IRIMEE JOURNAL

ANNUAL DAY ISSUE

2023

From the ADG's Desk

Starting out in **August 2020** as a pilot, the ***IRIMEE Journal*** has been acclaimed widely. I am thus pleased to unveil the **November 2022(Fifth)** edition of ***IRIMEE Journal*** comprising several facets of latest research and technologies being implemented in Indian Railways. Indian Railways is at the helm of transformational changes through visionary leadership and technological advancements. In order to keep pace with changing times, we should be aware of the latest technological and organisational changes.

The **IRSME** has always displayed **highest standards in adopting new technologies** and delivery of exceptional performance for Indian Railways. As the **Central Training Institute, IRIMEE** also has the responsibility of collecting the best knowledge from the field level, subject it to academic review of our faculty and disburse this at the field level. It is in these contexts this journal holds immense relevance.

Being both, a teaching and learning organisation, IRIMEE has always believed in the philosophy of the sloka from Apastambh Dharamsutra-

आचार्यात् पादमादत्ते पादं शिष्यः स्वमेधया । सब्रह्मचारिभ्यः पादं पादं कालक्रमेण च ॥

(Knowledge is sourced one fourth from the teacher, one fourth from own intelligence, one fourth from classmates, and one fourth only with experience.)

Thus this journal , provides the requisite platform to faculty, trainees and officers alike, to pen down their learning through academic study and experience. It is also a platform to disseminate the original researches in Technology and best practices in Management performed at field level. Thus the Publication of the journal is an effort in disseminating the knowledge for the benefit of Indian Railways and the society at large.

This issue of the journal contains articles about **Data Analysis in Rail Madad, ACP Data Logger, Rolling Stock way Forward : Planning digital transformation based on condition monitoring technologies, Analysis of Rail Stress Calculation Methodology in IR and Estimation of Rail Stresses for Higher Axle Loads and Sewage Treatment Facility using Hybrid Model of Constructed Wetlands by Carriage Repair Shop, Tirupati.**

While all attempts have been made to accommodate original views of the authors, errors inadvertent or otherwise are regretted in advance.

We, at IRIMEE, hope that this issue shall further add to the archives of knowledge of Indian Railways, to replicate best models and inspire officers for further innovations.

P. Ravi Kumar
Director/IRIMEE

From the Editor's Desk

Indian Railways is an engineering behemoth with large pool of research and application experiences generated everyday. The exhaustive schedules of officers in day to day working, however, make a large claim on their time and resources. For improving the efficiency and performance of Indian Railways systemically, latest research in technology and best practices of management need to be disseminated. With this in view, IRIMEE has brought out the Fifth Issue of ***"IRIMEE JOURNAL."***

IRIMEE, Jamalpur , is one of the six central Training Institutes of Indian Railways and is one of the oldest institutes of this country, established in 1888 as a training school. It presently conducts training courses for in-service Mechanical & Metallurgist & Chemist Officers and supervisors for Indian Railways.

At IRIMEE, we believe that **research formalises human curiosity** and paves subtly, the path to self-actualisation. Here I am reminded of a quote by Peter Morville **"Everything new we explore, changes who we become." IRIMEE** thus vehemently promotes cutting edge applicative research in mechanical engineering **to transform the Indian Railways towards its best possible avatar**. This issue of IRIMEE journal is another step in this direction.

This issue of the journal contains articles about **Data Analysis in Rail Madad, ACP Data Logger, Rolling Stock way Forward : Planning digital transformation based on condition monitoring technologies, Analysis of Rail Stress Calculation Methodology in IR and Estimation of Rail Stresses for Higher Axle Loads and Sewage Treatment Facility using Hybrid Model of Constructed Wetlands by Carriage Repair Shop, Tirupati.**

While all attempts have been made to accommodate original views of the authors, errors inadvertent or otherwise are regretted in advance.

Hopefully, this issue will not only add to the **systemic robustness** of Indian Railways but also satiate the **inner thirst of knowledge and research** that all us officers inadvertently crave.

Silabhadra Das
Professor (Trainset)

Contents

Data Analysis in Rail Madad

Capt. Parth Adhikari (TA), IRSME

Coaching Depot Officer, Lokmanya Tilak (Terminus) Coaching

Depot

Mumbai Division, Central Railway

Abstract

The use of advanced data analytics tools can help in the monitoring and assessment of grievances received over Indian Railways (IR). Analysis of big data generated through complaints' redressal mechanisms can enable the national transporter to enhance the experience of its passengers. With continued emphasis on the reduction in consumers' grievances, it is important to visualise the available data to identify the shortfalls in service delivery. The process involved applying data analytics principles to the data of train services of LT(T) Coaching Depot. The root causes were identified along with their correlations with various factors. The results generated, and actions thereon, reduced grievances *(23% month-on-month reduction for two successive months)* and improved passenger feedback.

Introduction

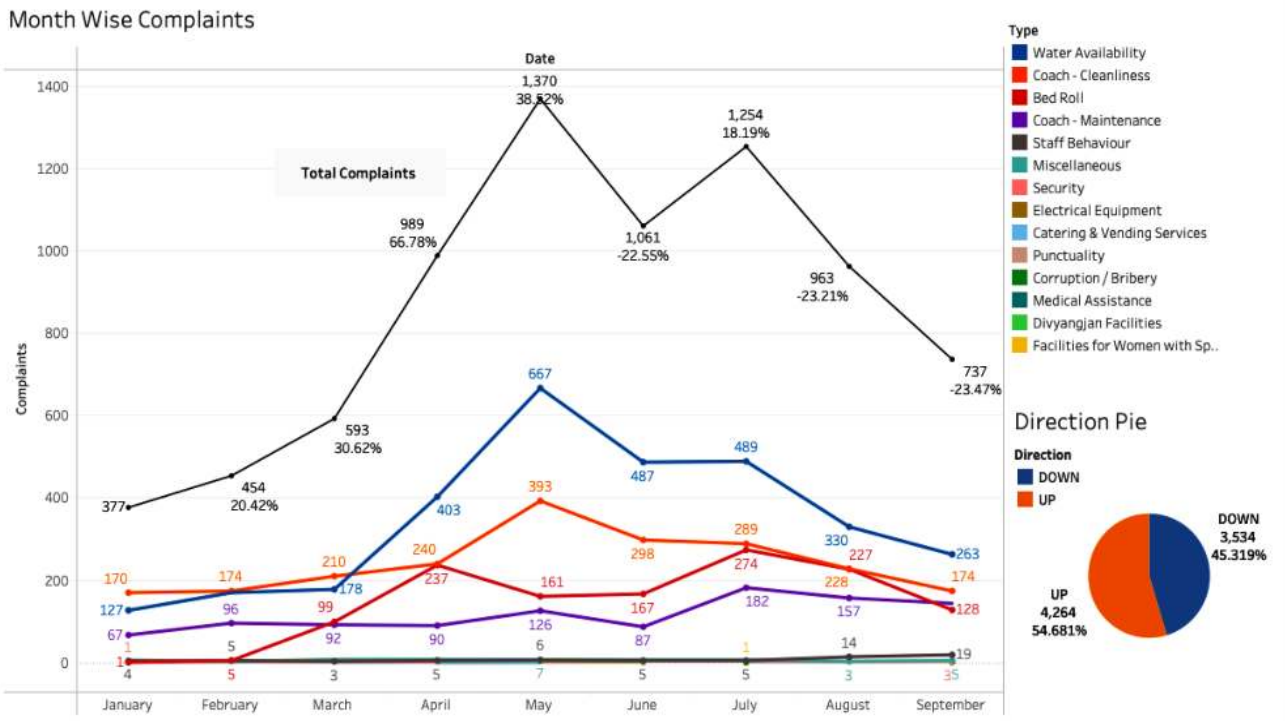
Keeping in view its organisational objective of providing safety and comfort to its users, Indian Railways (IR) is continuously striving towards the swift and satisfactory resolution of their complaints. Rail Madad (under the Transport services category in UMANG - Unified Mobile Application for New-age Governance) is an independent portal for the lodging and redressal of grievances raised by Railway consumers; it unifies complaints and suggestions from at least 8 sources and directs them to the concerned authorities over IR for rapid rectification, even allowing live-tracking of a complaint's status. The portal captures data gained from complaints and suggestions and generates reports that are exportable to MS Excel, among other forms. The grievance redressal mechanism generates a huge amount of data - in the FY 2022-23 (from 01 Apr to 31 Jul) 21 zones/areas of IR registered a total of 6,34,694 complaints, i.e. an average of 5,202 complaints per day.[2]

Data is a collection of facts that can be used to draw conclusions, make predictions, and aid decisions. Data analytics refers to the process and practice of analyzing data to answer questions, extract insights, and identify trends.[1] Application of the principles of this field for a thorough analysis of grievance-related data from Rail Madad can assist in finding the cause behind extant trends. This in turn gives insights into what is happening, which can further lead to data-driven decisions. The concomitant corrective measures, thus arrived at, possess the ability to reform service delivery over IR.

Offering a huge leap over the conventional methods of data interpretation, resources such as Tableau (covered here), Google Data Studio and R, with their capability of generating multi-dimensional visualizations, can overcome the linearity of the methods in vogue, and widen the scope of descriptive, predictive, diagnostic and prescriptive analytics.

Initially, post a 38% month-on-month rise in passenger grievances in the month of May, a five-month (from Jan to May 2022) period's data was taken up for analysis. Following this inchoate examination, efforts were made based on patterns observed and insights gained. After this rigorous exercise that stretched from June-July to September 2022, a nine-month (01 Jan to 30 Sept 2022 - 273 days) period's data of complaints arising

in primary-maintenance trains of Lokmanya Tilak (Terminus) coaching depot was analysed to detect and quantify the effects of the work done. *A total of 7798 complaints ranging over more than 10 types and 20 sub-types, and arising in 96 trains (49 train pairs - up and down directions) of the depot were studied:*



LT(T) coaching depot provides Onboard Housekeeping Services (OBHS) on all its primary maintenance trains. In addition, it also provides linen services, which were progressively resumed starting from April 2022.

Table 1 below illustrates the various parameters of Lokmanya Tilak Terminus Coaching Depot, Mumbai Division, Central Railway:

Table 1 (data as on date of submission)

S. No.	Dimension	Measure	
1	Coach Holding	LHB -	967
		ICF -	158
		Total - 1125	
2	Total Primary Train Services	33	
3	Average Daily Primary Trains Services	14	
4	Primary Maintenance Rakes	LHB -	41
		ICF -	6
		Total - 47	

The Process of Data Analysis

The process of data analysis [3] can be summed up as follows:

1. Ask The Right Questions - Business Challenge/Objective/Question
2. Data Collection - Data generation, collection, storage, and data management
3. Data Cleaning - Process the data and check its integrity
4. Analysing The Data - Data exploration, visualisation, and analysis
5. Interpreting The Results - Communicating and interpreting results

Some literature also adds the meaningful sixth step of 'Action' to the above process to direct the end-user to utilise the newfound insights to make decisions and solve the problem on hand.

'Analysing the data', the fourth and the most crucial step of the above series, calls for the transformation of the available raw data using graphics that aid the analyst in exploring and then communicating true patterns that become apparent as the data in hand is analysed. This transformation requires data visualisation tools, such as Power BI, Tableau, Google Charts et al. The exercise of data analysis illustrated with various plots in the following sections has adhered to the above-mentioned step-by-step approach

Follow the Process

At the outset, the issue at hand was to investigate the problem areas in order to identify the root cause of passenger complaints pertaining to Carriage and Wagon deportment arising in train services of Lokmanya Tilak (Terminus) Coaching Depot, Mumbai Division, Central Railway. The process was followed in the given manner:

1. *Ask The Right Questions* -

   1.1. Defining the problem statement was the foremost priority. The following was used as a start - To identify the cause of passenger grievances in train services of LT(T) Coaching Depot, and to examine passenger feedback.

   1.2. It was also essential to recognize what was required after the analysis afforded insights. So, the following was acknowledged as the logical conclusion of the exercise - To amend the status quo and make efforts to reduce the number of grievances, while increasing the quality of passenger satisfaction.

   1.3. Where would the data be collected from, and how would it be analyzed? - The data already generated on Rail Madad, as well as Mumbai division's in-house CMMS application needed to be exported from the

reports modules. Google Sheets (GS) and Tableau were selected for holding the exported database and analysis, respectively.

2. *Data Collection* -

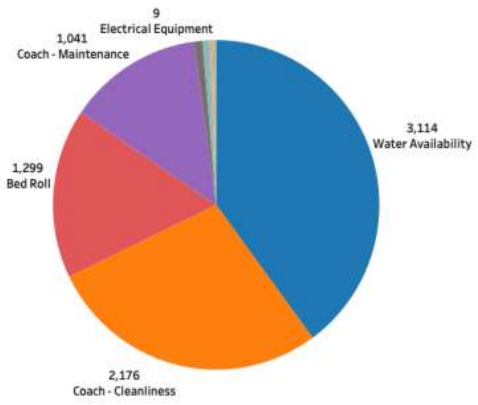
2.1. Data of complaints from 01 Jan 2022 to 30 Sept 2022 was stored in a GS spreadsheet.

2.2. Additional Data - Supplementary metrics, such as en-route carriage watering stations and their coordinates, rake maintenance engineers, OBHS staff, deficient amenities etc were compiled and collated with the exported data. Routes of all the trains were also collected along with coach numbers and transportation codes.

3. *Data Cleaning* -

3.1. Cleaning - The insignificant data points were removed from the spreadsheet. The data's integrity was checked with sample testing. Visible outliers (such as one-off complaints) were identified and excluded.

3.2. Modification - Additional metrics mentioned at 2.2 were joined with the existing data to add depth as well as explore correlations.



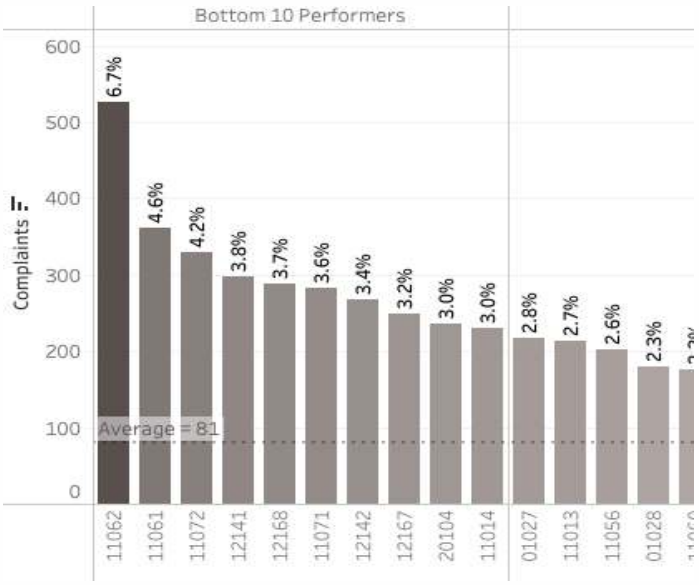
4. *Analysing The Data* - Data exploration, visualisation, and analysis

4.1. Sheets were created with multiple parameters across the X (row) and Y (column) axes. With tableau it was possible to add more dimensions inside the XY plots by varying colours and sizes of the bars/lines in order to gain wholesome insights from the same plots.

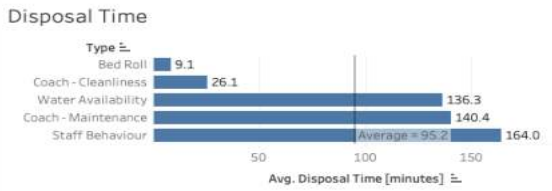
5. Dashboards were created by juxtaposing different dimensions and measures to observe their impact on each other. Filters were used to observe the performance of selected dimensions, such as trains, en route stations, divisions and zones. *Interpreting The Results* - The dashboards created helped in the easy identification of trains and staff's performance. The results generated were shared with the concerned authorities as well as the staff. Maintenance engineers and OBHS staff and counselled regarding areas of concern and advised to be more vigilant when scenarios similar to the patterns observed arose.

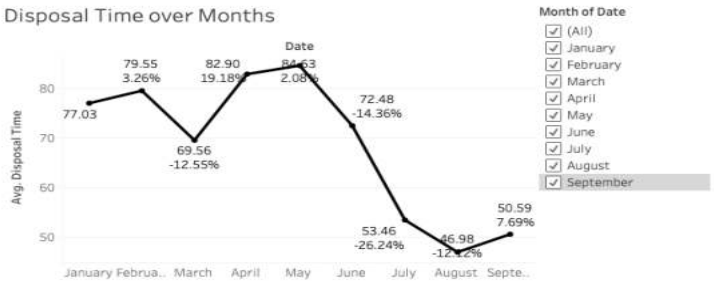
An Exercise in Pattern-Recognition

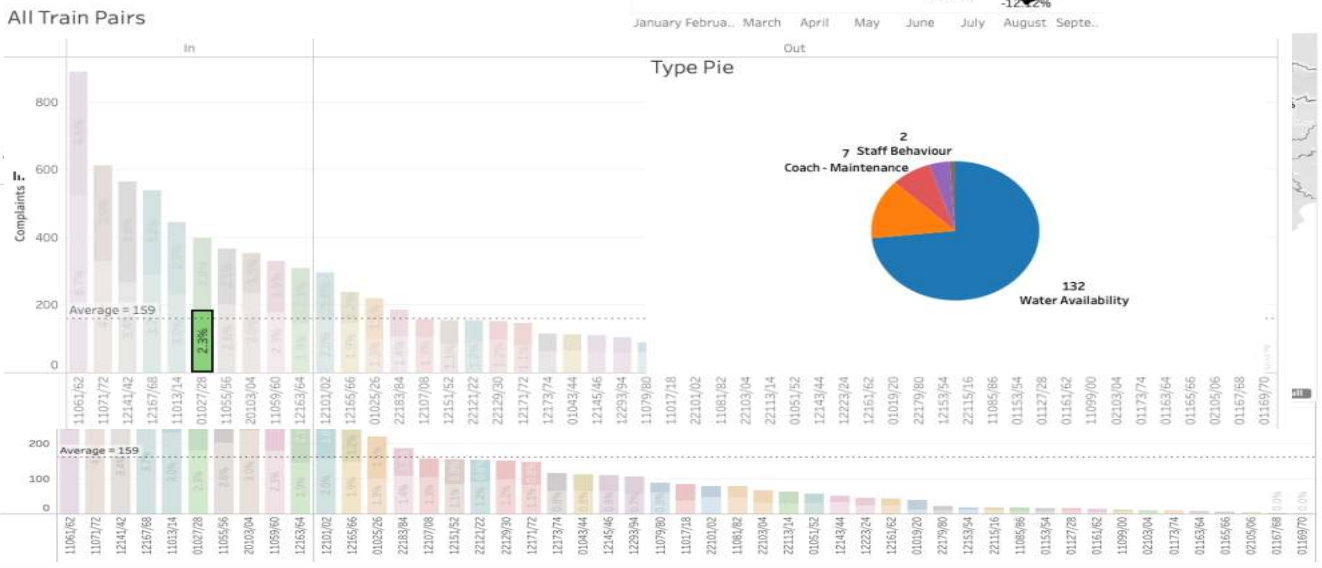
On analysing the organised and visualised data, the following observations were made -



1. Bottom Performers - Data from trains that regularly featured as bottom performers, not just in the division but also in the zone, was specifically analysed. Complaint type-wise bottom performers were also found out. *It was observed that 18 train pairs (37% of the total train pairs) caused 80% of the total complaints and that 10 trains pairs (20.4% of the total train pairs) caused 60% of the*

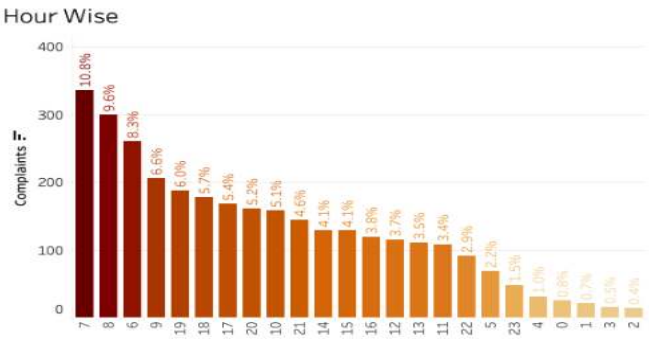






total complaints. This insight helped in focussing on trains/train pairs which had the lion's share of the grievances.

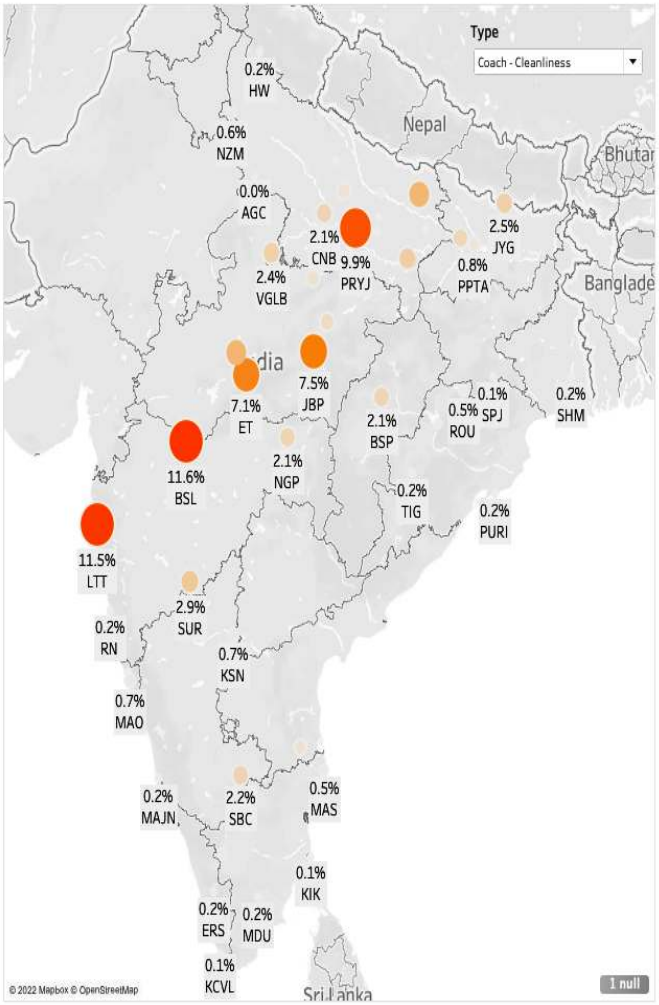
2. Timings - The available data of the registration date was analysed for the most complaint-prone timings. It was observed that some shifts/ periods saw more complaints than others. For example, *roughly 35.1% of water-availability complaints were caused in the 4 one-hour-time slots (16.6% of the day) from 6 am to 10 am (which includes 3 OBHS working hours from 6 am to 9 am and 1 OBHS non-working hour from 9 am to 10 am).* In Bedroll complaints, *roughly 26% of the total complaints were caused in the 3 one-hour-time slots (12.5% of the day) from 8 pm to 11 pm (which includes 1 OBHS working hour from 8 pm to 9 pm and 2 OBHS non-working hour from 9 pm to 11 pm).* Even though somewhat intuitive, these verified extant beliefs and helped in consolidating vigilance in the onboard staff during such 'complaint peak-hours.'



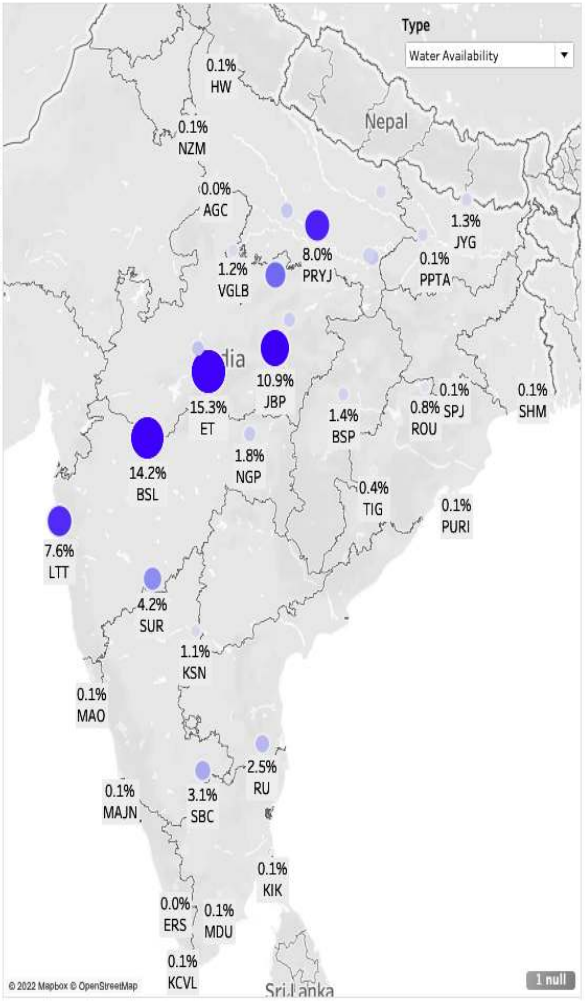
3. Water-availability problems - Particular stations appeared prominently under water-availability complaints. The route kilometres, arrival timings and hours elapsed between the adjacent stations were seen to be relevant to complaints. Long sections and partial watering, compounded with the rising average temperature in the areas to which a large number of long-distance trains catered were major factors at play.

4. Connect between coach cleanliness and water availability - A clear correlation between water availability and coach cleanliness complaints was established. This was arrived at upon juxtaposing the geographical maps of the stations which featured as 'previous stations' under coach cleanliness complaints and those which featured under the water availability complaints' head. The percentage complaints of the respective stations were commensurate. The trend of the two heads was also analysed. The slopes of the month-on-

Coach Cleanliness Station Mapping

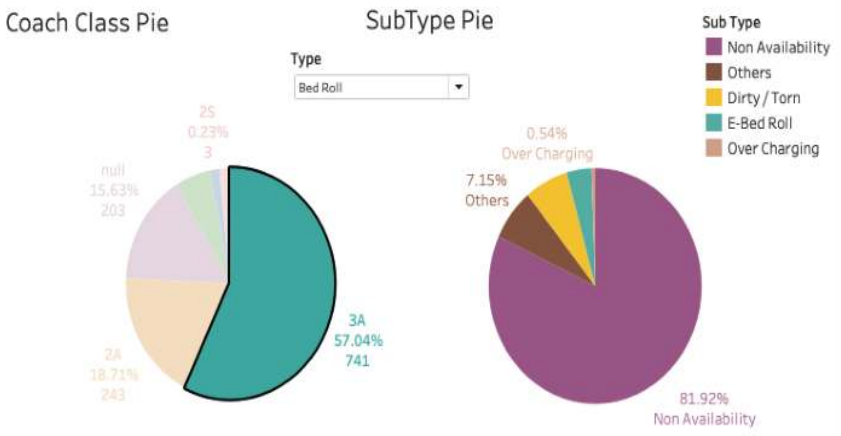


Water Availability Station Mapping

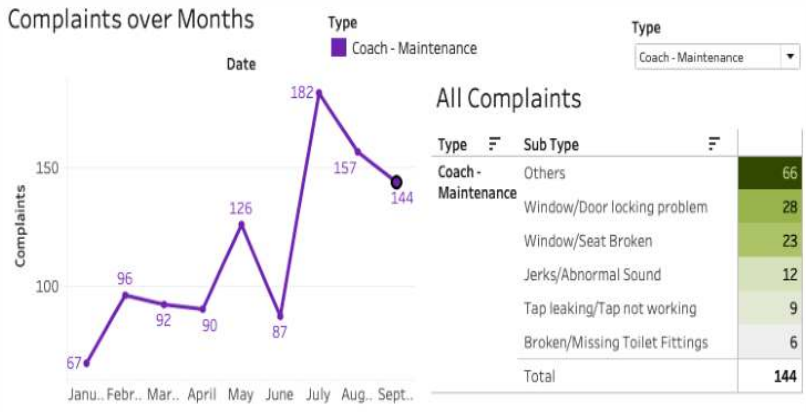


month trend lines were very similar for the two heads. Furthermore, the percentage share of each head between themselves remained constant when other heads were excluded from the calculations.

5. Linen Complaints - Linen-related complaints were compared against their timings and the coach class. *57% of complaints arose from 3-tier AC coaches, and even in these complaints, only 6.6% were related to the dissatisfaction of pax with the supplied linen.* Majorly, the complaints were due to the unavailability of linen in the respective train services.



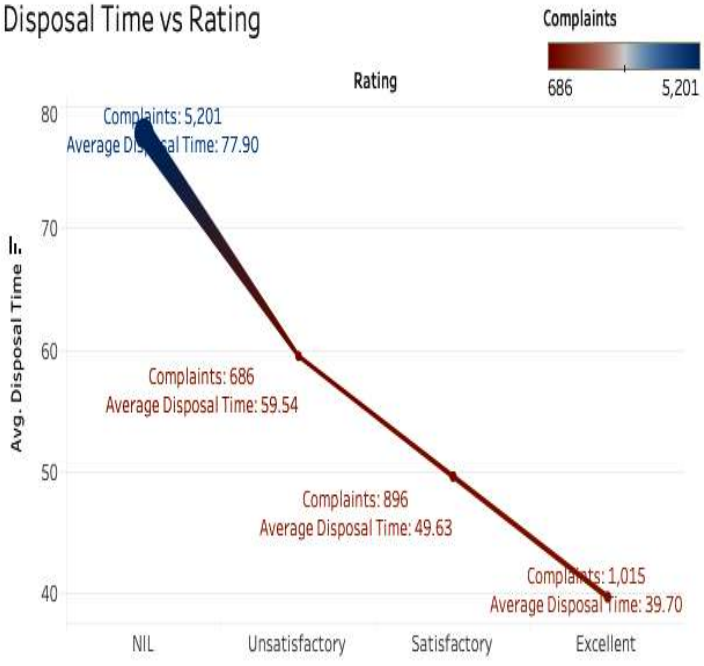
6. Coach Maintenance Complaints - These constituted *13.35% of the total complaints. 47.27% of maintenance-related complaints arose from AC coaches. 33% of all maintenance related complaints fell into the 'Others'* category, which included cases caused due to water ingress inside coaches.



7. Channels Used and Feedback Given by Passengers - Class-wise, Channel-wise and Average Disposal Time-wise analysis was conducted for feedback ratings. *It was seen that Helpline 139 was the most popular among pax (62.91% of all complaints were lodged on 139), but 69.5% of these complaints did not receive any feedback.* It was observed that in all channels, there was a relation between the complaint's disposal time and the rating received (*on average, lesser the disposal time, higher the rating)*. The relationship was particularly visible in coach cleanliness complaints.

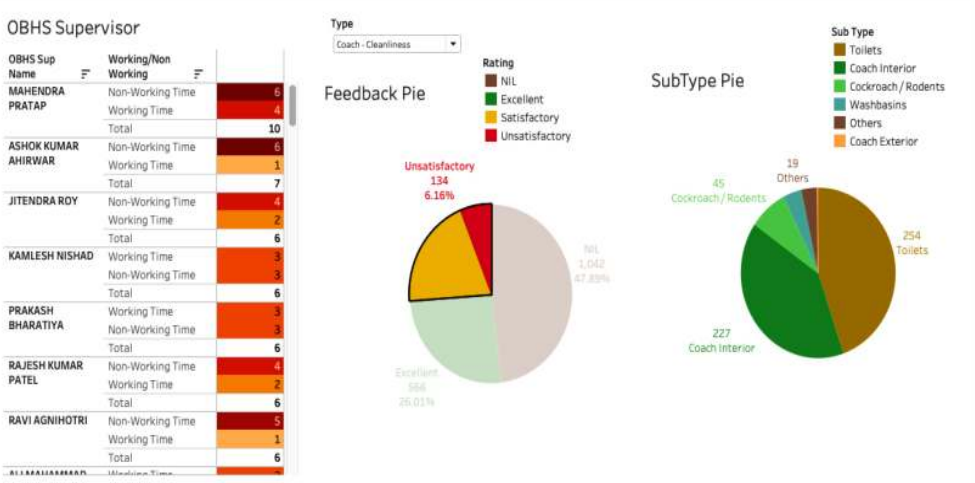
Channel and Rating

	Rating				
Channel	NIL	Excellent	Satisfactory	Unsatisfact..	Grand Total
Helpline 139	65.56%	60.59%	59.71%	50.44%	62.91%
Social Media	17.50%	16.95%	14.84%	18.51%	17.21%
Web	12.13%	17.14%	18.97%	24.34%	14.65%
App	2.52%	3.05%	2.79%	3.50%	2.71%
SMS	2.12%	2.27%	3.46%	2.92%	2.36%
Umang	0.06%		0.22%	0.15%	0.08%
CPGRAMS	0.06%			0.15%	0.05%
Dak	0.06%				0.04%
Grand Total	100.00%	100.00%	100.00%	100.00%	100.00%



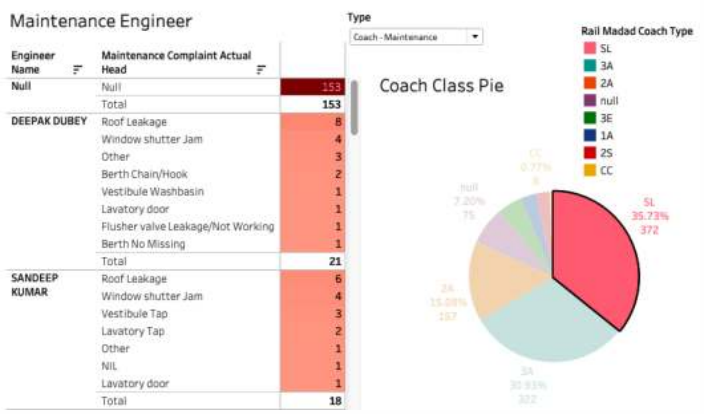
Measures Adopted

1. Bottom Performers - Special attention was given to trains and OBHS supervisors with consistently high complaints.



2. Water-availability and Coach-cleanliness problems - In addition to ensuring complete watering before trains' dispatch from the depot, emphasis was also laid on watering at en-route stations. OBHS staff was counselled to communicate the lack of water so that prior intimation could be given to the next nominated station, and also to adhere to the laid-down cleaning schedules.

3. Linen Complaints - Linen services were progressively resumed, affording priority to trains which had a higher number of complaints. Coach attendants were counselled to be extra vigilant to passenger requirements during the timings with frequent complaints.



4. Coach Maintenance - Defaulting maintenance engineers were counselled. Repeatedly featuring coaches were given special emphasis during pitline examination. A depot-level drive was also launched in tandem with the amenities' drive launched at zonal and divisional levels. Deficiencies noticed were made good.

5. Channels Used and Feedback Given by Passengers - Control office staff were counselled to address grievances effectively and expeditiously. OBHS staff was also up-skilled in the practice of interaction with passengers.

Conclusions

Data is indeed a powerful tool. The data collated enabled the understanding of the quantum and nature of complaints, along with their trends. Some observations made were quite intuitive. The analysis which helped establish such cases cleared the way from the implicit to the explicit.

Other observations, made after a comparison of multiple parameters of the available data helped in first noticing patterns, then in answering the why's of the present situation, and further in developing a corrective action for the future.

Analysis of the data from Rail Madad, fulfilled with the requisite additional metrics, can enable Railway authorities to gain insight into the trend of grievances. Implementing more stringent and well-directed measures, based on the Pareto principle etc can allow concerned departments to reduce complaints, and thus increase customer satisfaction.

Considering the high-velocity nature of the data that is generated - complaints come in round the clock each day - a live analysis of a set framework or structure can be extremely useful as it allows the user to transcend from the periodical monitoring of data to its periodical and minutest analysis. Also, time saved from the conventional linear identification of performance of different factors can be utilised for a better comprehension of the root cause of trends and the bearing various practices and circumstances have on all the dimensions of data and delivery in the field.

Even though this article has restricted its scope to the analysis of grievances received on Rail Madad, the tools and the process herein can be put to use in other areas of data analysis. Meaningful insights can also be derived from data generated over applications such as FOIS, and ICMS to effect a more punctual service schedule, as well as over portals such as ROAMS, and infrastructure such as OMRS and WILD, to put into operation more reliable and efficient rolling stock.

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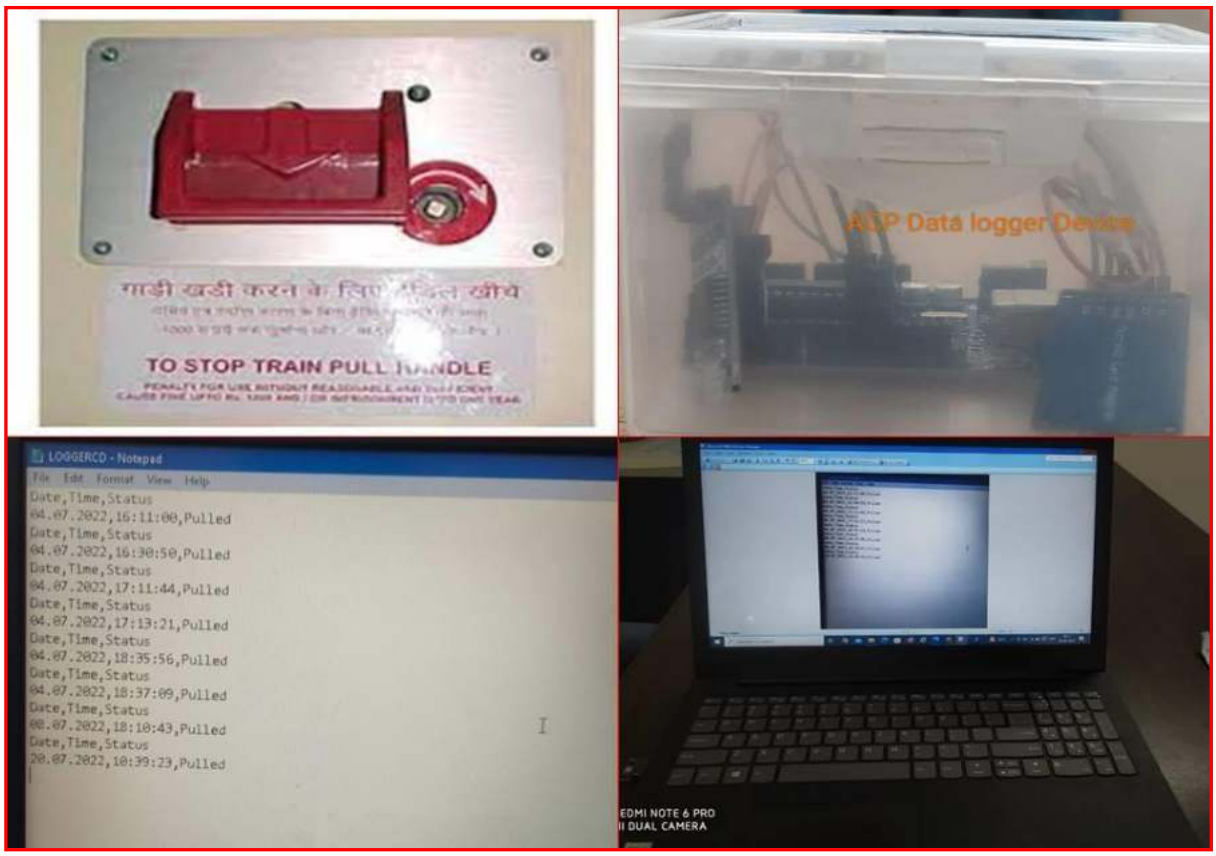
ACP Data Logger

Developed by-

Coaching Depot/Gorakhpur

North Eastern Railway, LJN Division



Abstract

ACP data logger has been designed to act as a watchdog to detect any cases of Alarm Chain Pulled en-route. It is a combination of micro-processor, realtime clock module, micro-SD card adapter with memory and programming. This device has been developed with in-house efforts except the help taken from IIT Patna for the programming part.

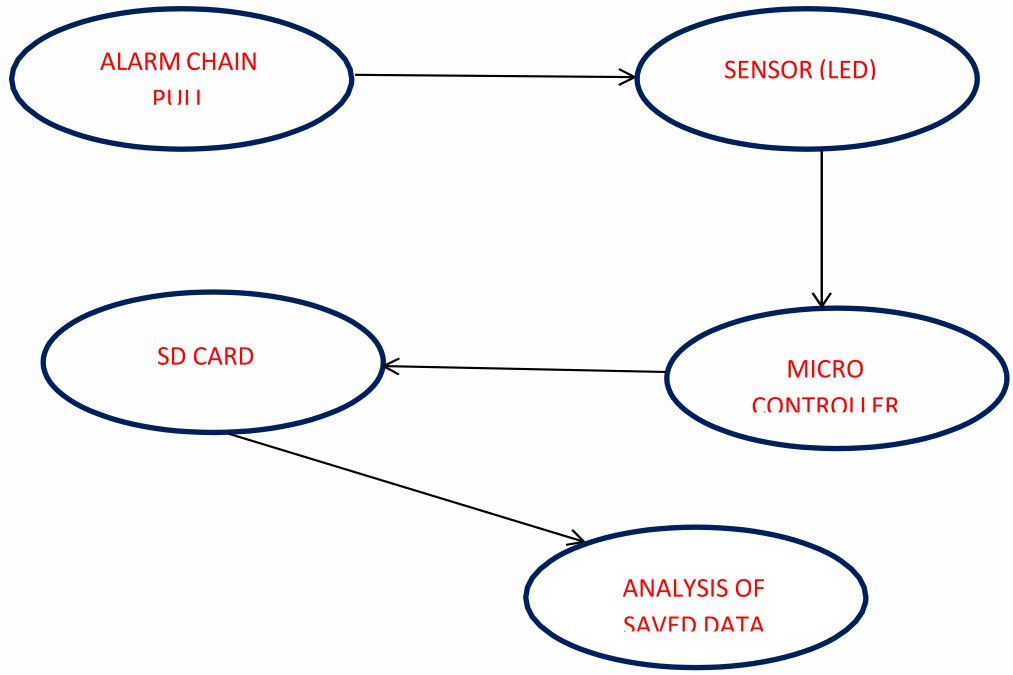
Problem Statement

In various cases it has been seen that complaints has been raised on account of brake binding reported by train manager and LP. After proper investigation it has been found that the case of brake binding is false and the pressure drop was due to ACP by any miscreant but the case has been lodged on account of C&W. If the brakes are not released properly by LP after ACP, there are chances of brake binding.

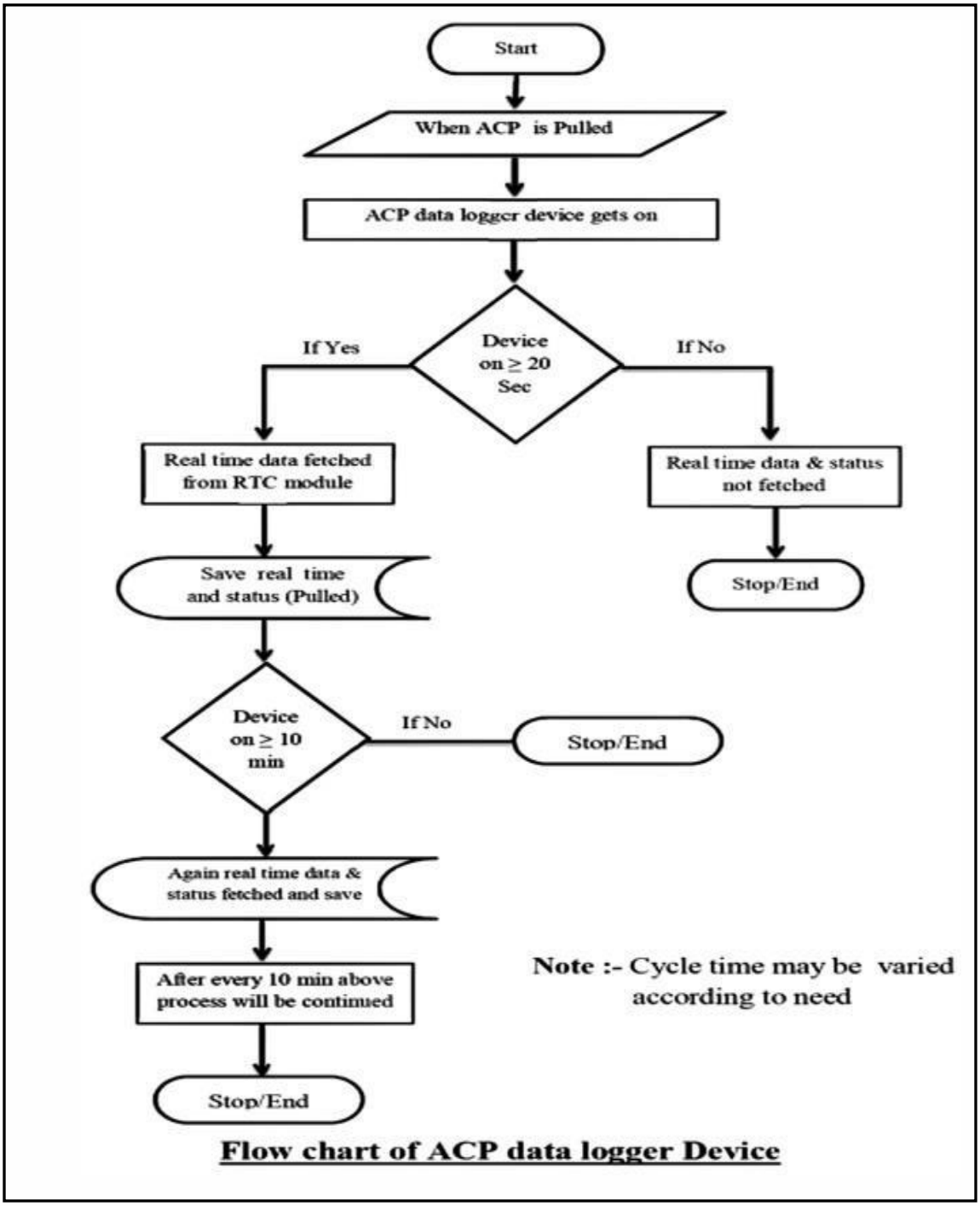
GKP depot has been facing lots of such false brake binding reports and when the rake is checked at pit, nothing has been found abnormal. To overcome this problem GKP depot has developed a device to detect ACP incidents en-route.

Methodology

This device is a combination of Microprocessor (arduino), Real time clock module (RTC) and micro SD card along with adapter. The device has been programmed in python language and programme is compiled in arduino IDE software. This is based on automation by integrating the micro controller (Arduino) with actuation of ACP. When micro controller gets on then after 20 second real time, data is saved in SD Card with help of RTC (Real Time Clock) module. Saved data can be obtained with the help of SD Card Adapter and Laptop/Desktop.



Flow Chart of Devices



Flow chart of ACP data logger Device

Results

1) It facilitates the detection of Alarm Chain pulled en-route with exact date and time of operation of ACP.
2) It helps in eliminating the false cases of brake binding which are otherwise loggedon C&W account.
3) It would also help in arresting the cases of unnecessary alarm chain pulling which leads to punctuality loss en-route as this device will keep a track of operation of Alarm Chains.
4) RPF may use this device to enquire about such cases and catch up the guilty which will sensitize the passengers to use alarm chains only when it is absolutely necessary.

Conclusion

This device is very economical and maintenance free costing only Rs. 1700/Per Coach so it is feasible to fit in every coach. (Rs 38000/Per Rake). This facilitates the ease of operation and maintenance of this device which can bring a revolutionary change in the field of inclusion of automation to ensure safe and punctual operation of Indian Railways.

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Rolling Stock way forward: planning digital transformation based on condition monitoring technologies (Enterprise Architecture approach)

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Abstract

This paper discusses a way to holistically plan major transformational efforts or projects at an organization level. It takes an example of digital transformation using Industry4.0/ condition monitoring technologies in Rolling Stock management in Indian Railways. The approach used is based on Enterprise Architecture: Architecture Development Method, which covers various aspects like Business, Data/Application, Technology and Implementation. The Open Group framework, one of the leading EA frameworks, has been referred.

Keywords: Digital Transformation, Rolling Stock Management, Condition monitoring, OMRS, Enterprise Architecture, Strategic planning, Architecture Development Method

1. Introduction

Today, Information technology has presence in almost all domains of Rolling Stock Management. Various applications are supporting the production management at production units; CMM & FMM are actively supporting the maintenance of Rolling Stock in field units; WISE is supporting the maintenance at a large number of workshops in the country. Similarly, portals for RSP and M&P are helping in planning of Rolling Stock and Machinery and Plant respectively. Apart from these core applications involved in the Rolling Stock, there are a number of applications under different verticals which are involved with Rolling Stock management in one way or the other; for example, RailMadad for passenger complaints and feedback, Integrated Coaching Management System (ICMS) and Freight Operations Information System (FOIS) regarding operation of coaching and freight trains, Crew Management System (CMS), Control Office Application (COA), etc.

The way forward for Rolling Stock management lies in the consumption of the large amount of data being produced post-digitization and further adoption of Industry 4.0, AI & ML and related technologies. This will drive a new wave of digital transformation. We need to support it with right strategy, plans and resources to get the best results.

In this paper, planning for IoT-based condition monitoring technologies is discussed in brief.

These technologies are intertwined with the digital ecosystem. The success of these technologies greatly depends upon how well prepared the organization is, in terms of Information and communication technology.

Preparation for induction of new technologies should cover four aspects i.e., business, data/application, technology & implementation. In technical terms, this may be seen as Business, Data/Application, Technology and Solution Architecture (Enterprise Architecture approach)

2. Phases involved in planning

2.1 Develop a vision

Architecture vision should have a problem description, summary views and key high-level stakeholder requirements.

A broad vision may be to adopt condition monitoring to reduce the maintenance time and resources, improve quality and reliability, and overall cost-reduction in maintenance and operation of the Rolling Stock.

Some questions that should be asked at this stage:

1. What are the expected benefits and the scope of the project? How to quantify the benefits and the KPIs?

Expected benefits can be reduced number of hot axle cases due to early prediction of bearing failures, reduced maintenance of wheel/track due to early detection of wheel flats. Economic costs of hot axles/wheel flats may be ascertained and expected reduction in such cases will determine the benefits associated with this technology. It should be tried to quantify it as much as possible, however, the detailed exercise may be done in the business architecture stage.

2. What is the cost of the technology? It should also include the additional expenditure that would be required to operationalize the particular technology. This needs to be done for a number of options available and a comprehensive cost-benefit analysis should be done for each option.

For example, one way can be using way-side technologies and other can be on-board technologies. Depending upon the desired use, one can be better than the other and accordingly, the decision should be taken.

3. Who will be the stakeholders involved and how will they be benefitted? Stakeholders can be the at different levels, primary being the operational control office and the maintenance units.

Protocols must be laid regarding how each stakeholder will be involved. Who will be in planning role, operational role, etc. will be needed to be identified. Zonal/Divisional controllers and the maintenance units may be in the operational roles, who will be taking day-to-day decision on the basis of information through condition monitoring devices. While the planning roles, would be establishing the protocols, laying policies, monitoring the overall performance, planning expansion, identifying other use-cases, etc.

4. What kind of data/information will be provided? And do we have the capability to process and consume the same? What additional inputs might be required in terms of data/IT on our part to make best use of the technology?

For example, having master data of the rolling stock can be very helpful in integrating the technology application with other internal applications.
The data corresponding to the desired business information should be identified at this level itself, although in a broad way. For example, if we need information on bearing health, the data element

could be the graded alert (high, medium, low) on the basis of unusual peak/amplitude on the vibration/acoustic spectrum. Here, one would be required to know if we need alerts, of what kind and under what conditions and what would they mean and how one will be supposed to act on them.

5. Which applications will be affected/involved with the given technology?

For example, maintenance and operations applications may be integrated with the technology-applications so that the stakeholders may be informed about the alerts who may then proceed as per the established protocols.

6. How will the technology be implemented? What will be the scale of it? Who all will be involved? And is there a broad timeline for the implementation?

Some of the deliverable at the vision stage include: Statement of Work

The output of this phase may include some or all of the following:

i) Stakeholder map matrix

Identify the stakeholders like Railway Board, RDSO, Zonal Railways, Research Institutions, Divisional Units, Executing Agency (or vendor), divisional controller, zonal controller, rolling stock maintenance units, etc and scope their requirements.

ii) Business Capability Map

This gives an idea about the association between the business capabilities and processes with the business goals. It helps in identifying the capability augmentation needed to achieve a goal.
If the capabilities of Rolling Stock Management in Indian Railways are identified as given below

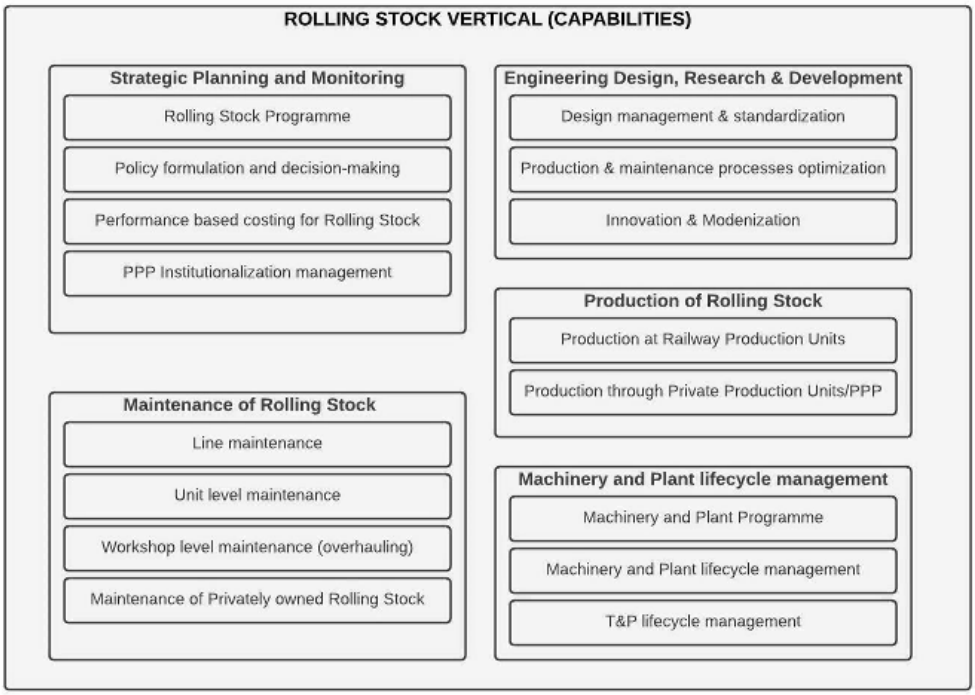


Figure 1 Rolling Stock management capabilities

The planning for condition monitoring would involve four main capability increments:

Strategic Planning and Monitoring – for overall business strategy, procurement decisions, policy making and contract management

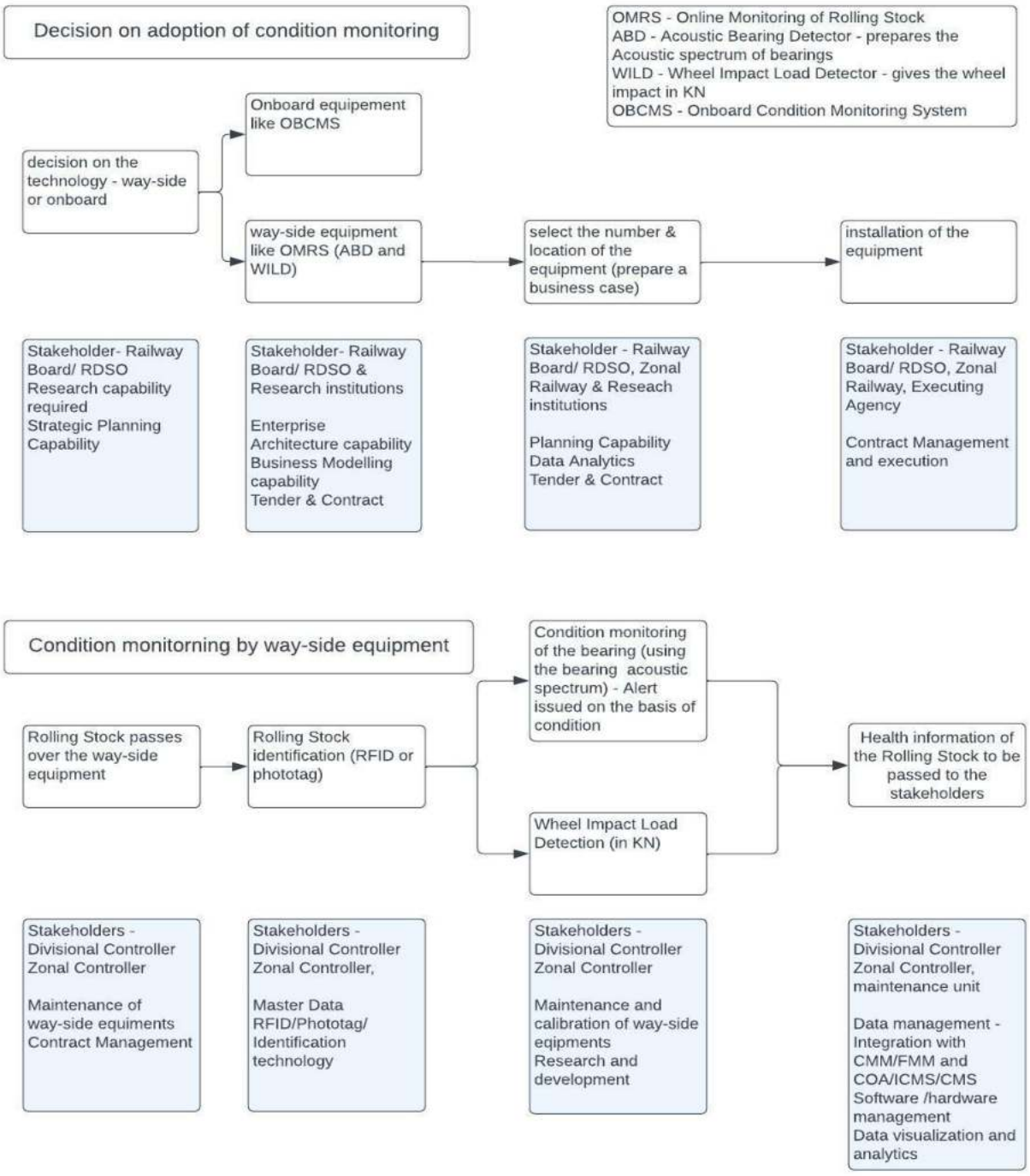
Engineering Design, Research & Development

Maintenance of Rolling Stock – maintenance will undergo a sea change with the introduction of condition monitoring

M&P management – for maintenance and management of way-side equipment

6. Value stream map

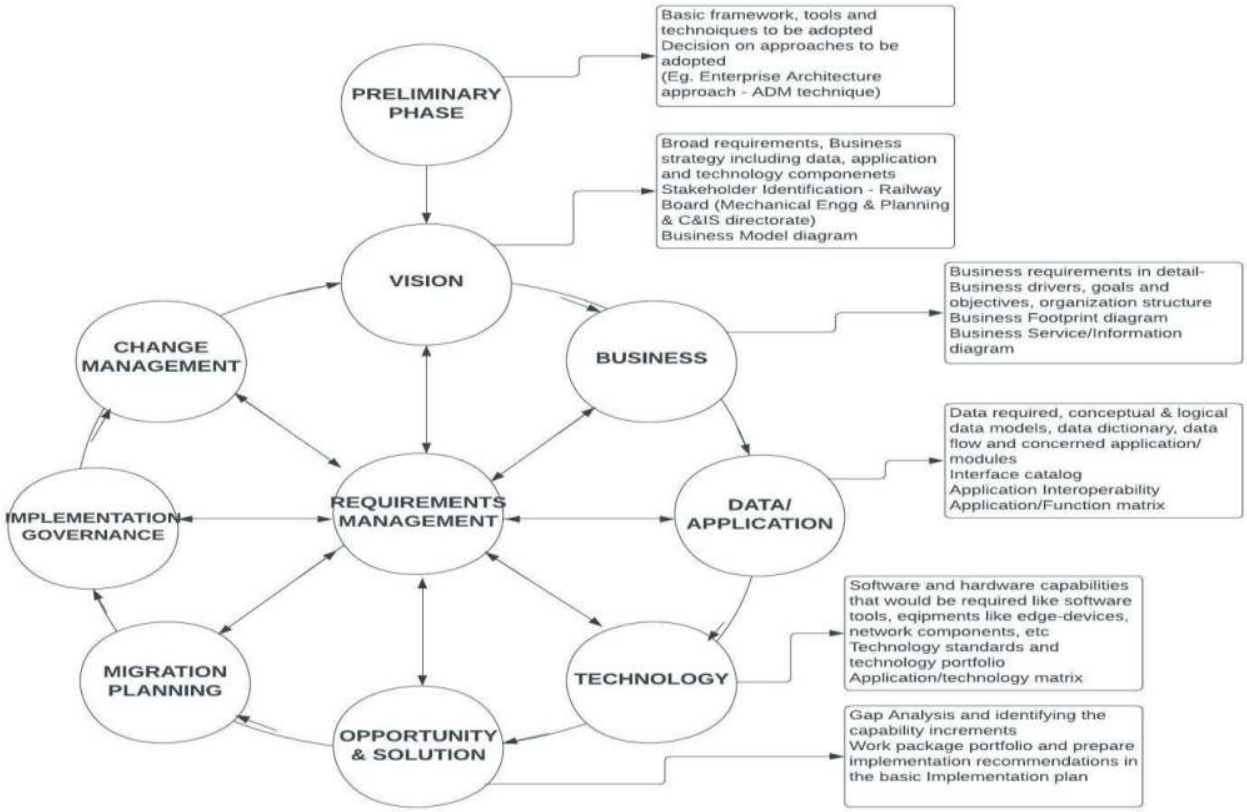
These give the idea of the business value and associated business capabilities. Some basic value streams related with condition monitoring of Rolling Stock are shown as illustration:



Similarly, more detailed value stream diagrams may be prepared. These help in identifying the processes that deliver the business value along with the associated capabilities with each process.

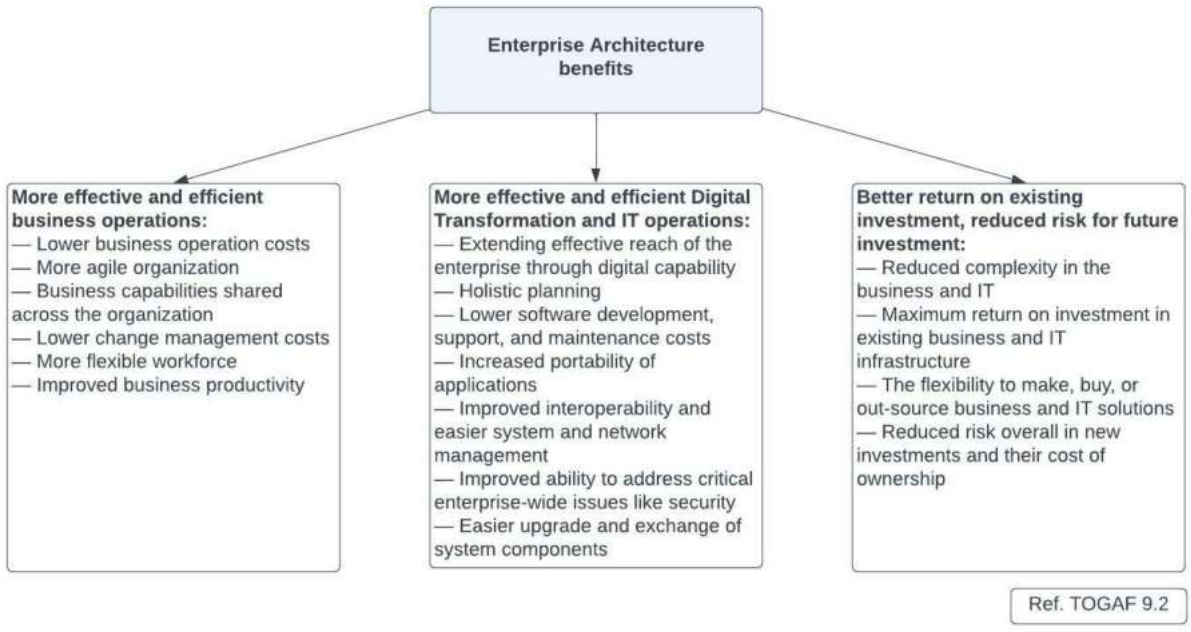
Vision phase is one of the most important phases during which the direction of the planning is established. Whatever is done in this phase is further developed in the next phases like business planning/architecture, data and application architecture, technology architecture, solution architecture and implementation planning

2.2 Deliverables of other phases: Business, data/application & technology (ADM cycle)



3. Benefits of this approach

This approach enables planning with due consideration to all components important for a particular work. This helps in sound planning as well as smoother implementation.



Planning of the digital transformation using condition monitoring can be beneficial in many ways.

Methodological approach – ADM cycle involves all components like business, data/application, technology and implementation	Ensures that no key component is missed. Like digital transformation planning should not miss the data and application component. E.g., what data should be generated, how should it be interpreted, who should be the owner of the data, how should the data be relayed, etc. Similarly, the application component would involve planning the integrations and upgradation to the existing applications and any new applications, if required The technology component would include the software and hardware support including the data centers, network, edge-devices, etc.
Identify the weak areas/gaps which need to be worked on for better results	Any transformation effort requires business support across a number of business capabilities. It is crucial to identify how a particular effort is impacting the existing business and what increments are needed to support it. Digital transformation requires integration with the strategic planning capability for policy and decision making. Condition monitoring being a technical field would require commensurate R&D capabilities- some centers of excellence should be established. Policy support in terms of the protocols for various stakeholders for handling alerts and data from condition monitoring should be established. Similarly, the impact of condition monitoring on the maintenance requirements should also be studied. This may require augmentation of planning, R&D, data analytics and operations capabilities.
Ease of implementation	Enterprise Architecture approach helps in a holistic planning with focus on complexity reduction, coordination and implementation. Proper planning, stakeholder engagement and focus on business value enables better implementation.

Enterprise Architecture is an established discipline which involves universal concepts and proven best practices adopted by the leading organizations across the world. It enables one to achieve the right balance between business transformation and continuous operational efficiency.

It will not just help in taking digital transformation in Rolling Stock on an entirely new scale but will also transform the way we plan and implement.

For more information on Enterprise Architecture/TOGAF:

1. Government of India: Enterprise Architecture (IndEA)

https://www.meity.gov.in/india-enterpise-architecture-indea

2. The Open Group TOGAF standard for Enterprise Architecture

https://pubs.opengroup.org/architecture/togaf9-doc/arch/

https://www.opengroup.org/about-us

3. Indian Railways Enterprise Architecture Project – 'VISTAR' Visionary Integrated and Sustainable enTerprise Architecture for Railways

https://www.youtube.com/watch?v=mv_pKN0o4HU&ab_channel=WSO2

Sewage Treatment Facility using Hybrid Model of Constructed Wetlands by Carriage Repair Shop, Tirupati

Developed by-

Silabhadra Das

Professor (Train Set)

IRIMEE

1. Synopsis

Wastewater treatment, also called sewage treatment, the removal of impurities from wastewater, or sewage, before it reaches aquifers or natural bodies of water such as rivers, lakes, estuaries, and oceans. Wastewater is treated in 3 phases: primary (solid removal), secondary (bacterial decomposition), and tertiary (extra filtration).

- *Primary treatment* is the first phase of sewage treatment: wastewater is placed in a holding tank and solids settle to the bottom where they are collected and lighter substances like fats and oils are scraped off the top.
- *Secondary treatment* is where waste is broken down by aerobic bacteria incorporated into the wastewater treatment system.
- *Tertiary treatment* is designed to filter out nutrients and waste particles that might damage sensitive ecosystems; wastewater is passed through additional filtering lagoons or tanks to remove extra nutrients.

At present, India is facing the worst water shortage in its history. According to a report by Niti Aayog, around 200,000 lives of Indians are lost every year owing to the contamination of water or inadequate water supply. Here comes, the need for safeguarding of water resources in our country. To reduce the contamination of water resources, wastewater treatment will play a predominant role. Sewage treatment processes can be low tech, extensive and nature-based processes or may be High tech, intensive and mechanized processes. The choice of type of sewage treatment may depend on factors such as cost, capacity, quality of treated water, space constraints etc.

2. Existing Practice of Sewage Treatment at Workshops

Railway Workshops generate a considerable amount of sewage coming from the staff toilets, administrative buildings, Training centers, bio tank cleaning facilities and Colony. Treatment of this sewage before discharge is necessary in order to confirm to the State Pollution Control Board Regulations. Sewage is treated by Sewage treatment Plants which can be of various types such as Activated Sludge Process (ASP), Extended Aeration, Moving Bed Biofilm Reactor (MBBR), Sequential Batch Reactor (SBR), Vermi-filtration technology, Johkasou process, Constructed wetlands etc. [1]. Workshops and Railway units across Indian railways have employed various types of sewage treatment plants of varying capacities. For the purpose of this white paper, Sewage treatment method of 3 Workshops/Railway unit were considered.

1. Moving Bed Biofilm Reactor (MBBR) based Sewage Treatment Plant at CRWS/Bhopal
2. Johkasou Process based Sewage Treatment Plant at Mumbai Central Station
3. Constructed Wetland/ Phyto- remediation sewage treatment plant at CRS Tirupati

2.1 Moving Bed Biofilm Reactor (MBBR) STP

It is the most common type of STP utilized for wastewater treatment. The treatment process is aimed to bring the effluent quality, so that the treated sewage water can be reused for non-portable uses such as Gardening/Horticulture or disposal to public drain/natural sources. Treatment of the effluent is proposed to be performed by aerobic biological process. The flow of effluent in the MBBR STP is depicted below-

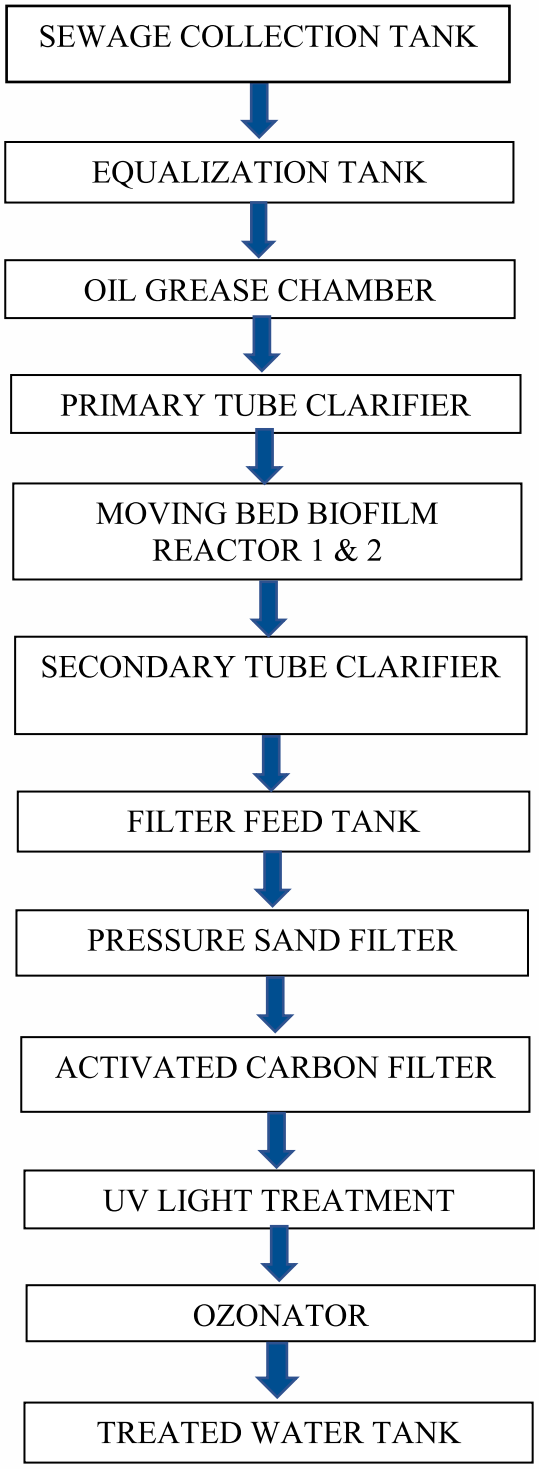
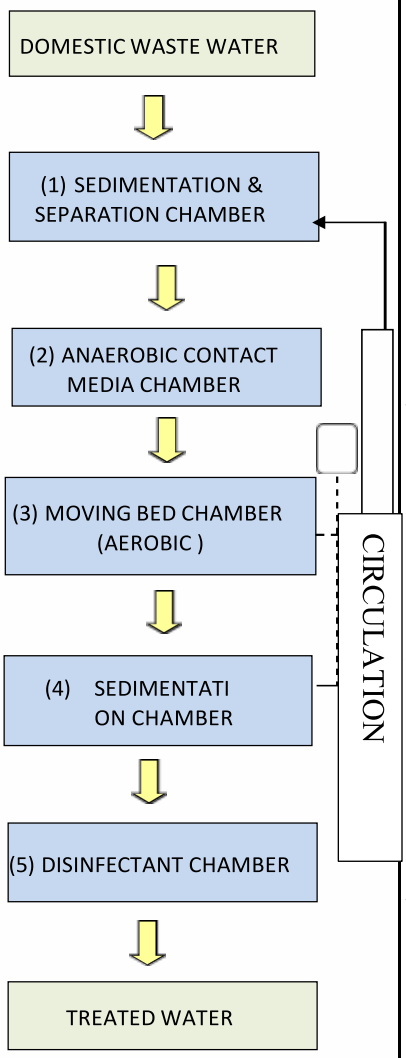


Exhibit 1: Moving Bed Biofilm Reactor Process Flow chart

The functions of Components of the MBBR Plant are as follows

- **Bar Screen Chamber** – The Bar Screen Chamber is used to trap the suspended flow and other solid waste of sewage water to avoid chocking.
- **Sump well -** The sewage water is collected in that well and transferred to equalization tank.
- **Sewage Lifting Pump-**The sewage water is transferred from sump well to the equalization Tank through Submersible pumps for a controlled flow. Using Submersible avoid choking as they have an excellent solid handling capacity.
- **Collection cum Equalization Tank-**The collection cum equalization tank is to collect the variable flow of sewage water and to equalize the quality of sewage.
- **Sewage transfer Pump-**The sewage transfer pump transfers the sewage water from collection tank to bar screen chamber.
- **Primary Tube settler -** Installed with tube settler media to increase the surface area and to enhance the settling process at a faster rate leading to consumption of very less space.
- **Aeration Tank-**The aeration process takes place in Biological Reactors in 2 phase which convert the finely divided and dissolved organic matter in wastewater into flocculent settleable solids. The Effluent is mixed with air round the clock to build up necessary environment within the reactor. The Effluent flows by gravity to the adjoining secondary settling tank.
- **Media for MBBR-**To enhance the contact surface area for proper oxidation MOVING BED BIO REACTOR (MBBR) is inserted in the aeration tank. These are optimally designed made by continuous forming to achieve high surface area for given volume and offer minimum resistance to airflow, providing more air contact with less power consumption.
- **Diffusers-**The Equalization and the Aeration tanks are equipped with non-clog diffusers to transfer diffused air. This allows maximum oxygen transfer having the Oxygen Transfer Efficiency up to about 3%-6%.
- **Root Air Blowers-**These are Positive Displacement Blowers. They have higher efficiency at moderate compression ratio and provide constant flow rates at varying discharge pressures in Equalization and Aeration Tanks.
- **Secondary Settling Tank -** Installed with tube settler media to increase the surface area and to enhance the settling process at a faster rate leading to consumption of very less space.
- **Filter Feed Tank -** This tank is used to collect clear water receiving from secondary settling tank and to feed tertiary treatment system.
- **Filter Feed Pump** – This is used to transfer the clear water from filter feed tank to tertiary treatment system.
- **Pressure Sand Filter** – This is MS structured vessel filled with multiple kinds of filter media to remove fine suspended solids from treated water.
- **Activated Carbon Filter** – This is MS structured vessel filled with activated carbon and anthracite to remove pathogens, colour and odour from treated water.
- **Ultraviolet System** – This system is used to kill all kinds of bacteria and pathogens which remains in treated water.
- **Ozonation System -** The clear water collected in treated water tank and ozonation system continuous provide ozone gas to stop growth of bacteria for disinfection purpose in treated water.

- **Treated Water Tank –** This is used to collect the treated water

Flow chart	Description
2.2 Johkasou Process STP 	(1) Sedimentation and separation chamber collects domestic wastewater. It also has function to separate solid wastes from liquid waste based on their gravity. (2) Wastewater then flows into anaerobic media contact chamber from sedimentation and separation chamber. It contains organic material which is decomposed by anaerobic microorganism. On the other hand, nitrite and nitrate contained in the circulated water are converted into N_2 gas by denitrification microorganisms. Anaerobic reaction shown as follow: Organic Material---> $CH_4 + NH_3$ + smaller materials + H_2O $NO_2 + NO_3$ -----> $N_2 + H_2O$ Anaerobic Microorganism (3) Anaerobic process treatment water flows into moving bed chamber. Organic material contained wastewater is decomposed by aerobic microorganism and becomes simpler product. In this case the organic waste material is used for development of new cells (protoplasm) and converted to other materials such as carbon dioxide, water, and ammonia. Aerobic reaction shown as follow: CHONS + O_2 + nutrient > CO_2 + H_2O + NH_3 + Microbial cell $NH_3 + O_2$ + nitrate cells > NO_2 NO_3 + H_2O + Cells nitrate increase Results of aerobic biological processes will also produce sludge which is suspended from treated water. (4) Sedimentation chamber has function as place of settled sludge which is resulted by biological processes in moving bed chamber. Settled sludge will be transferred to sedimentation and separation chamber. Concurrently NO_2 and NO_3 are transferred to its chamber. Note: Without sedimentation chamber sludge will flow out resulting turbid water detected as Total suspended solid and COD. (5) Disinfectant chamber serves as a place to put chlorine / disinfectant as a sterilization agent pathogenic microorganism in the waste processed before discharged into the environment.

2.3 Constructed Wetland/ Phytoremediation

Constructed Wetlands are engineered systems that utilize the natural functionality of the vegetation, sediments/substrate/natural filter media and micro-organisms that are present in a natural wetland system to purify the wastewater streams.

Constructed Wetland Systems are in a way oxygen supplying biological engines which can treat most types of wastewaters. The combination of substrates, plants, hydraulics and microorganisms efficiently remove organic pollutants, nutrient concentrations, even certain hazardous metals and toxic contaminants in the water. A Hybrid model of Constructed wetlands is a combination of vertical and horizontal wetlands, the selection of type of wetlands purely depending on the type of wastewater to be treated.

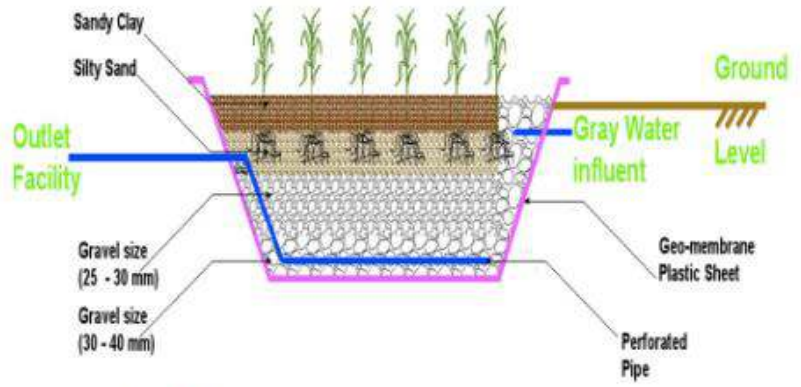
Wetlands have been used informally for water treatment for thousands of years. This knowledge is formalized into an applicable technology by various researchers/firms and institutions since late 1950s. Since then, there has been rapid growth and adaptation of this technology worldwide in both the municipal and industrial sectors. Early systems were more of horizontal/saturated (surface flow) flow across the wetland basin, and these were very much reliant on the diffusion of air from the atmosphere into the bed to 'fuel' oxygen driven microbial degradation.

Over the past 20 years the increased demand for more sustainable, low carbon footprint water treatment solutions has led to a sharp rise in the use of constructed Wetlands with a parallel increase in understanding how these systems function and can be optimised to provide much higher levels of treatment. Subsequent and ongoing client driven innovation has led to a range of different wetland system types and designs which can provide high levels of treatment across a broad range of effluents from the municipal and industrial sectors.

Aerated Wetlands

Aerated Treatment Wetland systems rely on the ability to inject small quantities of air in a very uniform pattern throughout the wetland bed. This allows operator control over the entire oxidation process during wastewater treatment while only using a small fraction of the energy required by conventional STPs. Intermittent operation of the aeration system can be fine-tuned to optimize treatment goals such as total nitrogen removal.

Originally developed in 1997 as a patented process in the United States, Aerated wetlands are now being used in Belgium, Brazil, Canada, China, Colombia, Denmark, France, Germany, India, Ireland, Italy, Martinique, Mexico, the Netherlands, Qatar, the United Arab Emirates, the United Kingdom and other countries due to the wide- ranging benefits of optimized, aerated wetlands.

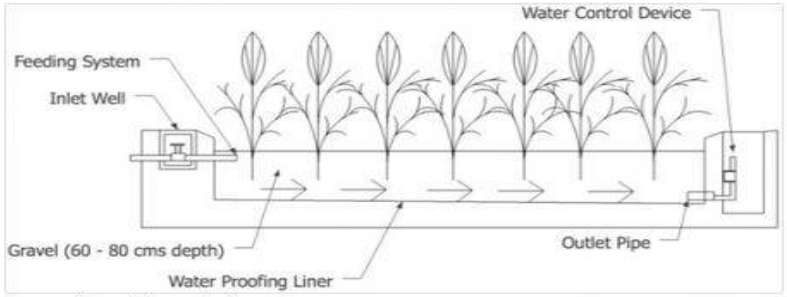


Source: Afifi *et al.*, (2015)

Exhibit 2: A Constructed wetland system

There are many types and classifications of constructed wetland ecosystem. But the sub surface flow type wetlands are the most effective for sewage treatment. This design allows water to flow below the surface of the wetland through gravel media. The macrophytes are planted in the gravel. There is no visible water in the bed and as such presents no public safety of odour problems. This design is effective in reducing Soluble Solids, BOD, COD and partial ammonia removal. Sub surface flow constructed wetlands are further classified into three types: Horizontal flow, Vertical Flow and Hybrid flow [6].

2.3.1 Horizontal Flow Sewage effluent fills the space between the gravel and circulates horizontally, naturally, each time water comes into the system. There is no external energy dependency (and therefore no contribution to pollution output).



Source: https://sswm.info.com

Exhibit 3: Horizontal Flow Constructed wetland

2.3.2 Down Flow or Vertical Flow (VF)- Sewage water is pumped at regular intervals (every 2–6 hours, depending on design and treatment levels sought) through a network of pipes laid on top of a bed filled with gravel-type media of generally three different granulometries through which the water percolates. Vertical flow Constructed Wetlands generally require 2/3 of the space of a horizontal flow one and can raise treatment quality in certain parameters yet they are fewer passive systems as they rely on a controlled source of energy. This design requires dosing of the bed's surface using a network of pipes using either pumping or a siphon system. The idea is to flood the surface of the reed bed several times per day. As the water flows down through the bed, it draws air in creating the right bacterial environment. VF reed beds are very effective in the removal of BOD, ammonia and some heavy metals and take up less area for similar treatment

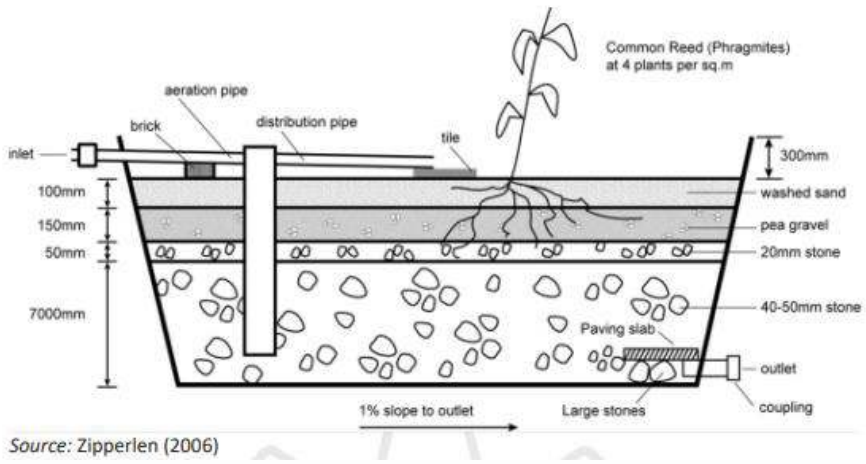


Exhibit 4: Vertical Flow Constructed wetland

2.3.3. Hybrid flow involves both horizontal and vertical flow. It incorporates one or two stages of vertical flow followed by one or more stages of horizontal flow in series. This type of hybrid flow was designed to achieve higher treatment efficiency of wastewater. Hybrid flow constructed wetland targets in total nitrogen removal, organic content reduction and pathogen removal from wastewater.

3. Constructed Wetland Sewage treatment at CRS

CRS Tirupati has employed the *Hybrid Model of constructed wetland* to treat 30 KLD sewage water released from the staff quarters. The treated wastewater is utilized for gardening purpose in the area surrounding the administrative building complex.

In order to reuse the released water from staff quarters, Constructed Wetland system of 30KLD was initiated, the proposed system is designed based on the principle of Constructed wetlands which is adapted worldwide. Wastewater is directed into a single collection tank called as holding tank with an HRT of 24 hours. The tank has 3 baffles which promote natural settlement of particulate matter. The wastewater from the last chamber of the holding tank is pumped into the wetland from where the water flows into multiple wetlands sequentially by gravity. The flow schematic is depicted in Exhibit 5 below.

SCHEMATIC OF SEWAGE TREATMENT

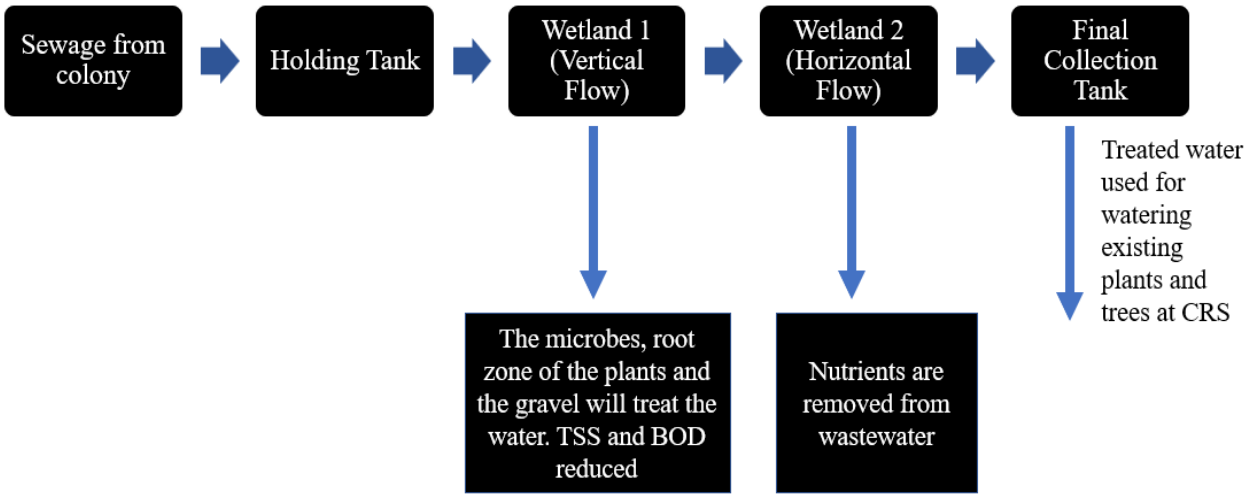


Exhibit 5: Schematic of Sewage treatment at CRS Tirupati

There are two wetlands, one with Vertical sub surface flow and the other with horizontal sub surface flow. The macrophytes/aquatic plants used in the wetlands are emergent plants (grow in water as emergent plants but they are capable of flourishing in in damp ground.) having most of their photosynthetic parts above the surface of the water and their root below it. The constructed wetlands contain 3 layers of gravels/chips of varying granularities. The bottom most layer contains 40 mm gravels up to a height of 2 feet. The middle layer contains 20 mm gravels up to a height of 2 feet and the top layer consists of chips of 6mm-12mm up to a height of 2 feet. The detailed layout of constructed wetlands with dimensions of the holding tanks, wetlands and collection tank are depicted in Exhibit 6 below.

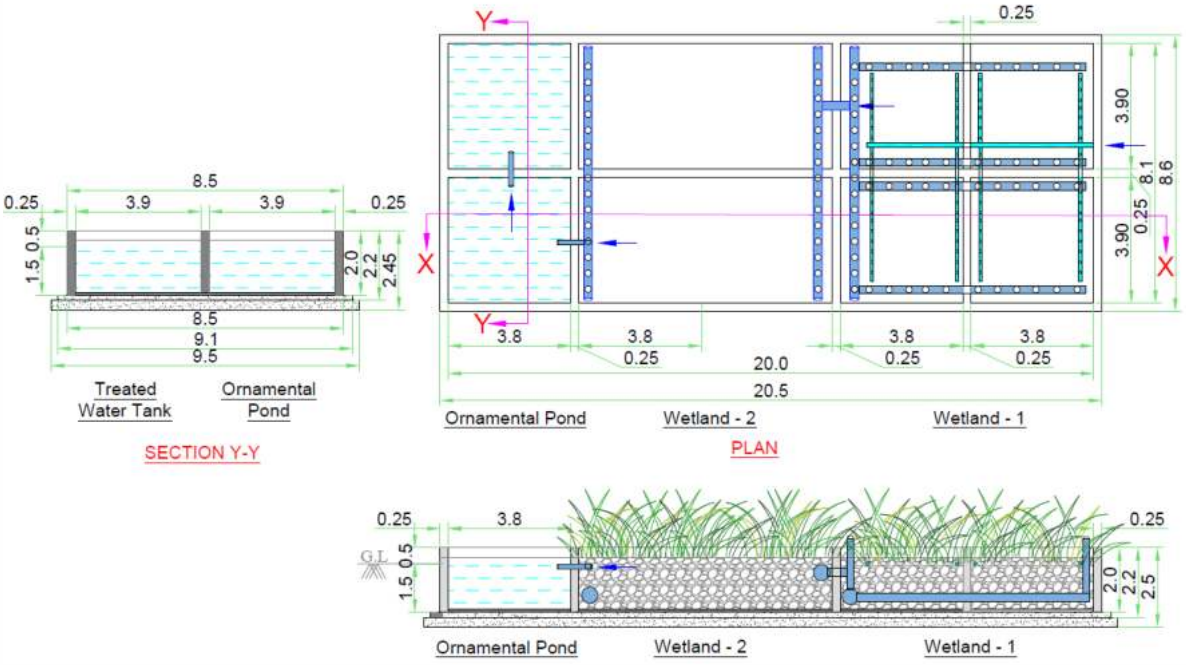


Exhibit 6. STP of 30 KLD capacity with Hybrid Model of Constructed wetland

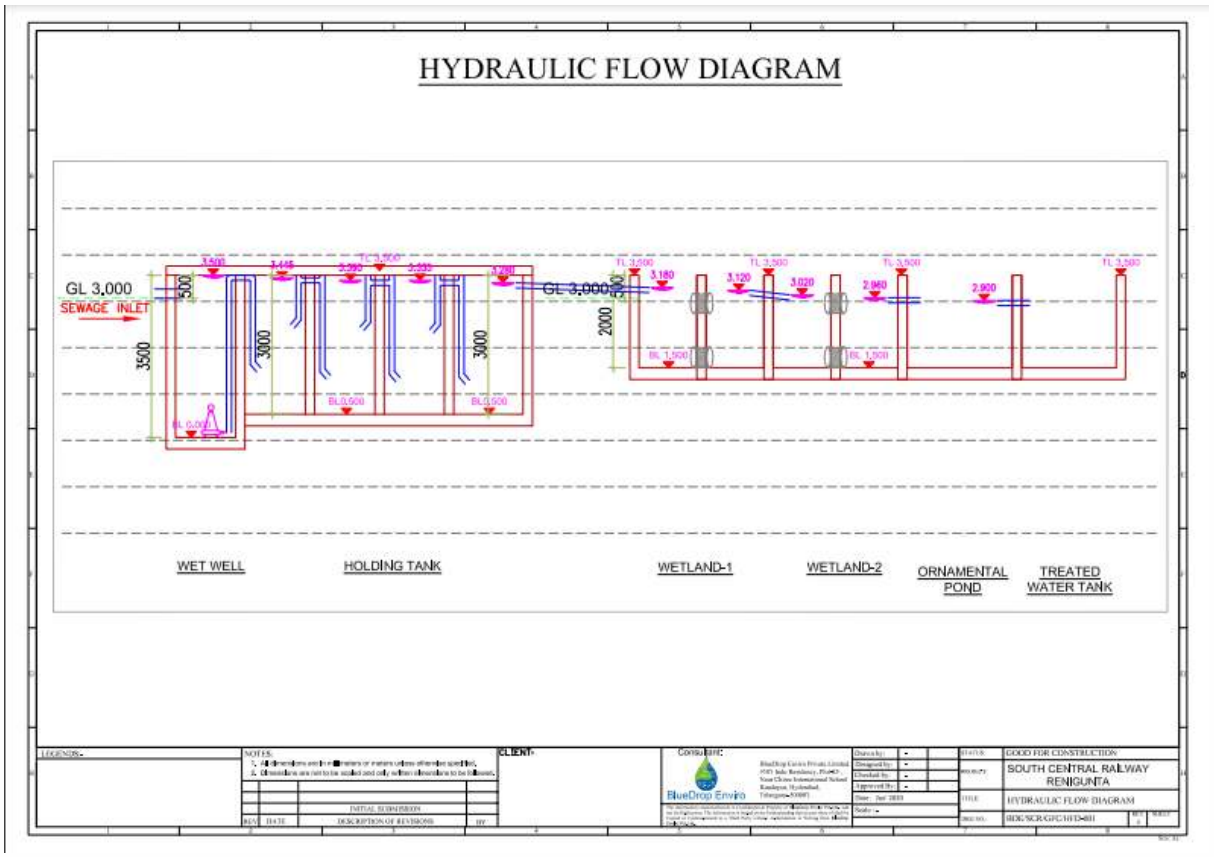


Exhibit 7: Hydraulic Flow Diagram of Constructed wetland

The pre-treated macrophytes used in constructed wetlands of CRS Tirupati were Spider Lilly, Heliconia and Umbrella Palm (Exhibit 8) which costs approx. 450 Rs. per plant (FOB Tirupati) and the cost may vary from location to location based on the availability and atmospheric conditions.

Exhibit 8: Spider lily, Heliconia and Umbrella palm (Left to right)

The water is collected in the collection tank after passing through the wetlands. The water is disinfected using Ozone and collected in the final collection tank. The sample of treated water is collected every 15 days to check for the Ph value, Total Soluble Solid (TSS), BOD, COD, Oil, Grease and turbidity. These parameters meet the CPCB norms as specified in Table.1 below.

S No.	Parameter	Unit	Input water quality	Outlet
1.	Hydraulic load	m^3/day	20	18
2.	Hours of operation	Hrs	16 to 20	
3.	pH	-	6.5-9	6-8
4.	Total suspended solids	mg/L	< 200	< 50
5.	Total dissolved solids	mg/L	850	No change
6.	BOD (5 day at 20 ^{0} C)	mg/L	< 250	< 10
7.	COD	mg/L	< 400	< 50
8.	Total Nitrogen	mg/L	< 50	<10
9.	Faecal Coliform	CFU	> 10^7	< 10^2

Table.1. Stipulated parameter ranges for treated water

The Total cost of setting up the Hybrid model of Constructed wetland is approximately Rs 23.34 Lakhs. The major component of cost is the construction cost of the Holding tanks, wetlands, Ornamental Pond and Collection tank with steel columns, RCC linings and brick masonry. The breakup of Mechanical and Electrical Components of Reed Bed system of Sewage

Sl. No	Item Description	Qty	Purpose
1	Float controlled Submersible Pump - 1Hp	2 Nos (Min)	For inter transfer of wastewater. Running period max 1 hr/ day and controlled by Timer
2	Ozonator(5gm/Hour)	1 No	For Disinfection, with a run time of 8 hr / day
3	PVC & CPVC Pipe	As required	Plumbing network for various activity of transfer of fluids and air
4	Ball Valves-1inch(Min)		For regulating the air/water pressure.
5	Electrical Panel	1 no.	For power distribution and controlling of run time of pump and ozone

Table 2: Electrical and mechanical equipment used in constructed wetland

Exhibit 9: 30 KLD Hybrid model of constructed wetland

4. Benefits of Constructed Wetland STP

- It is less expensive compared to other wastewater treatment methods
- It incurs low operational and maintenance costs.
- No noise and odour are generated from the STP
- Minimal usage of chemicals.
- No harmful by-products including Sludge generated during treatment process.
- It facilitates wastewater reuse and recycling
- It is tolerant towards fluctuations in water flow
- The system is flexible and scalable with the minimum of 500 Litres of wastewater available per day to 30 KLD wastewater flow without any deviation in quality of water
- Constructed Wetland act as Hotspots for Biodiversity
- It can be constructed harmoniously into the landscape
- Overall, Constructed Wetlands is an environmentally sensitive approach since less amount of chemicals are used for treatment.

5. Comparison

	Initial Cost (in Rupees)	**AMC cost/ year (in rupees)**	**Capacity (in KLD)**	**Area (in Sq. mtr)**	**Cost/KLD (In Rupees)**	**Capacity/sq.mtr (in KLD)**
MBBR STP at CRWS/BPL	52.6 lakhs*	18.57 lakhs*	500	1156	10,520	0.43
Johkasou STP at MMCT	78.57 lakhs**	4.79 lakhs**	100	120	78,570	0.83
Constructed Wetland at CRS/TPTY	23.35 lakhs	0.4 lakhs	30	206	77,833	0.145

*Relevant document attached at Annexure I

**LOA attached at Annexure II

Recommendations

- Constructed Wetlands based STP is an eco-friendly with minimal to no usage of chemicals and lesser carbon footprints
- The maintenance and operation cost of Constructed Wetlands based STP is very lessand hence these STPs are not maintenance intensive.
- The advanced Aerated wetlands are far superior and capable of handling heavy loads of nutrients and can be scaled up to any larger volume capacities.
- However, the cost/capacity of Constructed wetland is high in comparison to other STPs. Constructed Wetland STPs are not preferable when required capacity of STP treatment is in excess of 50 KLD.
- For the same treatment capacity, constructed wetlands occupy greater area. Constructed Wetlands STP can be employed only when there are no space constraintissues.
- Constructed Wetland STP can be used for treating Liquid effluent of Bio toilets which are cleaned and maintained during POH.
- Johkasou process STPs are preferable in workshops/railway units where there are Space constraints.
- MBBR STPs are an ideal option for wastewater treatment from the cost, capacity and space constraint point of view.

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DEVELOPMENT OF 2-TIER LOADING FOR MOTORCYCLE IN NMG COACHES WITH SIDE ENTRY AT CARRIAGE REPAIR WORKSHOP, MYSORE, S.W. Railway

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The ICF conventional coaches are converted to NMG to carry the Automobile with only end door opening. The loading of 4-Wheeler and 2-Wheeler in the existing NMG coaches are done through End-Door. However, loading the 2-wheeler in exiting NMG through end door is very slow, highly in-efficient, labour intensive and costly process. In the meantime RSDO has issued the drawing for development of prototype high speed NMG coaches with Side door to facilitate the easy and faster loading of 2-wheeler and other consignment in NMG coaches with higher carrying capacity (18 ton) at higher speed (110 kmph). Central workshop/Mysore was also assigned the job of prototype development of NMGHS coach. MYSS has successfully developed the Prototype for NMGHS as per RDSO drawings and sent for speed trial. The issue of side entry loading is addressed with the development of latest prototype NMGHS. However, during the process of prototype development, Team of MYSS had interacted with stakeholders (MYS div and TVS motors) and taken their feedback on loading of 2-wheeler on existing NMG and ongoing Prototype development of NMGHS. The following observations were made during interaction with stakeholders:-

1. The carrying capacity of a normal NMG coach is 9.2 MT.
2. It is possible to load only 44 Two-wheeler vehicles in single tier resulting in maximum utilization of 6 MT (considering their higher weighted motorcycle) but customer is paying for full 9.2MT for coach, which is underutilized. Hence the two wheeler manufacturer may opt for road transport to maximize their utilization.
3. The vehicles were loaded through end doors from platform side by temporary arrangement; this was found time consuming, expensive handling.
4. The lighting was poor throughout the rake.
5. Two wheelers were secured by conventional method by using bamboo, rods and ropes
6. Two wheelers are normally transported through road carrier vehicles which had proper securing provisions and recess on floor for proper seating of tyres

Although the new prototype design of NMGHS has solved the problem of Side loading and unloading of the motorcycle but the underutilization of carrying capacity of 9.2 ton for NMG coaches are major deterrent for 2-wheeler manufacturer opting Rail transport through NMG coach as preferred mode of transportation of two-wheelers.

Associated / Significant features of NMGHS are listed below:-

1. The loading capacity enhanced to 18 MT.
2. For enhancing the loading capacity, complete sole-bar boxing provided for strengthening.
3. 4-sliding doors of 1600 mm width provided for platform side loading.
4. Rail provisions made for 2 tier loading but silent about loading pattern, pallet design for two tier loading and handling of Pallets.
5. Roof angles provided in between end body doors at 4 locations for strengthening, but end body door portion is not strengthened.

Suggestions for further improvements in NMGHS:-

1. Pallets are required for loading of Two-wheelers in 2 tiers. For which factors like deflection, impact force, locking arrangements, vehicle lashing arraignments, size of pallet for easy handling and stacking/docking etc to be considered.
2. 4-sliding doors are felt not necessary. Can be reduced to 2 and can be planned at the middle of coach. The size of doors can be reduced to 1200 mm.
3. Sliding doors consume more space inside for provision of sliding space and its covering. Resulting less space available for rails for 2 tier provisions. Hence suggested for hinge doors. To be specific, doors similar to BCNA. With this bottom door which can acts even as ramp. There by additional flexible ramps and stacking pockets provided in prototype NMGHS can also be eliminated

On further interaction with various stakeholders and collecting information of present scenario, it was identified that two wheeler can be loaded in 2 fashion (transverse and longitudinal). One platform each was designed, manufactured & practically tested by loading two wheelers

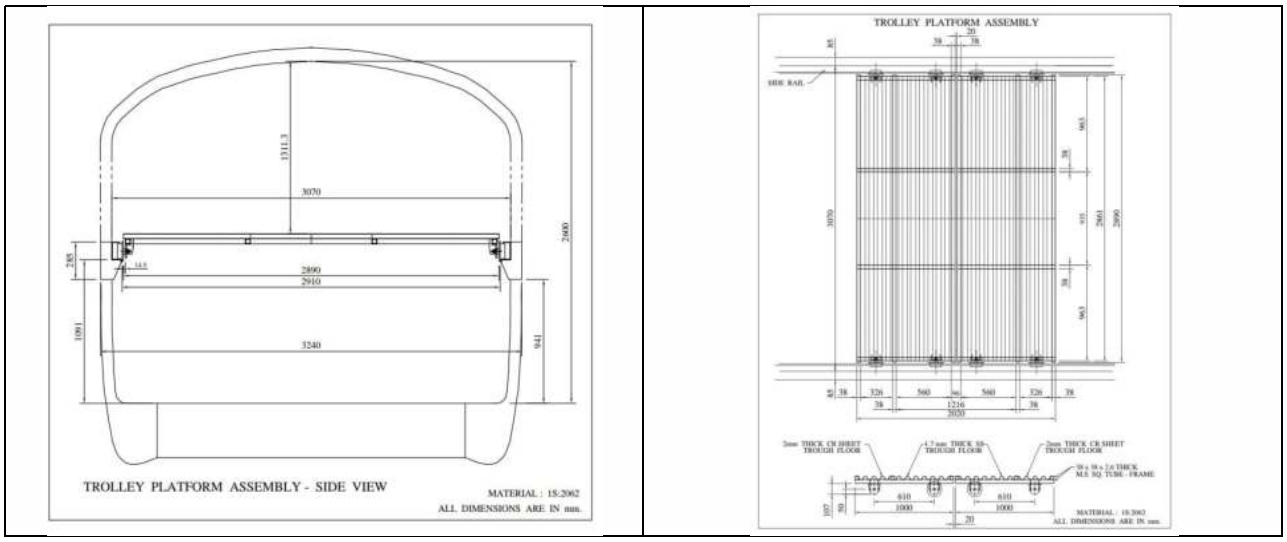
Ideas for Pallets for 2 tier loading:

1. The Pallet design must be light weight and portable so that one or max two people can handle it.
2. The Pallets must be sturdy so that it can withstand dynamic forces, deflection and rough handling during service.
3. Stacking/docking arrangement for Pallet is very important so that when the NMGHS coaches are used for transportation of 4-wheeler or other consignment, these pallets can be stacked inside coach without occupying much space. It should also not create hindrance for movement of 4-wheelers (LMV).
4. In 2-tier vehicle can be either loaded longitudinal or transverse. In longitudinal fashion 3 vehicles can be can be loaded in a row similar to bottom deck and in case of transverse fashion individual vehicles can be loaded across bottom deck.
5. Thus for longitudinal fashion, platform to be designed for 3 vehicles. And for transverse loading individual platform can be designed.

Pallet for Longitudinal loading with three vehicles on one Pallet:-

- To accommodate 2-tier loading the vertical size of the frame to be the least to equally accommodate vehicles on both upper & bottom decks.
- To accommodate 3 vehicles in a row, minimum platform size requirement has to be 2020 x 3070 mm. This size is huge to handle and would result in overweight to handle and difficult to stack while not in use. Hence decided to design the platform in 2 parts.
- Once 2-wheelers are loaded on Pallet in ground deck, it is difficult to load it over the rails on 2-tier and latch. Hence, the vehicle has to be loaded and latched elsewhere and transported. Thus the platform needs wheels to load over the rails at an end and pushed over vehicles loaded under deck.
- The wheels has to be sturdy and with bearings for smooth movement.
- The platforms need to be locked to avoid transverse, longitudinal and vertical movements while running.
- Lashing provisions for Vehicles need to be incorporated.
- Docking and stacking arrangement for such large size Pallets is to be made inside coach to accommodate when not in use, which may consume lot of loading space in Coach.

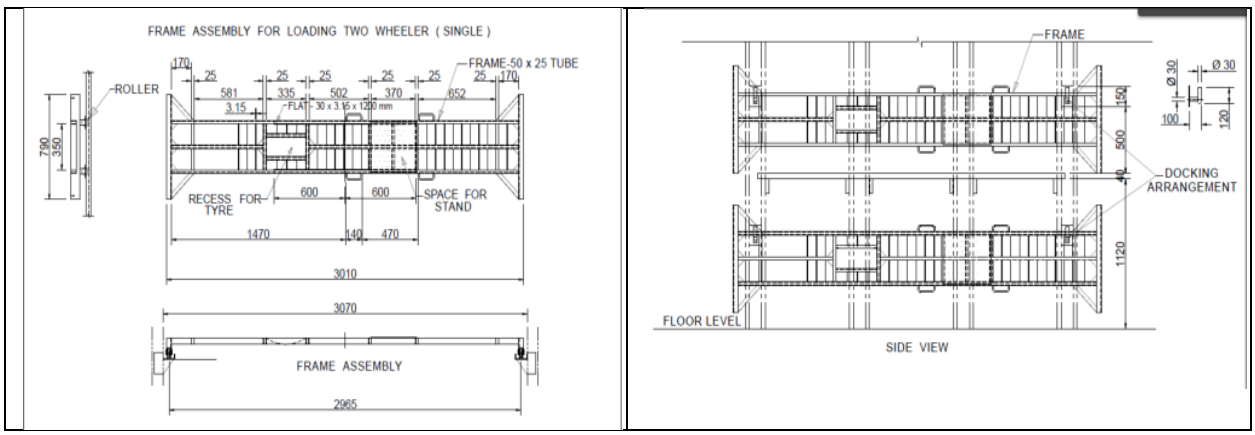
Design based on the criteria mentioned above:-



Pallet for Transverse loading with one vehicle on one Pallet:-

- To accommodate 2-tier loading Even in Transverse Pallet, the vertical size of the frame needs to be the least to equally accommodate vehicles on both upper & bottom decks.
- Individual Transverse pallet can be designed and the minimum size requirement is 3030 x 790mm.
- Similar to longitudinal Pallet, even in transverse Pallet, the vehicle needs to be loaded and latched elsewhere and transported. Thus the platform needs wheels to load over the rails at an end and pushed over vehicles loaded under deck. However the wheels can be lighter as it is designed to transport only one vehicle.
- And similar to longitudinal:
  - The wheels has to be sturdy and with bearings for smooth movement.
  - The platforms need to be locked to avoid transverse, longitudinal and vertical movements while running.
  - Lashing provisions for Vehicles need to be incorporated.
- Since the size of Transverse Pallet is much smaller and light weight, the Docking and stacking provision has been developed using simple hanger arrangement along the side wall of entire coach. It can accommodate maximum 24 such pallets hanged on wall which can be used whenever 2-Tier loading is required.

Design based on the criteria mentioned above:



Comparison of two types of prototype loading pallets for two-wheeler in 2-tier loading in NMGHS

Sl No.	Parameter	Transverse Pallet	Longitudinal Pallet
1	No of vehicles can be loaded on each Pallet (in nos.)	1	3
2	Weight (in Kg.)	43 kg	220 kg (110 + 110)
3	Nos. of Pallets can be fixed in one NMG coach (in Nos.)	24	8
4	Size (L x W x H) (in mm)	790mm x 3010mm x 160mm	2000mm x3030mm x 180mm
5	Handling	Easy to handle. One or two person can handle.	It is difficult. Minimum 4 people required.
6	Docking/stacking	On Side Body	On Side Body. It will eat out the space. Two level docking may be difficult due to heavy weight of Pallets itself.
7	Tare weight of NMG (in Ton)	32	32
8	Total Weight of Pallet (in ton)	1.032	1.760
9	Tare weight after adding Pallets weight (in Ton)	33.032	33.760
10	Carrying Capacity (in Ton)	9.2	9.2
11	Gross weight (in Ton)	42.232	42.96
12	Advantage to Customer	At present only 44 Two-wheelers are being loaded in single tier. However with two-tier loading using this Pallet, an additional 24 nos. Two-wheelers, which is 54% more, can be loaded in same NMG coach paying same Tariff.	At present only 44 Two-wheelers are being loaded in single tier however with two-tier loading using this Pallet an additional 24 nos. Two-wheelers, which is 54% more, can be loaded in same NMG coach paying same Tariff
13	Advantage to the Railway	Railway can capture the bigger share of business of two wheelers transportation.	Railway can capture the bigger share of business of two wheelers transportation

The design involved sturdy metal frame structure, wheels with bearing for easy movement, locking arrangement, space on wall for stacking, etc. Maximum 24 nos. additional Two-wheeler vehicles could be stacked in 2-tier using either type of Pallets.

Both the designs were practically tested by loading two wheelers in 2-Tiers. In both cases 5-12 mm deflections noticed. However Transverse Pallet is found practically feasible due to its size, weight, portability, ease of handling and docking on the wall of coach itself.

At present only 44 vehicles are being transported in one NMG coach in single tier mode. And average loading in NMG is around 6 MT which is highly underutilized. By adopting 2-Tier loading we can accommodate additional 24 nos. of two wheelers in the upper deck. This will increase the loading of two wheeler vehicles in one NMG coach by 54%. And a rake of 20 coaches can take 480 nos. of two wheelers additionally.

This will benefit the transporters for maximum utilization of the NMG coach. The cost of transportation per vehicle will come down substantially. The transportation of Two-wheeler through Rail for longer distance may be most economical and viable option. This modification may help in increasing the demand for 2-wheeler transportation through Railway and improve its share in two-wheeler transportation.

“Hungry for Cargo”