee for the verification.

Verification

Data reported by each institution will be verified by MTSM. After the data verification, all the data will be processed by the transport sector NDC unit. Once the GHG effects of NDCs were communicated to MEWR, MRV expert committee will verify the emission reduction from each NDC. Finally, MEWR will submit the progress of achieving the emission reduction from each NDC to UNFCCC through the CCS.

Outputs of the ICAT Phase 1

The MRV system was developed for above mentioned sub NDCs. The MRV system includes all the necessary components of an MRV system such as methodologies to measure the impacts of NDCs, data management systems indicating the data collection process (Annex 4), Procedures including the data collection templates (Annex 3) which are required for each institution, institutional arrangement for the successful implementation of the MRV including roles and responsibilities (Annex 5), reporting and verification process, data quality management process (QA/QC), MRV protocol (Annex 6) (including monitoring plan, monitoring methodology, parameters and procedure, organizations and their responsibilities and data management system for each selected transport sector NDC).

Requirement to digitalize the MRV system for Transport sector

Digitalization of the transport MRV system will not only reduce the administrative burden, but also avoid red tapes in monitoring and enforcing compliance. This will also simplify the process of users entering data and forwarding it to data monitoring authority and verifiers. Ultimately, an automated system will reduce workload and remove the potential for human errors. All information will be stored and available for checking.

Furthermore, lack of transparency, inaccuracy and obsoleteness of information have historically been a problem in the country. Respond to requests for information can take days as they travel up and down the chain of commands, even in emergency situations. With digitalization, the information gathered is combined with real-time analytical tools to provide insight into what is happening at any given moment. Increased transparency also helps to increase reliability of the system and complies with Article 13 of the Paris Agreement, which emphasizes the need for enhanced transparency framework "in order to build mutual trust and confidence and to promote effective implementation."

There were many requests from the stakeholders to develop a web-based system to implement the designed MRV system under ICAT phase 1 since a digitalized system can gain many benefits and make the implementation more successful than a manual system. Recognizing this need, UNEP DTU Partnership (UDP) facilitated to provide technical support for the digitalization of transport sector MRV system with the financial assistance from ICAT under phase 2.

1.2 Objectives

Objective of the Initiative for Climate Action Transparency (ICAT)

Monitoring, Reporting and Verification to track the progress of NDC implementation is needed to meet the country's international reporting requirements, and "to build mutual trust and confidence and to promote effective implementation" of the Paris Agreement (Article 13.1 of the Paris agreement).

MRV of NDC progress is also important to meet domestic requirements. These could include reports: (a) to the parliament and the public in order to improve transparency; and (b) to policymakers informing decisions on changes to the existing mitigation or adaptation actions.

ICAT project was founded to respond to these critical needs to support improved transparency and capacity building under the Paris Agreement. The primary objectives of ICAT are to:

- ✓ Strengthen institutional and human capacities in countries to develop and implement domestic system to MRV mitigation policies and actions (MPAs); and
- ✓ Develop tools and guidance that can be used for an effective system for MRV MPAs implementation.

Overall objectives of the assignment on digitalization of transport sector MRV

The main objective of the assignment is to implement the previously designed GHG MRV system for transport sector as a web-based system. The aims of this digitalized system are to measure, report and verify an emission reduction project under an NDC related to transport sector with more reliability, scalability, data integrity, adequate security and storage. As benefits, the system will enhance the efficiency, transparency and availability of the data for current and future use.

Objective of the First Deliverable

The main objective of this report is to explain how the MRV for transport sector will be converted into a web-based digitalized system. Report will provide a broader overview about the identified system and software requirements, process requirements and all the software and hardware architectural designs which were discussed with and approved by the relevant stakeholders of the MRV system for the transport sector.

1.3 Scope

The scope of this report is to provide an overview of the system and software design for the GHG MRV system of Transport Sector in Sri Lanka. This report will elaborate on the functional requirements, non-functional requirements, hardware planning for each stage of the software development and security and storage options for the data and the possibilities in integrating the available databases for the GHG data management of the relevant institutions.

1.4 Limitations

Transport sector MRV system can be implemented either as a manual system or a web-based system. Each implementation will have different limitations due to many reasons.

Identified constraints of the digitalized MRV system are summarized in Table 1-1

Table 1-1:Design and Implementation constraints

Area	Limitation	Specification
Software limitations	Number of simultaneous users	The MRV system will support 50 simultaneous users.
	Required Internet connection speed	Minimum internet speed of 1Mbs is necessary to get a good user experience.
	The time period of hosting web portal	The consultant (ClimateSI) will provide the hosting service for one-year period after the acceptance of the system.

	Backup Storage	Cloud Backup. An interface will be provided for MTSM to download and keep a copy of the data as and when required.
	Language Support	Current implementation is only in English. Provisions are available to include other official languages (Sinhala and Tamil) at a later stage if required.
	Browser Support	The application supports all the browsers which follow World Wide Web Consortium (W3C) standards.
	Platform Support	All the operating systems which run web browsers.
	Device Support	All devices that have access to web browsers can access the system. Using laptop or desktop computers or tablets is recommended for a better user experience.

Source: own work

1.5 Methodology

As the first deliverable for the digitalization of transport sector MRV system, this report will describe the development of the system and software design in few steps: i) develop overall requirements for the digitalized MRV system; ii) develop process requirements; iii) develop supporting process requirements; iv) design the templates and user interfaces for the digitalized MRV system; v) plan hardware architecture/options; vi) plan performance requirements; vii) consider storage options; viii) evaluate security options; ix) plan hosting solutions/options; and x) post-deployment warranty and support options.

1. **Develop overall requirements for the digitalized MRV system**

The designed MRV system for Sri Lankan transport sector was analyzed to understand how the existing data management system works and the institutional arrangement operates. Then a detailed system requirement specification (SRS) document was prepared (Annex 7).

2. **Develop process requirements including the process flow diagrams**

All the data categories of the digitalized MRV system, key institution types, and the user types in each institution type were categorized. Then access rights to the digitalized system of each user type and their functionalities were defined. Furthermore, the process flow diagrams were drawn in order to achieve the process requirements (Annex 8 & 9).

3. **Develop supporting process requirements**

Supporting process requirements are defined considering the function of the MRV system and will be validated with the stakeholders.

4. **Design the templates and user interfaces for digitalized MRV system**

The types of interfaces of the web portal were identified and sample user interfaces were developed using Adobe XD. These interfaces will be validated with the stakeholders of the MRV system[2].

5. **Plan hardware architecture options**

All the application components (web server, application server, database and reverse proxy) will be hosted on single server instance by leveraging virtualization technologies.

There are two possible ways to implement the system. One is to use a dedicated in-house server. The system can be installed on a single server (machine) using virtualization

[2] Interfaces will be validated through a series of validation sessions and a final validation workshop. The validated interfaces will be shared in an annex under deliverable 3(Report on Software development and web interface)

technologies. If this option is selected additional concerns like backup power and backup communication links may have to be considered to maintain a reasonable reliability.

The other option is using a commercial online hosting service. Such services offer backing up of data, reliable power supplies and security at professional levels using the best industry practices. Therefore, this option offers the best performance and reliability at a lower cost too.

There are commercial hosting services provided by international providers like Amazon Web Server (AWS) and local providers like Sri Lanka Telecom (SLT). Also, the Lanka Government Network (LGN) too may be a possible hosting platform. It is necessary to select a suitable hosting arrangement after consultations with the main stakeholders (MTSM and CCS).

5. **Plan the performance requirements**

Based on expected functions of the system, the requirements like the response time, the workload, scalability, platform are defined.

6. **Consider storage options**

Proposed storage options will be discussed with the stakeholders in a way that fulfills their requirements. Backup options and the storage options for the period of hosting were clearly determined since it will influence on the confidentiality of the data.

7. **Evaluate security options**

When evaluating the security options many points are considered such as: a) firewall to protect unauthorized access to application server and database if hosted inhouse; b) Authentication and access; and end-to-end secure connection The owner of the digitalized

MRV system (MTSM) will be informed about the good practices in terms of security and the consequences[3].

8. **Plan hosting options**

Hosting options were decided considering the technical requirements such as scalability, fault support, high up-time, security and backup. The consultation with the relevant stakeholders will be conducted to select the cloud service.

9. **Post-deployment warranty and support options.**

Once the digitalized MRV system is commissioned (accepted by the key stakeholders and put into live operation), ClimateSI will maintain the software as well as the hosting platform for a period of one year starting from the day of completion of acceptance test. This section describes how the post deployment support works.

[3] The Good practices will be shared during the final stakeholder workshop which will be held before handing over the digitalized MRV system. Further, the good practices and its consequences will be discussed in details in the user manual for digitalized MRV system.

2.System & Software Design/Architecture

2.1 Requirements for the digitalized transport sector MRV system

2.1.1 Scope of the digitalized system

The scope of the digitalized MRV system will support five sub NDCs representing four main NDCs[1].

1. Introduce park & ride system (sub NDC 4.1)
2. Electrification of the railway system from Veyangoda to Panadura (sub NDC 5.1)
3. Purchase new rolling stock for Sri Lanka Railway (sub NDC 5.2)
4. Introduce other electrified vehicles such as cars (sub NDC 8.4)
5. Transport of heavy loads by railway (sub NDC 9.4)

Table 2-1 indicates the methodologies, reporting and verification entities for the selected NDCs and sub-NDCs.

Table 2-1:Summary of the transport sector MRV system

Sub NDC (NDCs 2016)	Mitigation action[4]	Measuring	Reporting	Verification
1. Introduce park & ride system (4.1)	Introduce LRT system from Pettah to Mala be	CDM ACM0016: Baseline Methodology for Mass Rapid Transit Projects; Version 4.0	1.O&M company 2.SLSEA 3.CPSTL	1. Data verification - NDC unit of MTSM 2. Calculation

[4] Even though the table only shows one mitigation action, proposed methodology for each sub NDC can be applied for the similar mitigation actions fall under the respective sub NDC

2. Electrification of the railway system (5.1)	Electrification of Veyangoda to Panadura railway line	JICA guideline-Transport / Railway (Passenger) / Electrification-Version 2	1.SLR 2.SLSEA 3.CPSTL	-MRV expert committee
3. Purchase new rolling stock for Sri Lanka Railway (5.2)	Purchase six power sets for Sri Lanka Railway	JICA Transport / Railway (Passenger) / Modal Shift -FIT Version 2.0	1.NTC 2.SLR 3.CPSTL 4.SLSEA	
4. Introduce other electrified vehicles such as cars (sub NDC 8.4)	Imposing carbon taxes on motor cars Reduction of excise duty of electric cars	ICAT transport pricing guidance	1.DMT 2.SLC 3.VET 4.SLSEA 5.CPSTL	
5. Transport of heavy loads by railway (sub NDC 9.4)	Transport aviation fuel from Kolonnawa main terminals to Katunayaka Airport	CDM AM0090, "Modal shift in transportation of cargo from road transportation to water or rail transportation	1.CPSTL 2. SLR	

Source: Own work

2.1.2 Functional requirements of the digitalized MRV system

The MRV system for the transport sector is going to be implemented as a web-based system, which is hosted in a cloud and can be accessed over the internet. The digitalized MRV system

will have modern and user-friendly features, interfaces, graphics and high-performance databases. This system will reduce the time and the effort of the stakeholders and make the emission data more transparent and available to the users. As such, identification of the way that the system should function is key to develop the system.

2.1.2.1 Stakeholders, users and their roles and responsibilities

The MRV system's management institutions, data reporting institutions, supervisory institutions are the main operational units of the MRV system.
As per the existing institutional arrangement of the transport sector, mitigation actions (GHG reduction projects and policies) can be proposed by ministries, provincial councils or private sector organizations.

The details of proposed mitigation actions will be provided to the technical team of the NDC unit, who will categorize the mitigation actions under the transport sector NDCs. Based on the guidance provided by the MRV expert committee, a methodology to assess the GHG impact of the mitigation action will be decided by the team members of the technical team.

The list of institutions, who are responsible for provision of data, will be identified by the technical team. The data collection team of the NDC unit will request data[5] from the respective institutions based on the instructions provided by the technical team. Gathered data will be stored and directed to the QA/QC team. Quality of the data will be assured by the QA/QC team. Data that are not up to the required quality will be requested again from the respective institutions by the data collection team.

[5] Ex-ante/ex-post data depending on the status (proposed/implemented) of the subjective project

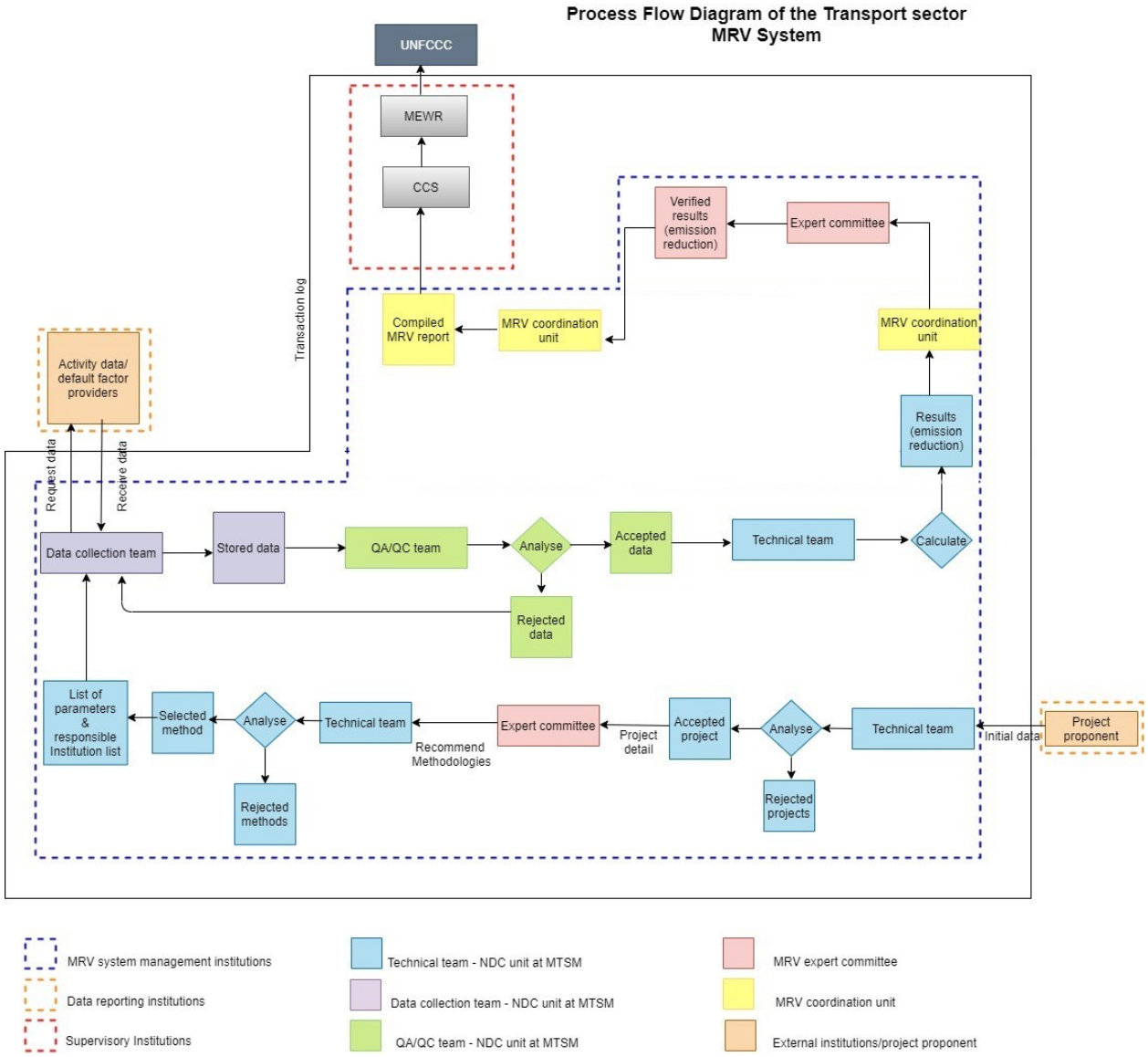

Figure 2-1:Process flow diagram of digitalized MRV system

Source: Own Work

The technical team will calculate the GHG emission reductions attributed to the mitigation actions, based on gathered data. Technical assistance required to the process will be provided by the MRV coordination unit established at the CCS. Calculation will be submitted to the MRV expert committee through the MRV coordination unit for the verification. Verified results will be submitted to the MRV coordination unit. MRV coordination unit will compile the GHG emission reduction reports according to the NDCs and submit to the CCS to proceed.

Table 2-2summarizes the roles and the responsibilities of the core institutions of the GHG MRV framework for transport sector. A clear definition of roles and responsibilities will allow mapping of the interaction among each agency and decide the access control for the web portal for the GHG MRV for the transport sector.

Table 2-2:Roles and responsibilities of the institutions of the MRV System of the transport sector

Institution	Role	Responsibilities
MEWR	National Focal Point to UNFCCC	Reporting the progress of NDC implementation to the UNFCCC through CCS
MRV Coordination Unit at CCS	Monitor the progress of achieving NDCs in the country	1 Provide guidance and training to stakeholders for accurate data collection, data recording, data reporting, data analysis, and calculations of impact of policies or actions on GHG emission
		2 Channeling technical and financial support for MRV of NDCs
		3 Establishment of extensive and effective communications with stakeholders
		4 Plan and conduct all coordination and consultation activities with governmental and if appropriate non-governmental stakeholders in relation to MRV of policies, strategies and mitigation actions
		5 Capacity building and keeping track of domestic (unilateral) as well as international capacity-building efforts.

Institution	Role	Responsibilities
		6 Conducting an evaluation exercise to identify key lessons learnt and areas for improvement.
		7 Compiling and integrating all the sectoral MRV reports and transform into a cohesive document to be submitted to UNFCCC
		8 Incorporation of reporting from all line ministries and their regulatory bodies and keeping an updated registry of relevant actions (eg. policies and projects)
		9 Collection and aggregation of information on new mitigation actions and directing those to the MRV process
		10 Maintaining and updating the registry of all the mitigation actions in the country
		11 Reflecting on progress of NDC implementation and making adjustment to new circumstances
		12 Keeping the MRV expert committee informed of progress and emerging issues
		13 Establishing guidelines for quality control and the quality assurance of collected data and developing and overseeing the implementation of a quality assurance/quality control strategy for the entire MRV process

Institution	Role	Responsibilities
		14 Mediate between parties when concerns surface, for example, over a disagreement in terms of responsibilities or a potential conflict of interest
MRV Expert Committee	Verifier	1 Verification of the emission reduction calculations done by sectoral NDC units.
		2 Provide necessary guidance and feedback to sectoral NDC units on calculations and selected methodologies.
		3 Make recommendations for improving the data collection process
		4 Provide recommendations on suitable methodologies to calculate the impact of the mitigation actions
		5 Establishing systems and procedures for the verification of reported impacts of NDCs
Transport sector NDC unit at MTSM	Tracking transport sector NDCs	1 Coordination of the flow of information from individual institution and ministries for a collective assessment of impacts and multiple benefits of policies, strategies and actions.
		2 Calculation GHG impacts of transport sector policies strategies and actions

Institution	Role	Responsibilities
		3 Quality assurance and quality control of data
		4 Identify all institutions that will be involved in data collection
		5 Allocate responsibilities for all institutions ensuring that there is a clear lead for each institution, and establish an institutional level formal approval process
		6 Develop and monitor a time frame and schedule for the preparation and submission of necessary data including specific dates for deliverable
		7 Documenting systematically, as appropriate, all the assumptions, data and methods used
		8 Storing and safe keeping of data and calculations.

Source: Own work

2.1.2.2 Requirements for data exchange and integration

Assessing GHG impacts of the transport sector NDCs will require data from multiple institutions. Some of these institutions already maintain web-based data management systems. Integration of these systems into the proposed digitalized MRV system will enhance the efficiency and accuracy of the process as no human intervention is required.

Exchanging data and integration with third party systems is considered when designing the software architecture of the digitalized MRV system. The MRV System exposes two groups of APIs namely, Private API and Open API. Private APIs will be accessible only for the MRV system. If an institution wishes to automate data reporting through their own software system, they can integrate the open APIs of the MRV system. Open APIs provide the means for integration with third party systems. Other than exposing the own APIs, MRV system is also able to integrate with consistent APIs exposed by the data reporting institutions. The MRV System restricts database level integration with third parties because of security concerns.

2.1.2.3 Identification of data requirements

The categories of data which will be processed by the system should be clearly classified under the functional requirements since they will influence the system. Basically, these data can be categorized into three main categories namely, activity data, default factors and other project specific data. Table 2-3 provides a clear image on the functional requirements for each data category.

Activity data, default factors and other project specific data will be provided by different stakeholders such as Sri Lanka Railway (SLR), Sri Lanka Customs (SLC), National Transport Commission (NTC), Department of Motor Traffic (DMT), Vehicle Emission Testing (VET), Ceylon Petroleum Storage Terminals Limited (CPSTL), etc. However, the data providing institutions may vary depending on the mitigation action.

However, in order to calculate the emission reduction from a mitigation action, the selected methodology will need the data only from two data categories mentioned below;

1. Activity data: Data specific to the mitigation action under consideration
2. Default factors: which are independent of specific mitigation action, and will be constant for certain period

Further information related to a project which are in the category of other project specific data, will not be required for calculations. However, these data will be needed for the identification and monitoring purposes.

In general, mitigation-specific data (project specific data such as activity data) can be considered variable while the default factors are mostly a constant. However, some default factors like fuel prices will be constant only for a particular period of time. Therefore, when default factors are stored in the system, they should be accompanied by a period of validity.

The scope of mitigation action defines by the values of activity data. However, there is a possibility that the scope of a mitigation action can be varied at planning as well as implementing stages due to various reasons not foreseen earlier. This would be addressed partially by the fact that activity data are recorded periodically. However, it is desirable to leave the provision to store a few scope revisions for each mitigation action.

One crucial requirement of all data is that their values must be associated with a unit of measure like kg, Gg, tCO_2e, MW, GWh etc. Both activity data and default factors must be associated with measurement units.

Sometimes there are mismatches between the measurement units of activity data and the default factors used in the calculations. Some instances of such occasions are where activity data is available in kilograms while the default factor gives a value per ton, where a fuel consumption is measured in liters but the default factor is in peta joules per ton of oil etc.

Therefore, it is desirable to have conversion tables built into the system which can do the conversions automatically for the most commonly used calculations. If the conversion is not available and there is a mismatch of units, the system should produce an error message. (A simpler way would be to limit the entry of activity data to a given unit of measure, requiring the users to convert the units manually. However, this could be error prone.)

Some default factors have different values during the same period such as:

1. Country specific value
2. Regional value
3. International average

During the calculations, it is desirable to use the country specific values. However, if such values are unavailable, regional and international values are considered in that order. In all cases, the available most recent value for the period under consideration is used.

Table 2-3:Functional requirements for different data categories

Category of data	Description	Examples	Functional requirements
Activity Data	Quantitative data indicating various inputs used by project and outputs produced by project. In this context, by-products and waste are also considered as project outputs.	Inputs: Distance travelled (km), Electricity Consumption (MWh), Diesel Consumption (liters) Outputs: Electricity Generated (MWh/Year), Food Waste Generated (kg/Day)	Activity data providers should be able to enter NDC Project activity data The system should aggregate the activity data fed by multiple activity data providers and show them in a summary table The system shall check the validity of the user inputs using range checking, type checking, etc.
Other Project Specific Data	Details needed to identify the location, cost, fund source, etc. of a project	Province, District, DS Division, GN Division, GPS coordinates etc. Fund Source, Cost, Loan Amount, Interest Rate etc.	Users should be able to enter project specific data for completeness
Default factor	Non-project specific values which will be constant for certain period and these are needed for the calculations specified in the selected methodology	Grid Emission Factors (tCO_2e/MWh), Diesel Price (Rs./Ltr), Calorific Value of Diesel (PJ/ton), Average fuel Economy of a small car in the Asian Region (km/ltr)	When a project is created and a suitable methodology is selected, the list of default factors and required project data will be identified by the system. Those items will be used for data entry and calculations."

Source: Own Work

2.1.2.4 Identification of Types of users

There are different types of institutions in the MRV system for transport sector such as data reporting institutions, MRV system management institutions and supervisory institutions. Table2-4 provides a clear description for the types of institutions in the digitalized MRV system.

In each institution type there are different types of users (user profiles) with different functions in the MRV system, as listed in table 2-5 . The key users of the MRV system are admins, data entry users, verifiers, MRV system monitors and other users.

Table 2-4:Key institution categories of the digitalized MRV system

Type of Institution	Description
Data reporting institution	Activity data providers: Institutions which are responsible for providing data required to assess the GHG impact of the NDC Default factor providers: Institutions which are responsible for the entry and update of emission factors and other parameters which are non-project specific. Project proponent: Institutions which submit new mitigation projects /policies to the MRV system and responsible for providing project specific data
MRV system management institutions	Institutions, which are directly involved in the function of the MRV system. Ex:, Transport sector NDC unit under MTSM, MRV expert committee, MRV coordination unit
Supervisory institutions	These institutions will not actively participate in regular operations of the MRV system. However, they have the right to see the entire process of MRV (CCS, MEWR).

Source: Own work

Table 2-5:User access rights and functionalities

Key Users	Sub categories	Institution category	Functions in the system

Admin	Master Admin (Ex: the secretary or an assistant secretary of MTSM)	MRV System Management Institutions	The master admin has the right to provision, access or modify any user below them in the hierarchy. However master admin will not involve daily with the system functions. The key functions of the master admin in the system are,
			• Put the whole software system into any of the following modes of operation:
			  ○ Stopped
			  ○ Normal operation
			  ○ Reduced functionality
			  ○ Maintenance
			• Can view any information on the system but can't modify.
			• Can transfer his/her authority to a successor (retirement, transfer)
			• Can create and manage the admin user and backup master admins

	Backup master admins (BMAs). (Two from MTSM and one	MRV system management institutions	In the event of non-functionality of the master admin (death, disability etc.), a new master admin can be created with the combined approval of these three BMAs. BMAs will be created by the master admin. BMA's account will be used only when nobody can log in to the system as MA, due to the person having credentials of MA has left organization, died, or MA credentials are lost

	from MEWR)		
	Admin	MRV system Management institutions (Admin will be chosen from the NDC unit of the MTSM)	Creation and maintenance of institution level admins, overseeing the operation of the software system, co-ordination with help desk, system maintainer etc. • Add /manage/delete institutions in the system • Add or delete Admins from the institutions of the digitalized MRV system • Update Usernames of the admins of the institutions of the digitalized MRV system • Reset Password[6] of the admins of institutions of the digitalized MRV system • Enable / Disable / Limit any users access of the system
	Institutional admin (Admins from the data entry institutions)	Data Reporting Institutions	(These users are created and managed by the Admin) • Add data entry users within institution • Delete data entry users within the institution • Allocate user names for the data entry users within the institution • Reset password[6] of the data entry users when the system does not do it automatically

[6] System will reset the password upon request of the user, in exception situation where automatic reset is not working, the password reset will be done by admin.

			• Liaise with the Admin on operational matters, help and troubleshooting of the system
Data entry Users	Activity data providers	Data Reporting Institutions	• Input activity data and parameters • Edit activity data and parameters
	Default factor providers		• Input emission factors/coefficients • Edit/Update emission factors/coefficients
	Project proponent		• Add a project/policy • Input project specific data • Edit/update project specific data
Verifiers	MRV expert Committee	MRV System Management Institutions	• Verify the data and calculations and provide the feedback to NDC unit (Admin will be within the NDC unit of the MTSM)
MRV system Monitors	CCS of MEWR	Supervisory Institutions	• Review data entry and calculations • provide feedback to admin on the assessing the GHG impacts of the transport sector NDCs
Other	General public	-	• View the status of emission reduction projects under each NDC

Source: Own work

2.1.2.5 Functional components

The design of the digitalized MRV system took account of all major functional components such as data inputs and uploads, data validation, mapping & transformation, calculation engine, document management, quality Assurance & quality control, report generation & data exports, data confidentiality requirements, analytics, user information, communicating with users within the system, system documents, and relevant regulations & guidelines. The following sections explore each functional component separately.

Data inputs and uploads

The digitalized MRV system incorporates many institutions to enter data, so the data input options were considered when designing the software architecture. The web interface is considered as the primary means of data entry (through forms) into the system. Additionally, manual import of excel sheets which comply with an agreed format is also considered for bulk data entry. APIs will be provided for integrating with authorized software systems in other institutions for automatic data entry and/or retrieval of agreed processed information.

Data validation, mapping & transformation

Data mapping and transformation reduce explicit data conversions. The users are not required to do manual conversion of data before submitting. The digitalized system has co-operated inbuilt data conversion to support the users.

The user perspective of data (project activity data and emission factors) and software perspective of data are different. This leads to a process of data mapping and transformation. Data validation is needed to maintain the consistency of the data base.

The data mapping can be explained with an example as follow:

When creating an institution, the category, for which it belongs (Government, Private etc), has to be selected. The user can select one option from the drop-down menu. The frontend application will send only a number associated with user selection (eg: if Government = 1, If

private =2 etc). Before sending a request to the backend server, the front application will figure out the respective code for the user selection. Another example of data mapping is transferring Data Transfer Objects (DTOs) from the backend application. The backend application will fetch relevant data from tables and map those data (only required fields) to a DTO object. The Data mapping technique reduces the request and response size.

Data Transformation is also very common in software applications and it bridges the gap between User Interfaces (UI) and backend server. The user interfaces will be developed to enhance user experience, and the backend entities (tables) will be developed to make the database design simpler. One possible scenario of data transformation is "entering fuel consumption for mitigation action". The user interface should support all possible ways to enter fuel consumption (Liters, m3, Rupees, or Distance and Fuel Economy). However, the table will be designed to hold only fuel consumption in liters. Then the fuel consumption in different units should be transformed into liters before posting to the database since keeping of all the possible fields in the table (Fuel consumption, Fuel economy, and distance) will result a poor database design (many null values).

Data validation will be done through range checking if it is a number or a date, format checking if it is an email, phone number etc., and eligibility of the value to the particular data entry field. Data Validation is more about maintaining the consistency of the database and warning the users if they entered any wrong values for the fields. For instance, a user can enter negative value to fuel consumption. According to programming language type-level, the value is a legal value (JavaScript Number and Java Double), but it is an illegal value to fuel consumption. Data entered by users should be validated prior to data mapping and transformation. Failed to validate the data entered by users will result an unwanted or incorrect result in other places (eg: Emission Calculation)

Calculation Engine

The calculation engine will be developed as a separate module in the backend. The Calculation Engine takes inputs from the backend core MRV system and returns calculation results. It can be seen as a black box (inputs, outputs). By separating the calculation engine

from database connection and request handling enables this to be a pluggable module. Modification to an equation will not affect other parts of the system. The figure 2-2 explains the process of emission calculation for a sample project while figure 2-3 illustrates the calculation engine.

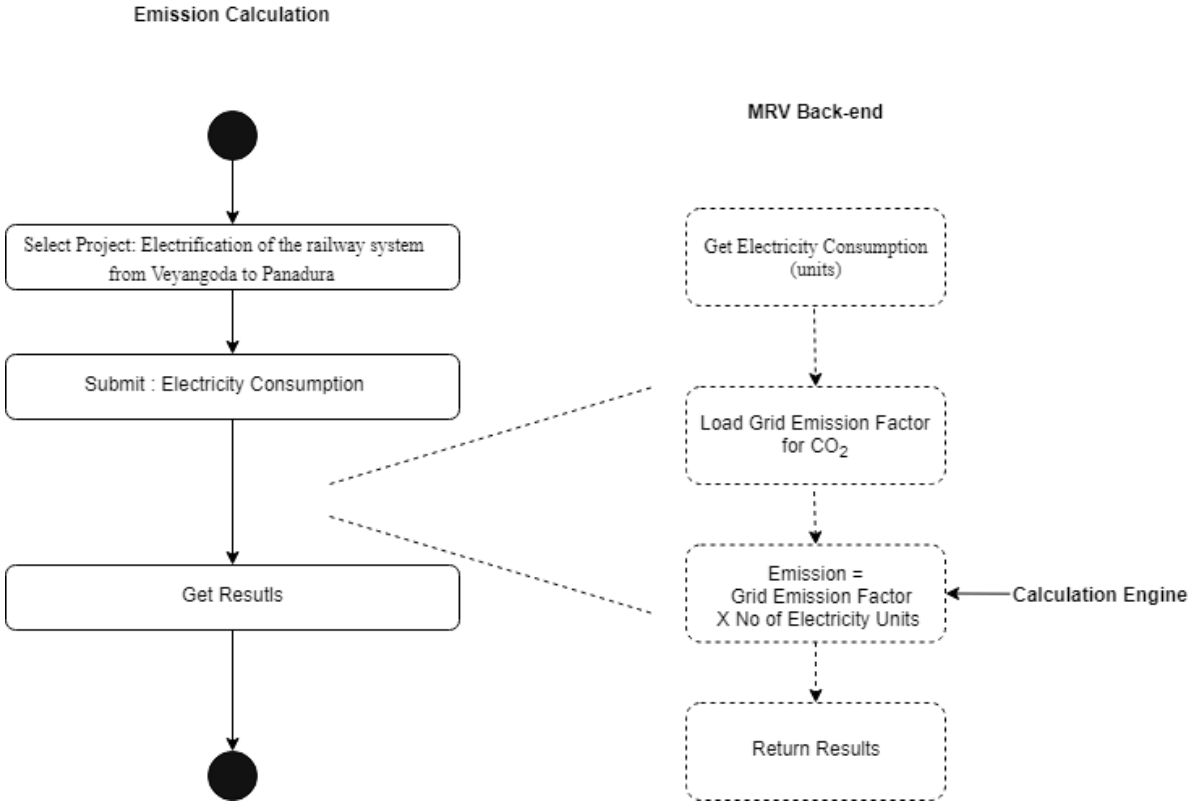

Figure 2-2:Sample emission calculation for a mitigation action

Source: Own work

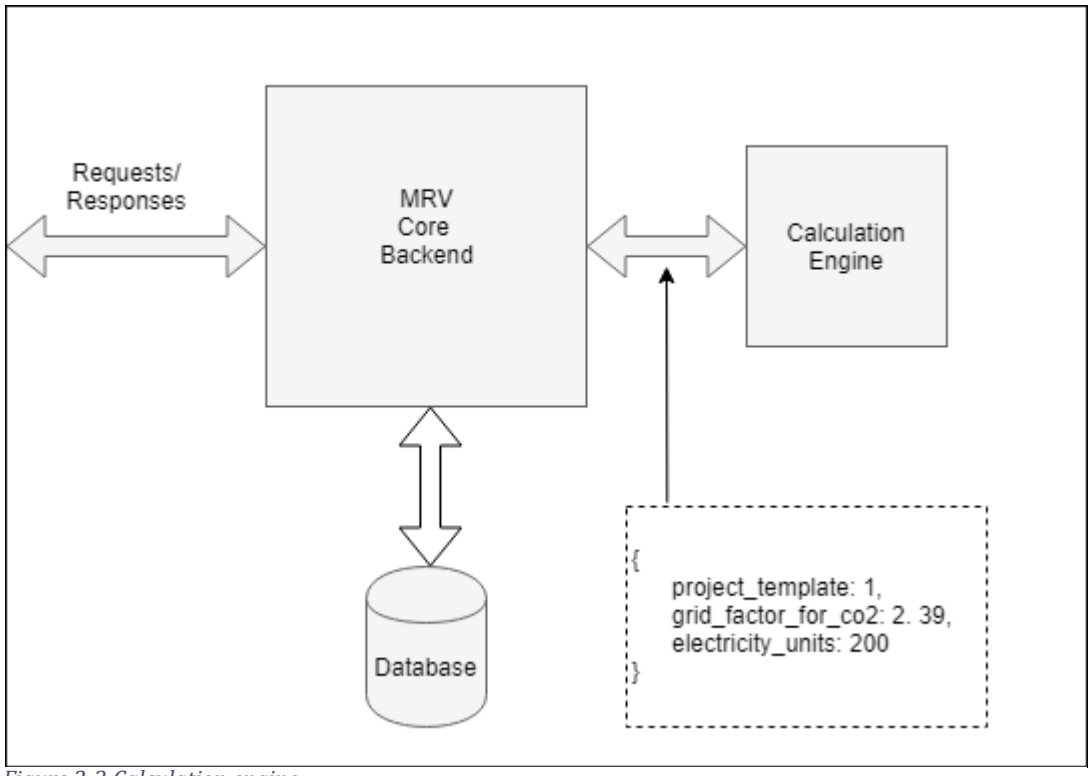

Figure 2-3:Calculation engine

Source: Own work

Document management

The digitalized MRV system needs to handle some sort of document management. The digitalized MRV system will support generating (creation) final NDC report and summary report for each mitigation action (project report) etc. The generated documents should be stored and made available (sharing documents) to others. (Verifiers and Institutions). The activity data can be exported as an excel sheet and to reduce the number of exports it can be stored in the system. The digitalized MRV system will consider provision for new project proponents to upload their proposal documents to the system through a form. The system will support to attach some extra documents to each project if necessary (eg: Base year documentation, monitoring plans etc.). The deleting right of the document will reside with the owner (who uploads the document).

Quality Assurance & Quality Control of the Software

Quality Assurance ensures whether the approaches, techniques, methods and processes used to design the projects are implemented correctly, while Quality Control ensures that the approaches, techniques, methods and processes which used to design the project are followed correctly. However, the QA/QC process is also related to the different software testing processes.

The functional testing will ensure whether the software meets the expected functionality by the users. For example, when the activity data of a project are entered correctly then the emission reduction should be calculated correctly.

In addition to this, a usability test will be carried out to determine the user experience. For example, the time taken by a user to learn the basic operations of the system, ease of using the system etc. This usability testing will include validating the interfaces to see how easily the users can handle the system.

In addition, performance testing will also be conducted to determine the speed at which the system performs a particular task while load testing will be conducted to test the scalability of the system when the number of users increase and the data load is high.

Also, this includes different levels of testing such as developer testing done by the developer, code review done by senior developer as well as using an automated code review and analysis tool, such as "sonar cube", to analyze the code quality and standard.

QA testing for the software is done by a separate team. This team will validate the system with the requirement specification to ensure that the software does the expected functionalities and verify the performance parameters like page loading time, time taken to save data, report generation time etc.

The user acceptance testing (UAT), is the next level of testing. During the UAT the users from the stakeholders will test the system and will provide feedback on their experience and what further changes they expect. Once all user comments are addressed and the stakeholders are satisfied with the system it can be put into operation. These tests can be done part by part on system components iteratively to reduce the defects that can add up to the overall system.

Integration tests should also be done. This will help identifying the defects at the early stage and make it easier to fix them. However, for the digitization of transport sector MRV, it is suggested to have phased out deliverables where the most frequently used pages are released first and the least used pages are released later.

Report generation & Data exports

Users will be able to generate reports based on data for which they have authority. Exact format of the reports will have to be decided based on stakeholder consultations. Permission to export data is also provided only for the top-level users. Lower level users have to request reports from top level users if needed. The MRV system considers report generation and sharing as a key feature.

The generation of consolidated reports can be done by the top-level management (MTSM and MEWR). They can generate detailed reports about mitigation actions and their performance as well when required. The MRV system considers report generation and sharing as a key feature.

Facilities will be provided to generate 'ad-hoc' reports by the users, subject to the availability of access to the data.

Data confidentiality requirements

From the initial design, the data confidentiality is highly emphasized. The MRV application gathers data from many institutions and data breach (knowingly or accidentally) can cause problems for continuation of data collection. The flexible user access levels and default access levels are designed to restrict unauthorized access to data.

Analytics

The MRV system is designed to give the visual representations in the forms of charts and tables. The dashboard, which can be seen by all users, will be utilized to show the analytics/ whole picture of the current status of the projects, institutions, and users.

Language Requirements

Language requirements were considered during the digitalized MRV system design. Supporting all three languages will facilitate an effective MRV process. However, due to time constraints, only one language (English) will be supported at the beginning. Provisions are made to accommodate support for other languages such as Sinhalese and Tamil in the future.

User management

The involvement of many types of users and institutions is necessary for a successful MRV process. Incorporating all the users will be challenging unless the system provides flexibility as well as strict control of managing users and privileges. Strict access control is crucial as users are connected to the system through the internet.

User management is viewed at two angles when designing the software architecture. One is user creation and the other is user access level management.

The User creation needs to select the user profiles (the user profiles covers the default access rights allowed within the system). In case if the Master Admin or Admin wants to control the access rights beyond the User profile it will be supported by the entitlements.

Access level management is done by administrative users through defining classes of service for each user. At the same time, each user's position in the MRV framework also imposes restrictions on what information is available to a user. For example, a user belonging to one institution can't access information related to a project owned by a different organization, the admin user of each institution has access to all information related to their institution etc. Figure 2-4 show an overview of the user management process.

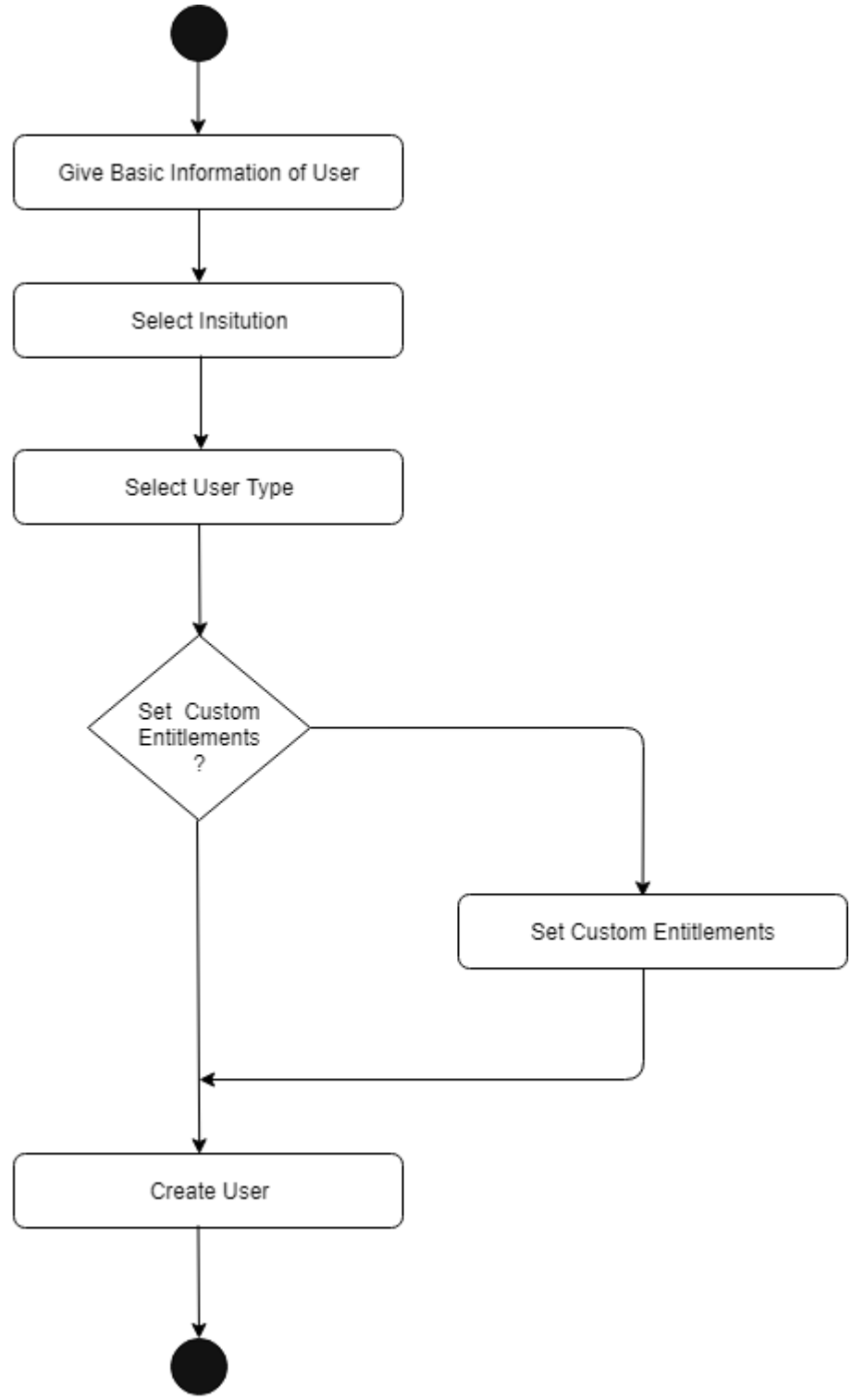

Figure 2-4:User management process

Source: Own work

Communicating with users within the system

The digitalized MRV system design considered communication with users within a system for the effective MRV process. It's expected to build a simple messaging system where users can send messages to others where necessary. This messaging system can be used to guide novice users, getting help and reporting problems as well.

System Documents

(E.g. Legal disclaimers, terms of use, information on data exporting options, forms, user manuals, troubleshooting instructions, etc)These documents will be attached as annexes.

Relevant regulations & Guidelines

The digitalized MRV system operates on data from various institutions. Therefore, protection of the data is an important requirement. That responsibility lies on the software system as well as the users. The system is designed to remind users on regulations and guidelines before they export or retrieve data. For example, the user who downloads information from the system should accept the non-disclosure agreement.

However, users too should take basic precautions like not disclosing their passwords to others, not leaving the systems running unattended, using anti-virus software etc.

A deeper view of each functional component is considered when the software architecture is designed. Figure 2-5 describes users' activity and interaction with software components.

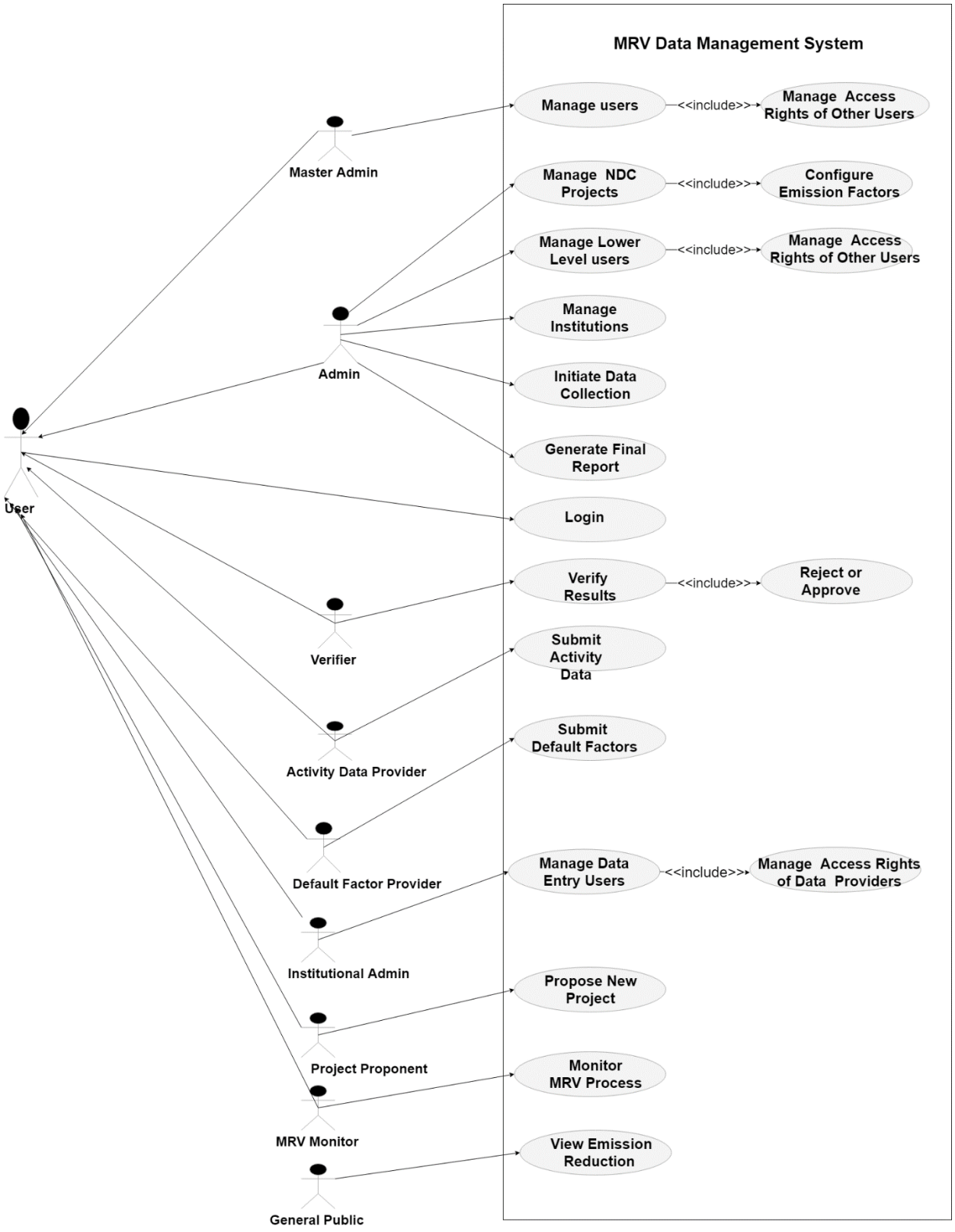

Figure 2-6:User's activity and interaction with software components

Source: Own work

2.1.3 Supporting Process Requirements

By means of supporting process requirements, the ability of adaptability, maintainability, internationalization, and configurability of the digitalized MRV system are considered. There are many functionalities in the digitalized MRV system which are not required to run the core MRV system but to facilitate the smooth run of the system.

From deployment point of view, the system should be able to adapt to increasing loads (number of users, growing database size). The use of load balancer and reverse proxy for the application server will support adaptability requirements in the deployment. From development point of view, the digitalized MRV system should be capable of integrating new features if required in the future. The system design considered a component-based architecture for the front-end development and separation between components logic (to render UI elements) and data fetching (from server). It gives more flexibility to add new components if required. The backend architecture is designed to accommodate new services in the future.

Maintainability is one of the key features in deciding the sustainability of the system. Usually, maintainability takes account of backup, fault management and system health monitor. The system is designed in a way to report faults (any user can report system faults), system health status and record the user activities. The digitalized MRV system will allow any user to inform admin and Master Admin about the faults as notifications. However, the reported faults will be addressed based on the severity of the faults. The admin or Master admin can communicate and fix those faults with developers.

Internationalization is the process of supporting multiple languages. The language requirements are analyzed in another chapter (2.1.2.5 Functional components). The configurability is the one feature that enables the customization of the existing software features. It has identified the requirement of dynamic controlling of user access rights. The system design considered a combination of user roles and entitlements to achieve configurable user access rights.

2.1.4 Performance Requirements

The most obvious parameter which displays the system performance is average page load time. It is expected, that the system should not take more than 4 seconds to load a web page given the minimum internet speed criteria is met.

The digitalized MRV system will support up to fifty simultaneous users at a time.

Although the digitalized MRV system has provision for future improvements like adding other languages (Sinhalese and Tamil), adding more NDCs, adding new methodologies, including qualitative sustainable Development (SD) impact assessments of transport sector projects, inking the digitalized MRV system for transport sector with National Carbon Registry and keep a record of non NDC projects which cannot be list under transport sector NDCs[7]

The digitalized MRV system supports all browsers which follow World Wide Web Consortium (W3C) standards, all the operating systems with web browsers, all the devices which have access for the web browsers. However, the digitalized MRV system will provide a better user experience when using tablets, laptop and desktop computers.

2.1.5 The design of the digitalized MRV system and interfaces

ER diagram

ER diagram has been drawn to demonstrate the relationship between tables related to the features of the digitalized MRV system as shown in figure 2-6

[7] There is a chance that an emission reduction project that received from a project proponent may not possible to list under any of the NDCs proposed for the transport sector. Therefore, the digitalized MRV system will keep provision to keep a record of such projects separately for the future use of the MTSM.

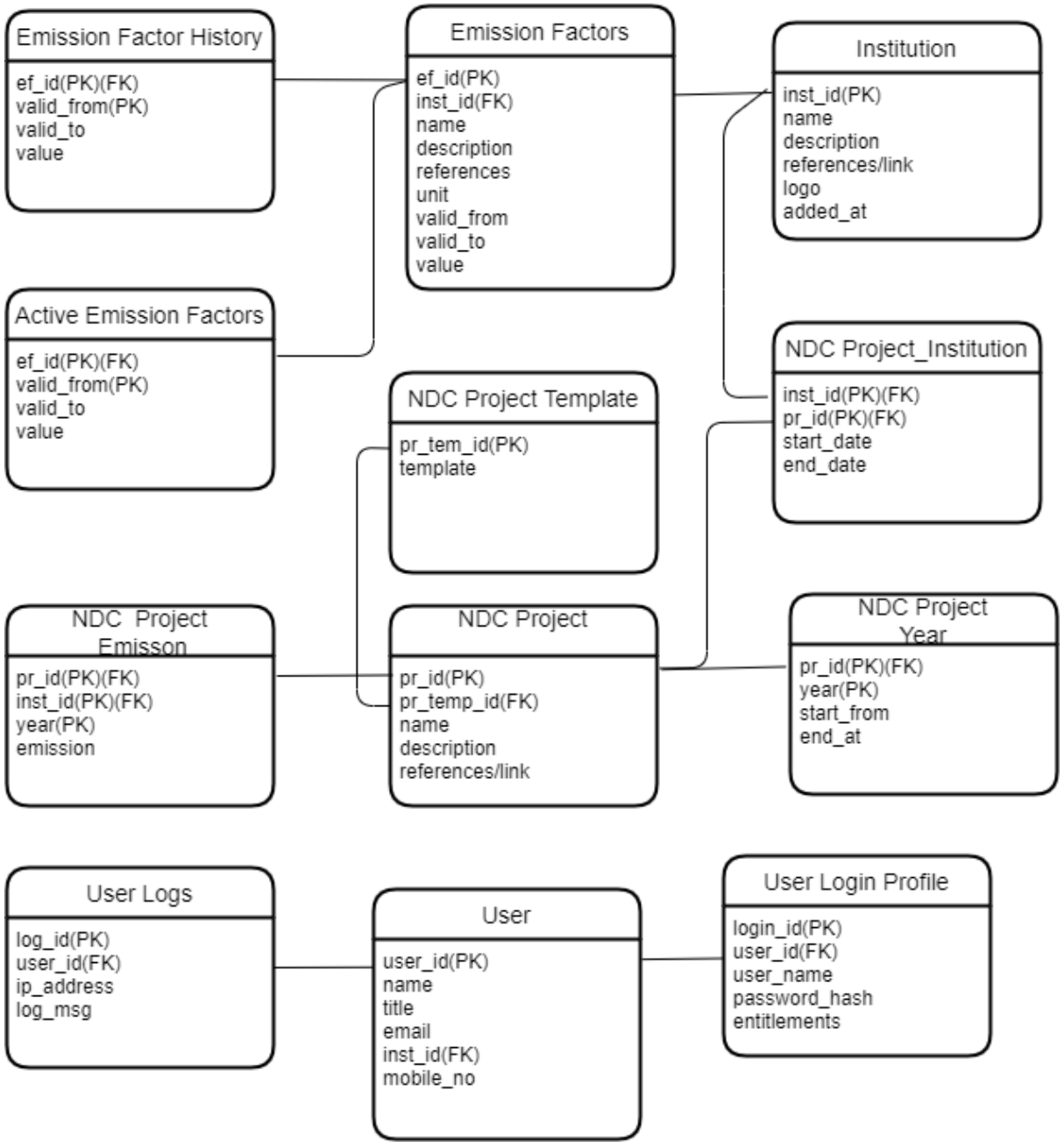

Figure 2-7:Entity relationship diagram of the digitalized MRV system

Source: Own work

Process level overview of the digitalized MRV system

Figure 2-7 illustrates a process level overview of the application. Processes shown here are high level entities. Deeper level flow diagrams of the processes are included in Annex 10 - the Software architecture document.

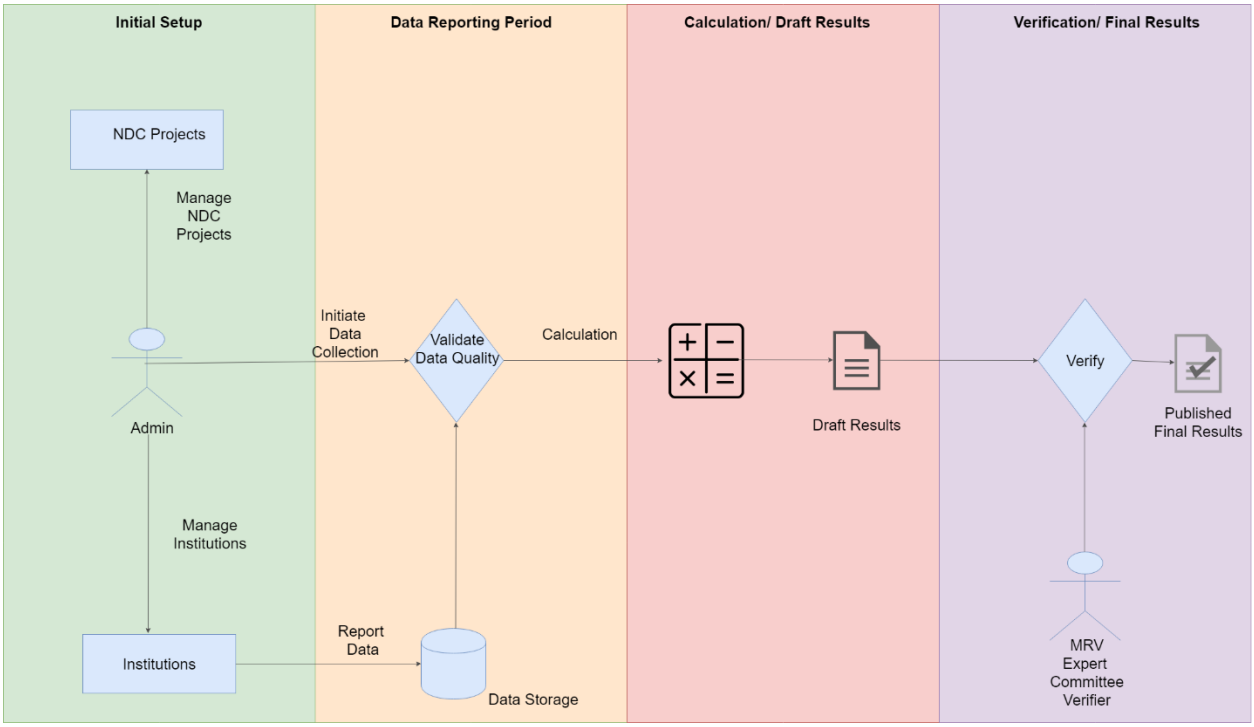

Figure 2-8:Process level overview of the digitalized MRV system

Source: Own work

Interfaces [8]

The following figures (Figure 2-8 to Figure 2-15) are sample interfaces of the digitalized MRV system for interacting with users for activities like adding a new mitigation action, managing institutions, adding a new institution, creating a new user, user access management, error reporting

[8] These are the sample interfaces which will be validated through series of validation sessions and a final validation workshop. Therefore, the content shown can be changed after the validation sessions. However, the validated interfaces will be shared in an annex under deliverable 3(Report on Software development and web interface).

and GHG verification. These sample interfaces need to be reviewed by relevant stakeholders and approved in order to be used in the digitalized MRV system

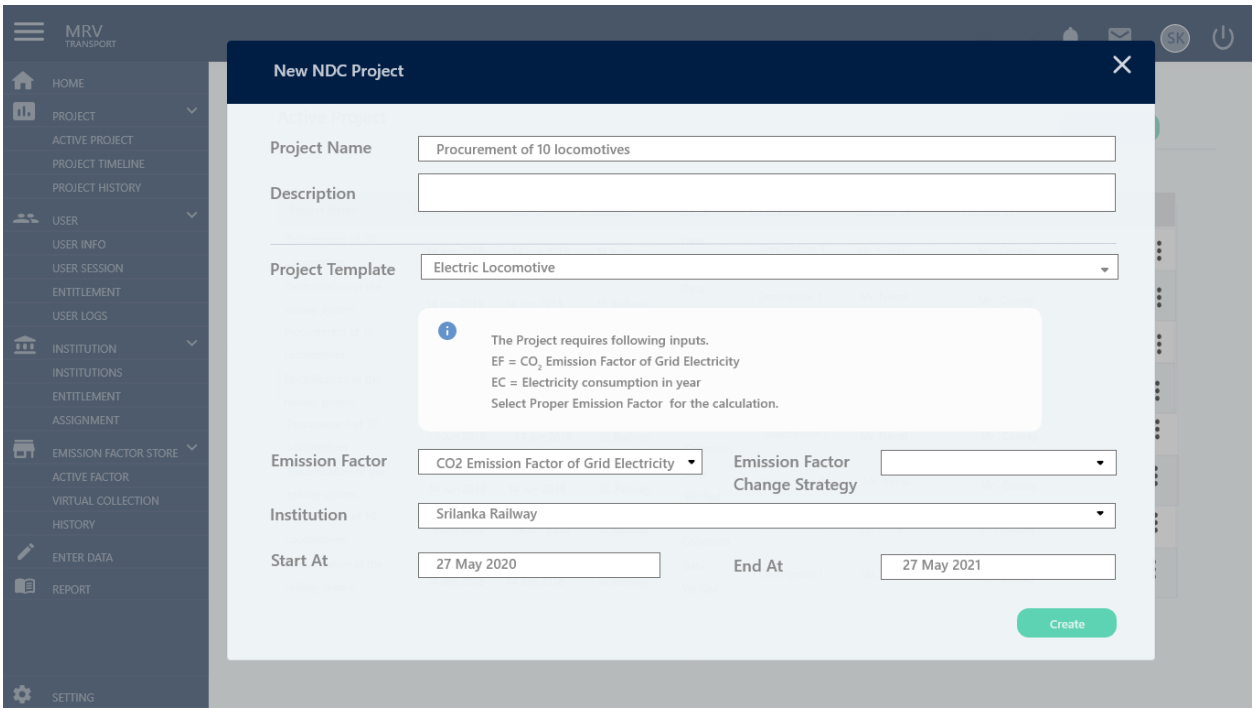

Figure 2-9:Creation of new NDC project

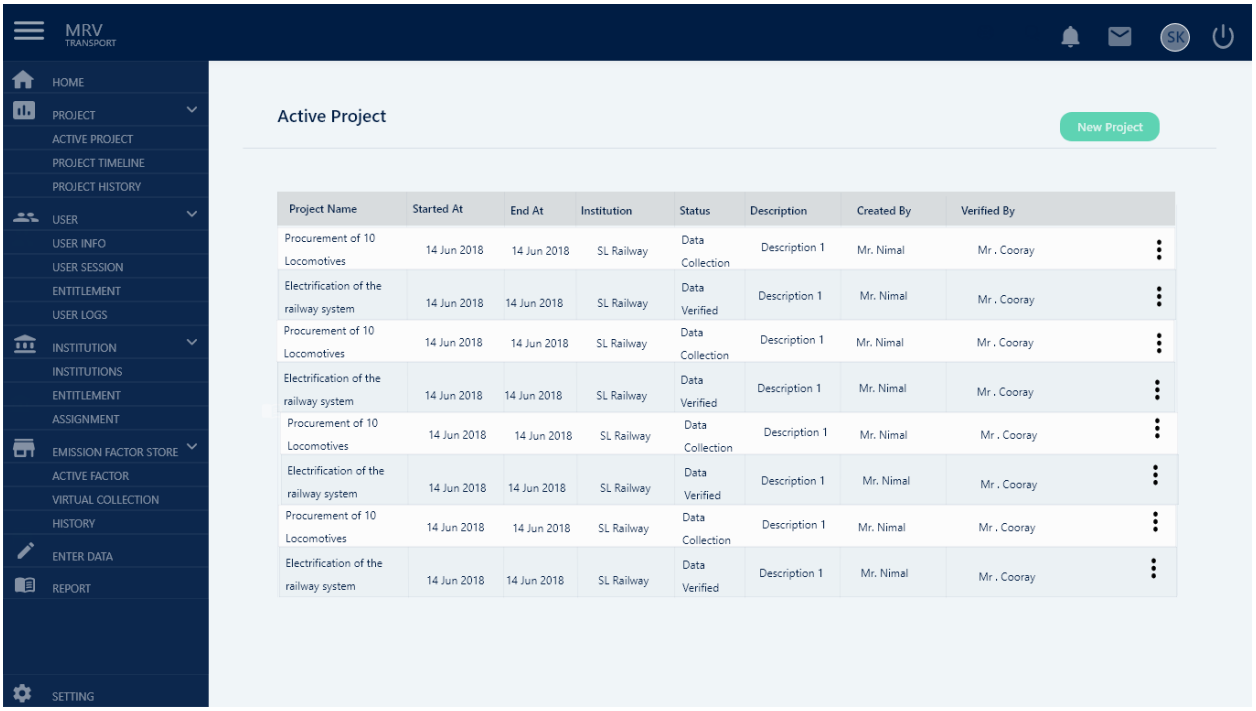

Figure 2-10:Active projects

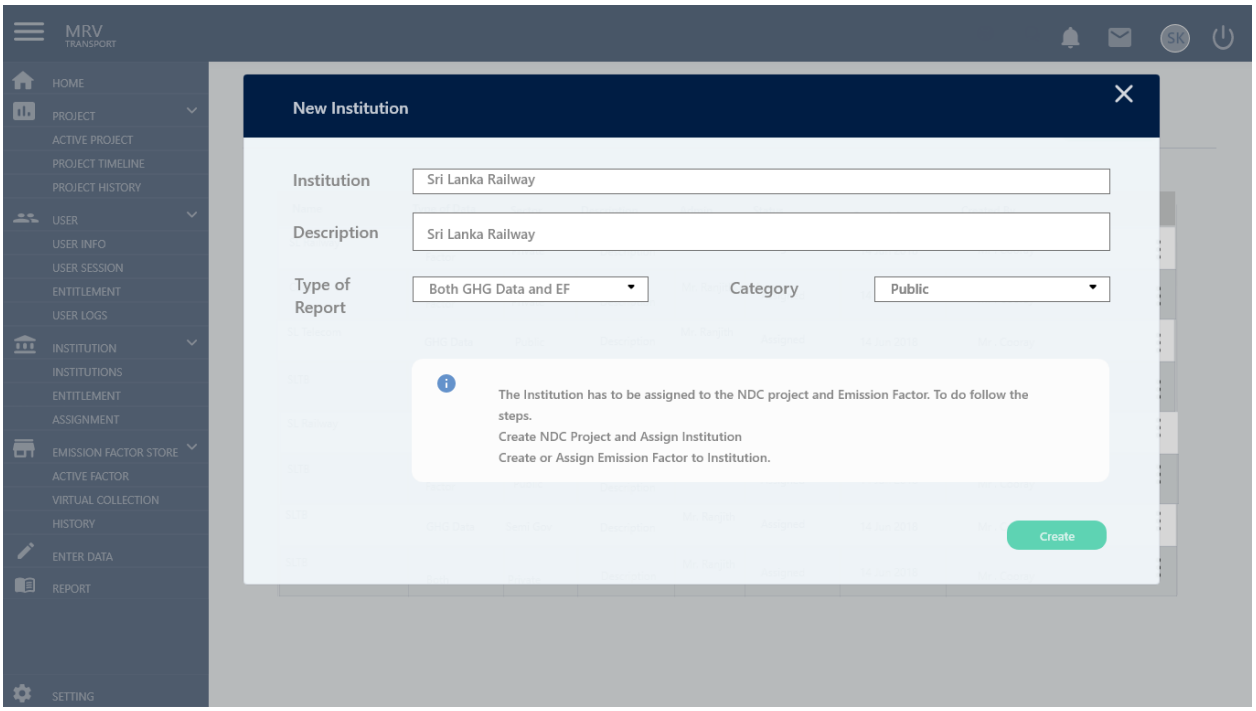

Figure 2-11:Creating new institution

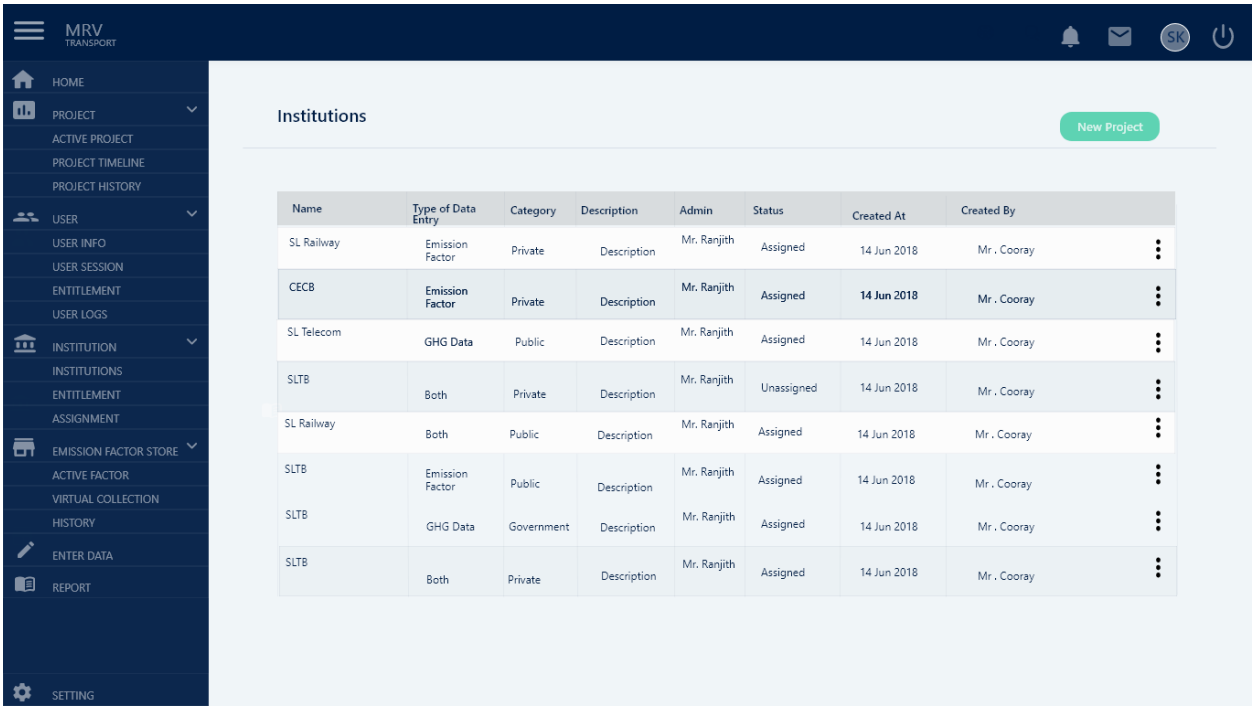

Figure 2-12:Institutions

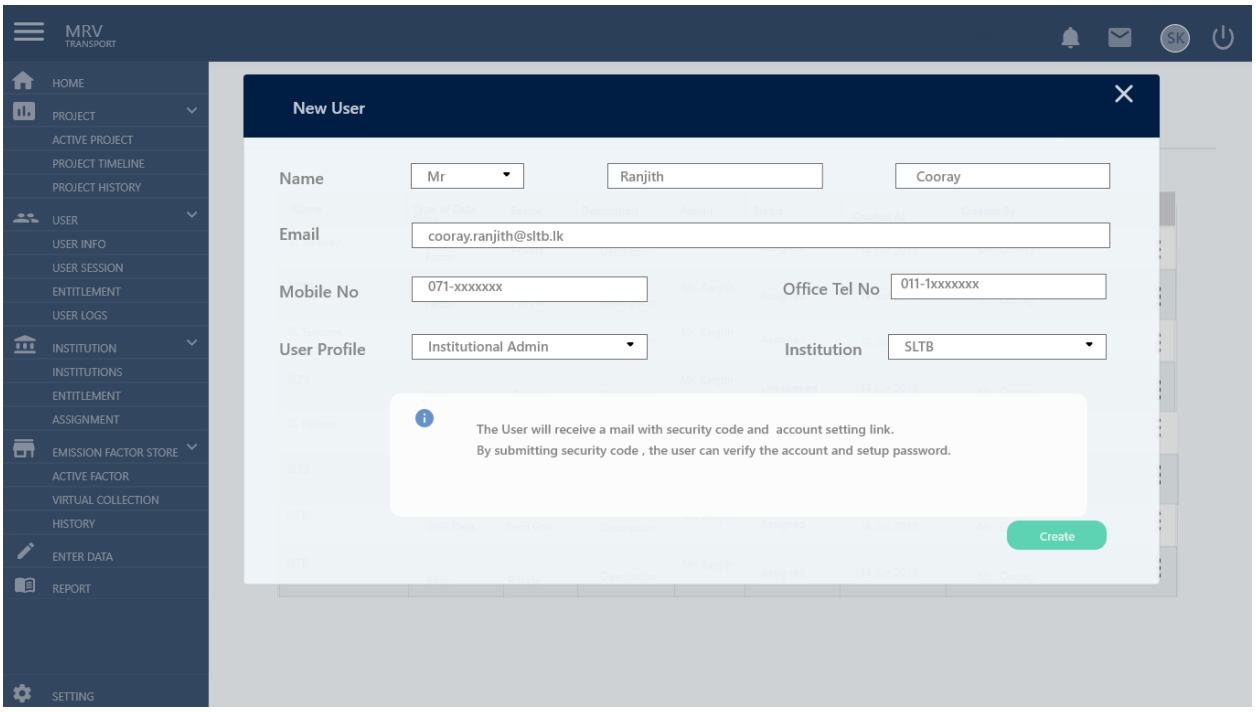

Figure 2-13:Creating a user

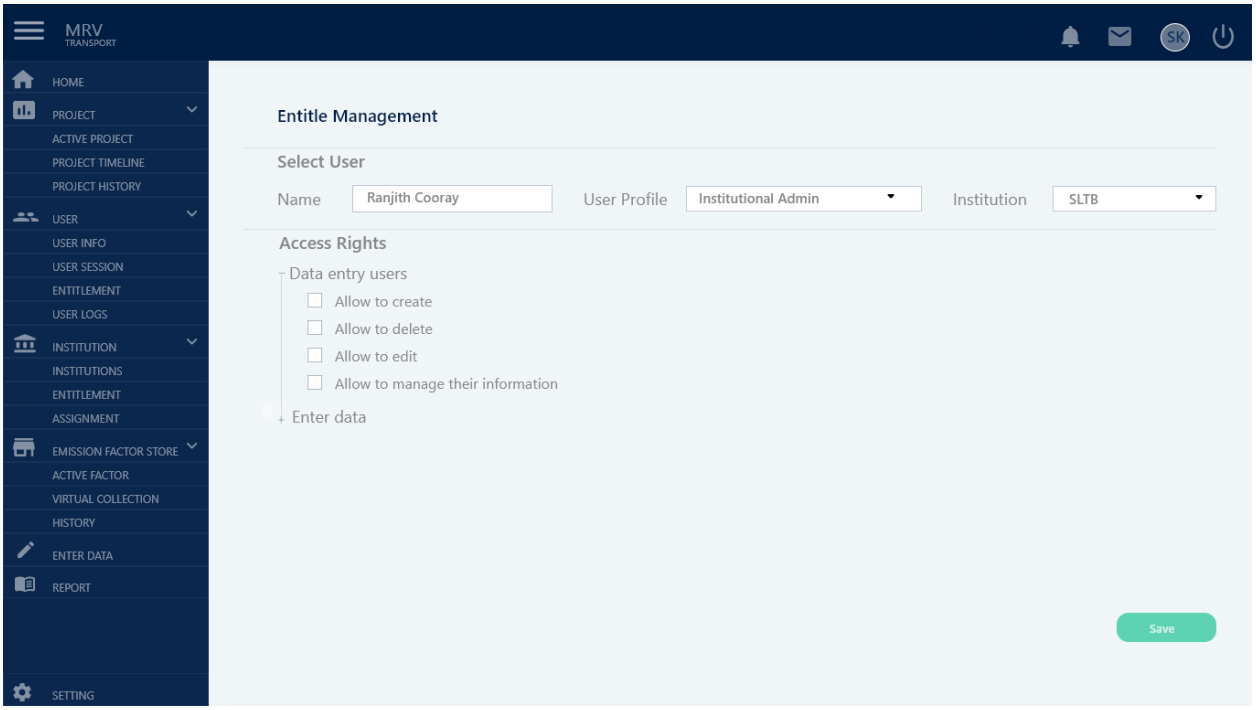

Figure 2-14:Setting user entitlements

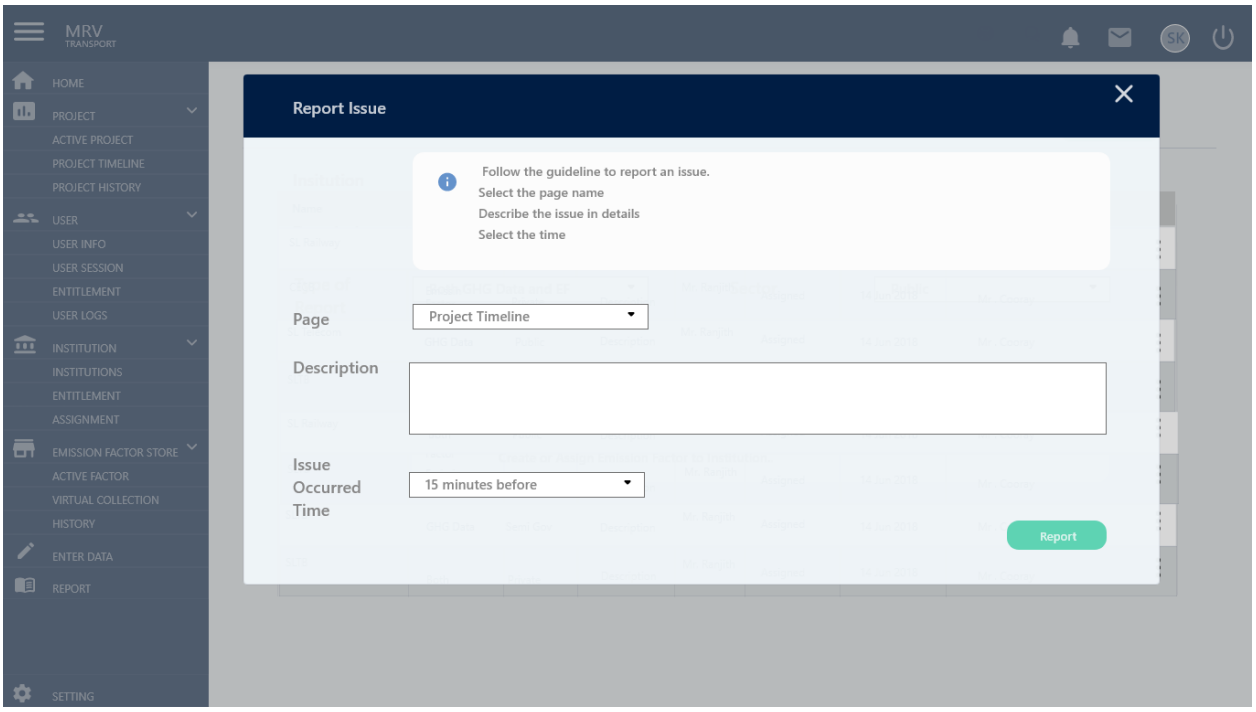

Figure 2-15:Error reporting

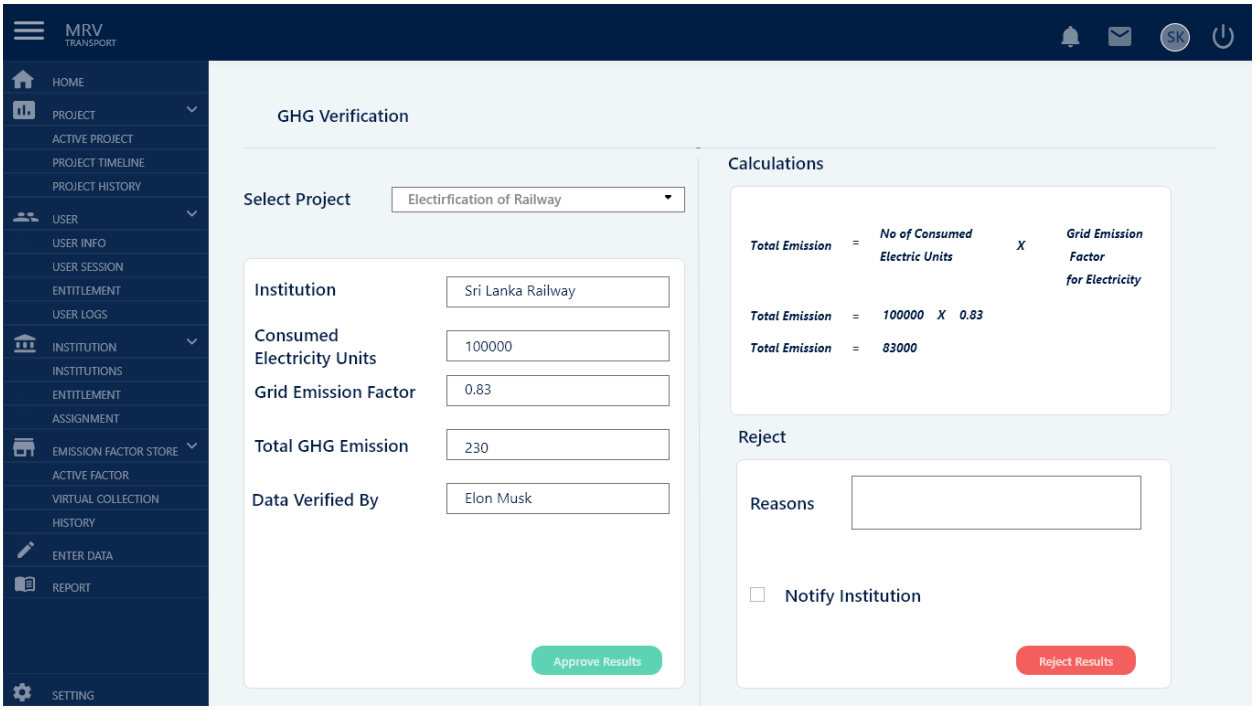

Figure 2-16:Verification

Source: own work

2.1.6 Hardware architecture

The Infrastructure as a Service (IaaS) solutions (from Lanka Government Cloud or Amazon Web Services (AWS)) allow to install and setup required software. The backend system is being developed using the Spring Framework and the Tomcat server. The Java Development Kit (JDK), MySQL Server, Nginx, Docker, and Docker Swarm has to be installed on the server machine. Figure 2-16 illustrates a hardware architecture of the digitalized MRV system.

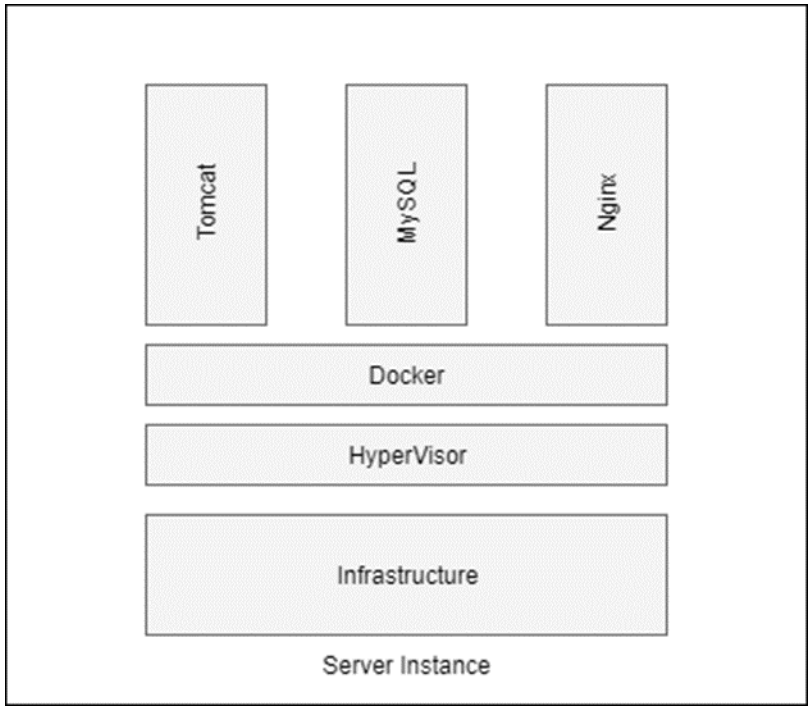

Figure 2-17:Hardware architecture

Source: Own work

2.1.7 Data Storage options

Data storage options are tied with hosting options. It's easy to migrate/store data by developing the application free from platform dependency. The most popular cloud services offer backup services with the hosting plan.

As a standard practice, maintaining on-premise backup storage is necessary for governmental applications. The following figure illustrates the backup storage plan for the MRV system. Having two backups will prevent a possible complete loss of data due to a failure in the hardware or software in a situation like a fire or a virus attack. The cloud database and on-premise database/ storage can be synchronized to maintain up-to-date replicas. In addition to two backup storage, the tape storage is necessary and the tape storage will be kept isolated from the Internet(Figure 2-17). MTSM's involvement is necessary for the maintenance of on-premise backup and tape storage by providing the necessary hardware (a computer), internet connection, and services of the administrator. It's noted that the cloud backup (AWS) and tape storage will be maintained by ClimateSI during the free hosting period.

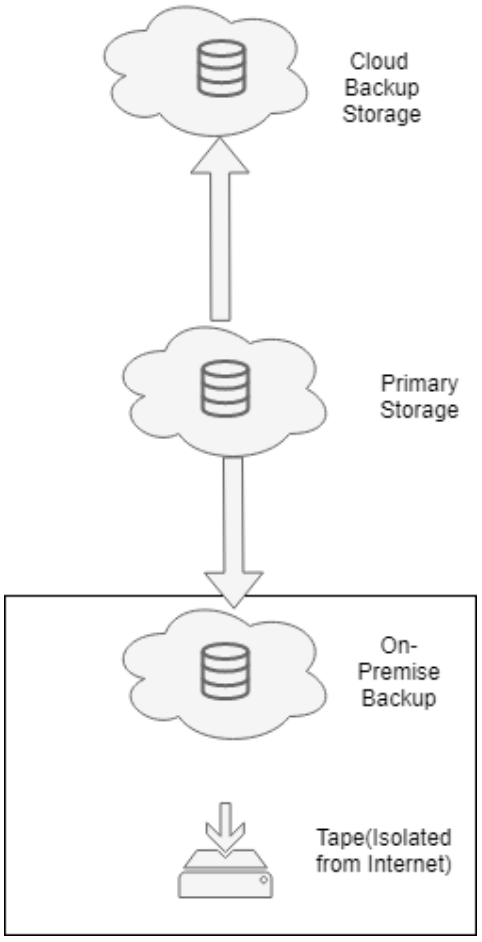

Figure 2-18:Data storage options

Source: Own work

2.1.8 Evaluate Security options

Authentication and authorization of users at the application level, prevent unauthorized access to the data. User access rights can be controlled by top level users. The flexible access control allows to set specific access rights to each user depending on the needs. The system is designed to restrict any database level connections from third parties. Therefore, the above-mentioned considerations create a secure environment.

2.1.9 Hosting Options

The hosting plan and maintenance are well connected. As this digitalized MRV system is being a web application, it can be hosted anywhere (cloud, on-premise servers, or hybrid server arrangement). The MTSM has the right to decide the suitable hosting plan based on their requirements (security, backup, etc.) and constraints (budget, IT workforce). It is good to compare the available hosting options by addressing features offered by them and this comparison may be useful for MTSM to decide the hosting option.

The hybrid server arrangement will introduce more complexity to the system and require more IT workforce to maintain. Therefore, the report will only discuss the cloud services and government on-premise servers as hosting options. The Sri Lankan government has established Lanka Government Cloud (LGC) in collaboration with the Ministry of Telecommunication and Digital Infrastructure. The key purpose of LGC is to enable and support the national policy of “Digitalization of Economy”. It provides infrastructures to government IT systems and has the capacity of adopting any government requirements and it ensures scalability, availability, efficiency, flexibility, and usability.

The cloud services (AWS, GC, Azure, etc.) are very popular and trusted by many organizations. These cloud services also offer features such as distance backup, high availability, security, load balancing, system health check, and many more as add on services.

These services have many data centers across the world and based on the proximity, the Mumbai datacenter would be good a choice if the system has to be hosted in the cloud.

Both Cloud Services (AWS, GC, Azure) and LGC offer containerization. The containerization enhances resource utilization (e.g.: low memory is enough compared to Virtualization: VMware) and security of applications (Containerization isolates all the applications running on the same server). In addition to the Containerization, the Cloud Services (AWS, GC, Azure) provide services called self-managed containerization (e.g.: EKS, ECS) and it reduces the IT workforce required to manage the containers.

However, the MTSM may take time to find the funding source or planning budget for the maintenance of the digitalized MRV system. Therefore, MTSM can take the decision of choosing the hosting options and they can also switch from one option to another during the pilot run.

2.1.10 Post Deployment Warranty and Support

This section describes the post deployment support and warranty service options available from ClimateSI. Once the MRV web portal and the accompanying web services are deployed and accepted by the owner of the software system (Ministry of Transport Services & Management), it will be put into production mode where all end users can access and use the system. Upon the acceptance of the software by MTSM, they can pilot the software for a period of 6 months. For the first year (starting from the day of completion of acceptance tests) ClimateSI will offer standard software warranty and support services as a part of this project. After the first year, if Ministry of Transport Services & Management wishes to extend the warranty and support services, mutual agreed annual payment plan can be signed between MTSM and ClimateSI.

Scope of the warranty and support offering

The standard warranty and support services covers both software system and the hosting platform. However, if the warranty and support services are not extended by the Ministry of Transport Services & Management after the first year, then the responsibility of maintaining software and

the hosting platform will not be undertaken by ClimateSI. Warranty and support service consist of technical support and trouble resolution, which are the two important aspects of the sustainability of digitalized MRV system. Table 2-6 describes their details.

Table 2-6: Categories of warranty support services

Technical Support	Trouble resolution
Providing answers and remote assistance for technical and operational queries. 8x5 Support. Response within the agreed response time	Investigation, isolation and troubleshooting of issues faced by users or fault events reported by the system. 8x5 Support. Response within the agreed response time

Source: Own work

Technical Query

Admin users of the Digitalized MRV system may create operational or technical queries about the system via email or phone to ClimateSI. ClimateSI technical support team will provide a qualified response, within the defined time frame, per the agreed priority of the query.

Users of the digitalized MRV system are required to check the reply and confirm if the case can be closed. ClimateSI technical expert will be appointed as the designated point of contact throughout the process, until a final answer is accepted. Ministry of Transport Services & Management will be kept informed regularly about the status of the query.

Trouble Resolution

In case the digitalized MRV system users identify or suspect a software defect in the digitalized MRV system, they can initiate a trouble resolution process. A trouble ticket will be opened with a defined handling priority per the severity of the incident. ClimateSI technical support expert will be assigned for investigation and troubleshooting of suspected defects.

Ministry of Transport Services & Management should provide all details- including all

necessary symptoms, information and system configurations - within the agreed time frame. Interim workaround may be provided to mitigate the impact of high priority problems, if that is possible from a technical point of view. A comprehensive statement and final corrective measure will be made available by ClimateSI within the agreed response and resolution times. The trouble ticket will be closed after the Ministry of Transport Services & Management has accepted the provided solution.

A software bug-fix patch may be provided if necessary. However, Trouble Resolution covers only the scope of initial deployment. ClimateSI can provide up to 30-man days of free services for change requests for a period of six months starting from the date at which the software was accepted by the MTSM. Any additional feature or scope additions are not covered under trouble resolution and those must be considered as change requests.

Prerequisites and service levels for Warranty and Support services.

Ministry of Transport Services & Management must make remote access available for ClimateSI technical specialists to log in to the system for troubleshooting. ClimateSI will provide the preferred contact methods for technical support services. Proposed Service Levels for Warranty and Support services are listed in the table 2-7.

Table 2-7:Prerequisites and service levels for Warranty and Support Services

Service	Category	Action	Response Time
Trouble Resolution (8x5)	Major Fault *	Initial response	< 2 hours
		Restoration	< 1 day
		Resolution Time	< 1 week
	Minor Fault **	Initial response	< 1 day
		Restoration	< 1 week
		Resolution Time	< 1 month
Technical Query (8x5)	Urgent	Initial response	< 4 hours

		Answer	< 3 days
	General	Initial response	<1 day
		Answer	< 1 week

Source: Own work

**Major fault is an issue which cause digitalized MRV system to become unusable at all, like a system crash, fault report generation or access rejection.*

*** Minor Fault refers to random issues like GUI loading speed, user specific issues etc. which will not refrain users from using the system.*

2.1.11 Summary of Validated information on digitalized transport MRV system

Annex 11 to this report includes the summary of validated information on digitalization of Transport MRV by MTSM and CCS of MEWR based on the look and feel.

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Annex 1: NDCs of the transport sector

Transport Sector NDCs of Sri Lanka -Submitted to UNFCCC as the NDCs in 2016

1. Establishment of energy efficient and environmentally sustainable transport systems by 2030.
    1. Develop Urban Transport Master Plans (UTMP) to improve the transport system in line with the Megapolis Plan that is currently being finalized, and integrated into key urban areas of the country,
    2. Introduce an Intelligent Transport System (ITS) based bus management system,
    3. Introduce a canal transport system
2. Upgrade of Fuel Quality Standards (FQS) to reduce harmful emissions that cause environmental pollution and health hazards.
    1. Introduce 95 octane petrol.
3. Reduce unproductive transport systems from current usage.
    1. Reduce unproductive vehicles by 25% in 2025 unconditionally. This could be increased by 50% with conditions.
4. Shift passengers from private to public transport modes.
    1. Introduce park & ride system,
    2. Establish bus depots next to railway station
5. Enhance the efficiency and quality of public transport modes.
    1. Electrification of the railway system from Veyangoda to Panadura,
    2. Purchase new rolling stock for Sri Lanka Railway,
    3. Rehabilitate the Kelani Valley railway line.
6. Reduction of GHG emissions in the maritime sector.
    1. Implement international laws and regulations on maritime safety & security related to climate change,
    2. Maintain international standards related to climate change in maritime transportation.
7. Gazette new emission standards to reduce GHG emissions
    1. Improve vehicle emission testing programme, and spot testing for all vehicles,

2. Introduce a heavy smoke vehicle spotter programme
3. Introduce a road side vehicle emission testing programme
4. Inspect and monitor vehicle emission testing centres

8. Encourage and introduce low emission vehicles such as electric and hybrid.
    1. Introduce electrified three - wheelers to reduce emissions,
    2. Introduce electrified boat service,
    3. Introduce electric buses,
    4. Introduce other electrified vehicles such as cars
9. Reduce traffic congestion in order to reduce GHG emission.
    1. Introduce canal transport systems
    2. Introduce Centralized Traffic Management Systems (CTMS)
    3. Establish highways
    4. Transport of heavy loads by railway
10. Reduction of GHG emissions in the aviation sector.
    1. Identify the current profile of GHG emissions from Sri Lankan operators (Sri Lankan Airline and FITS Aviation) in international operations and domestic operators
    2. Forecast the BAU future emissions from the above operators
    3. Identify GHG mitigations options
    4. Identify implementation mechanisms and resource requirements for the implementation of mitigation options
11. Establishment of a database management system for monitoring NDCs of transport sector.
    1. Establishment of a separate unit for the implementation of NDCs
    2. Software development
    3. Capacity development

Annex 2 Revised NDCs of the transport sector

Revised Transport sector NDCs in year 2019

1. Shift freight from road to rail/pipeline
    1. Promote transporting flour by rail
    2. Promote transporting petroleum products by rail9.4
    3. Promote transporting petroleum products via pipelines d) Introduce rail based Inland Container Depot (ICD) system)
2. Promote Public passenger Transport
    1. Shift passengers from private vehicles to public buses
    2. Shift passengers from private vehicles to existing rail -5.2
3. Electrification of railway system 5.1
4. Promote mass rapid transit for passenger transport
    1. Introduce Light Railway Transit system 4.1
    2. Introduce new railway line
5. Promote non-motorized transport modes
    1. Construct new bicycle lanes and bicycle parking areas
6. Introduce carbon tax based on fuel consumption (with a dedicated environment fund to implement low carbon transport projects)
7. Promote electric vehicles for specific transport purposes
    1. Provide subsidies when replacing old vehicles with electric vehicles
    2. Increase the tax rebate for electric vehicles -8.4
    3. Provide subsidies to continue using electric vehicles
8. Introduce cordon price for the vehicles entering into identified cities
9. Improve the efficiency of vehicle fleet
    1. Conduct awareness on Eco-driving (highways and interprovincial) transport, eco-driving training at initial and regular intervals)
    2. Promote Intelligent Transport System (ITS)
10. Introduce canal transport

Annex 3 Procedures for the prioritized NDCs

Annex 4 Data Management systems for the prioritized NDCs

Annex 5 Institutional arrangement for the MRV system

Annex 6 MRV Protocol

Annex 7 Software Requirement Specification

Annex 8 Data flow diagram to digitalize the MRV system

Annex 9 Work Flow diagram for QA/QC

Annex 10: Software architecture document