Design for the Implementation of Train Link System for Konkan Railway in India

Akshaya Sudhakar[1], Sushma R Iliger[2,] Saviti[3]Amogh A. Sanzgiri[*]

[1,2,3,*]*Department of Information Technology, Goa College of Engineering, Farmagudi, Ponda, Goa, India*

---***---

Abstract - *Hundreds of Express/Passenger trains are managed by a handful of crew booking depots in Indian Railway on a regular basis. A Loco Pilot /Assistant Loco Pilot needs to be efficiently assigned to sequence of train pairing, starting and ending at the same railway station(headquarter). The challenge for the Railway crew booking depots is to manually generate sequence of train pairings which covers finite set of trains for a definite time period while satisfying numerous constraints defined by the Railway Board. In this paper we present a constraint-implicit mathematical model taking into account various kinds of constraints. We have proposed a model that renders a number of train link systems for the trains that cover circular routes in the train network. The goal is to effectively utilize manpower, time, resources that will benefit the Railway Board and the operating employees. This is a decision support tool that gives a number of feasible and optimal train link systems at a time and the best fit one is chosen by the Loco pilots.*

*Key Words***:** Train Link System, Train pairings, Crew booking depots, Konkan Railway, Constraint-implicit model, Loco Pilots

1. INTRODUCTION

The Indian Railway is divided into 17 zones for systematic and cost-effective operations of the trains. The zones are further subdivided into divisions where each of the division is monitored by their respective divisional headquarters. For our research purpose, we will be taking Konkan Railway as our region of interest. Because, even though Konkan railway is a subsidiary part of Indian railway it cannot be termed as a zone or a division because of the small route length it covers and hence it lacks of subdivisions. This railway belt is stretched over a distance of approximately 740 kilometers. It employs more than 800 Loco Pilots and Train Managers (Guards) which forms

the basic functioning team, responsible for train operations. Hence the Railway spends a lot on their training and resting facilities. The Indian Railway uses a Crew management system (CMS) that allows crew controller to assign loco pilots (LP), *assistant loco pilots* (ALP) to the locomotives, who take charge from the crew changing depots.

Loco Pilot (LP) and *Assistant Loco Pilot* (ALP) are the people who pilots/drives the train. Train Managers are the people who are in charge of the train along with the Loco Pilots. Train Pairing is a pair of connectable trains that help the LP/ALP to start and end a Duty Shift at the same station (headquarter).Train Link System is a timetable which displays a sequence of the most efficient and valid train pairings for the Railway administration as well as the LPs/ALPs to work on for a period of time. In order to assign the LPs and ALPs to operate all the trains running in a particular section, a timetable that deter-mines the circular duty shifts (Ds) has to be defined. Such an arrangement of the circular duty shifts (Ds) generated is called the Train Link System(TLS). TLS is the combination of valid train pairs that are constructed within the given perimeters. These perimeters consist of several constraints defined by the Railway Board, of which few are discussed in the further sections [Section 2.1].

Fig. 1 is an example of one such TLS which is developed by the Margao headquarter (one of the two headquarters of Konkan Railway) for 7 weeks and correspondingly, 7 LPs and ALPs of the Margao headquarter follow this TLS. Fig. 2 represents a graphical representation of two week duty shifts (Ds) of the TLS.

2. TLS DERIVING PROCESS IN THE CURRENT SCENARIO

Crew booking depot is the railway station that is responsible for the generation of TLS for the LPs/ALPs and other staff, wherein the TLS for LPs/ALPs are given highest priorities since they are responsible for the operation of trains. The destination station of a duty shift is termed as an outstation.

Periodical rest (Weekly Rest) is the resting hours that may extend to 30+ hours which is given to the LPs/ALPs at his/her headquarters after a number of consequent duty shifts.

	SUN	MON	TUE	WED	THU	FRI	SAT
1	11097 DN / 22114	→	22660 DN / 12483		R	10112 UP / 22656	
2	10215 DN / 12217		R	12283 UP / 12133		22475 DN / 22636	
3	R	22150 DN / 19577		12449 UP / SP 12619	12134 UP / 12051		
4	22113 DN / 16346	R	10112 UP / 12051		16338 UP / 12133		11086 UP / 19578
5	R	12134 UP / 12051		22635 DN / 12620			22659 UP / 12618
6	R	12618 DN / 22149		12134 UP / 12051		R	SP 10104 UP / 22113
7		12977 UP / 16337		12133 DN / 16346		22907 DN / 12133	

Fig -1: Train Link System

Fig -2: Graphical Representation of 2 weeks link

This rest period is calculated from the previous sign off to next sign on. Line of duty is the combination of train pairings that is lined up for 7 days, which may include

appropriate *out-station rest, headquarter rest, periodical rest* along with appropriate Duty Shifts (Ds). *Traffic time*, in terms of trains, is the buffer time given to each train in between stations, to handle the delays due to crossing/ precedence of other trains. *Engineering time*, Is the buffer time given to each trains in between stations, to handle the delays due to caution orders/other track related issues. Another important circumstance is the spare movement of LPs/ALPs. Railway has weekly, bi-weekly, tri-weekly etc. trains. Therefore, sometimes it is not possible to find a pair for such trains. In such cases, the TLS allows the LPs/ALPs to move as a passenger from headquarter to outstation or from outstation to headquarter.

It is estimated that it takes approximately 2-3 weeks to develop the entire TLS, and to do so, a subset of LPs are sent off duty for this purpose. Meanwhile the remaining Loco pilots are subjected to stress due to stringent duty hours and sometimes compromising on their periodical rest hours, due to shortage of LPs/ALPs. The TLS is generated using the Working Time Table (WTT) issued to each LP/ALP by their Railway, which is updated annually or as prescribed by the Railway. WTT contains the timings of all trains running in that Railway along with traffic time, engineering time and many other details.
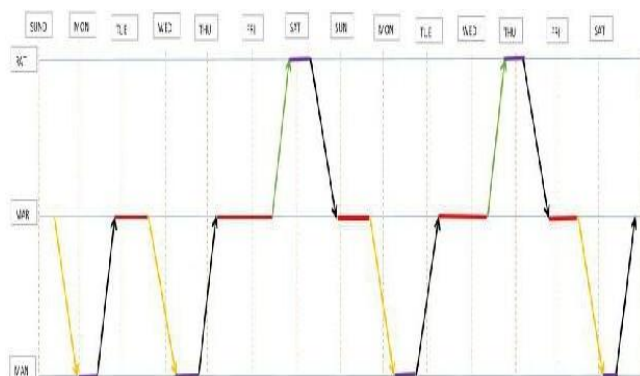
2.1 Constraints

1. Rest Requirement: At headquarter, minimum 16 hours rest to be given from previous sign off time to next sign on time. At Outstation, if then total duty hours is 8 hours or more, LP/ALP should be given minimum 8 hours rest. At headquarter, if staff is required to work before completing his stipulated rest hours, then breach of rest allowance is payable to the respective LP/ALP. Minimum number of periodical rests in a month should be 5 of 22 hours each or 4 of 30 hours each including a full night in bed from 22.00 hours to 6.00 hours.
2. Duty kilometer coverage constraints: Max. duty hours in any one trip should not exceed 10 hours. Average duty hours in a fortnight should not exceed 104 hours. No LP should cover more kilometer than the limit set by the regulation board.
3. Night shift constraints: Not more than 2

consecutive night shifts are allowed as it leads to Signal Passing At Danger (SPAD) and also affects the human biological clock on a long term.

4. Train category compatibility: Pairing of trains is constituted by different train categories that are recognized after classification. Each combination of different trains creates a domain for deriving different links.

5. Efforts should be made to include all the sections in the TLS to avoid giving road learning repeatedly. Road Learning is done when the LP/ALP has not worked on a particular section at all or for a long period of time. It helps them to familiarize themselves with that section. Link having the maximum earning kilometers should be worked by senior most LPs on top priority trains and so on. Separate links should be prepared for Rajdhani and Shatabdi Expresses.
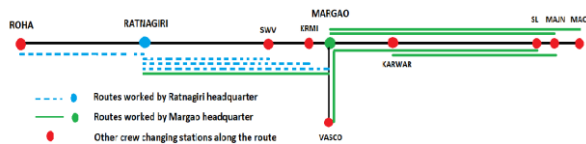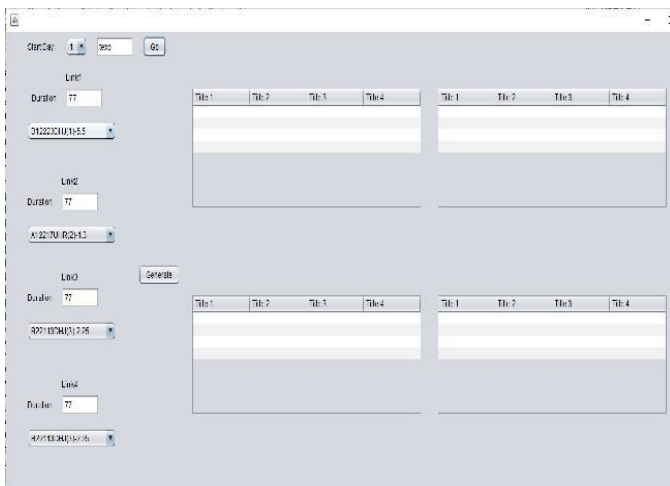

Fig -3: Routes covered by the headquarters

Fig -4: UI of the system

3. PROPOSED MODEL

In any Railway, the trains are operated from one or more headquarters. At each headquarter, depending on the

strength and category of the Loco Pilot, multiple links are generated for each headquarter. In the current manual method, trains are distributed to each headquarter according to their strength. Each link is generated one at a time. Hence, it takes about 2-3 weeks to generate all the link types.

For example, the two headquarters in Konkan Railway are Margao and Ratnagiri. Both at a distance of 240km from each other. Margao and Ratnagiri lies on the same linear route (Fig -3). As shown in the figure, the two headquarters are in charge of different routes within Konkan Railway. Hence the trains assigned to each headquarter varies. The number of trains assigned also varies since that depends on the strength of LPs/ALPs at headquarter.

The aim of this system is to generate multiple links simultaneously within minutes at each headquarter. Fig -4 shows the User Interface (UI) of the system for a single headquarter wherein; the Crew Controller can generate 4 links simultaneously. The inputs to the system and the algorithms are discussed in the further sections [Section 3.1 and section 3.2 respectively]
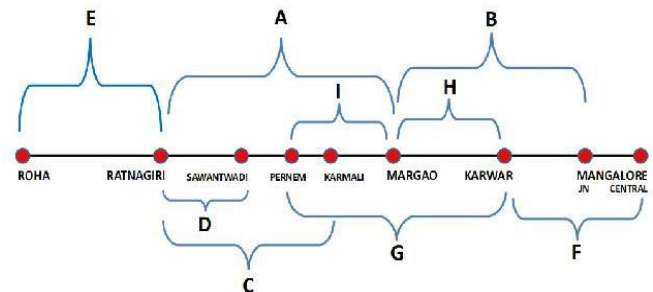

Fig -5: Sectioning of the Konkan Railway Belt

The proposed model is generated to handle routes that are of circular type. In our case before taking over the next pair of Ds, it should be ensured that the last pair of Ds should start and end at the same point. Also the arriving and departing station should be the same, or else the LP/ALP will have to depart from a different station that will cause unnecessary spare movement.

3.1 Input

As explained in section 3, major Crew Booking Depots in KR are Margao and Ratnagiri, where LPs/ALPs are head-

quartered. Therefore, there arises a need to distribute trains among the two crew booking depots to accommodate trains according to the strength of LPs/ALPs in each headquarter. And since they have 2 headquarters, they will need two separate TLSs to coordinate the LP/ALP with the trains. Not all trains start or end at these crew booking points. They might originate from different stations other than these crew booking depots. (For example, in Konkan Railway trains are originating from SWV, KRMI and Karwar - Refer Fig -3)

Hence, for programming purpose, sectioning of the KR route becomes necessary to avoid conflicts during assignment of trains to LPs/ALPs as shown in Fig -5. Nomenclature of train codes as shown in Fig -6 is solely for the string scanning function to identify and set the variables when each module is executed. This system will have a master database of 164 trains. Out of which trains are sorted according to their priority. Priority of a train is decided based on the type of link it is assigned to i.e. , first link will contain top priority trains which will be assigned to the senior most Loco Pilots and so on and so forth. This database is used for the generation of the Train Link System (TLS).
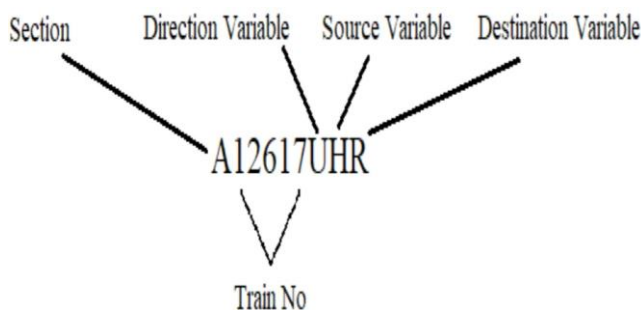

Fig -6: Train Code Nomenclature

3.2 Proposed Algorithms

3.2.1 Overall Flow Control

We propose to solve the problem by searching for the best, legal and valid train pair. From the User Interface (Fig-4) the crew controller will select:
a) 4 trains (because 4 links) as starting point (i.e. start trains of each link). Say T1, T2, T3, T4.

b) Duration of each link.

Next the algorithm will select the first train (T5) from the database. T5 is compared with T1, T2, T3, T4 applying the various declared constraints such as work hours, rest hours, night shift etc. The pair with the most favorable results will be assigned together. Once paired, that train will move to the Assigned (History) List. Similarly, this process is continued till T2, T3, T4 have a pair. Then the newly found row of T5, T6, T7, T8 becomes the new starting point. From the flow chart (Fig -7), Steps 3 and 4 are repeated till the stopping condition is reached (i. e. Day Counter == Duration).
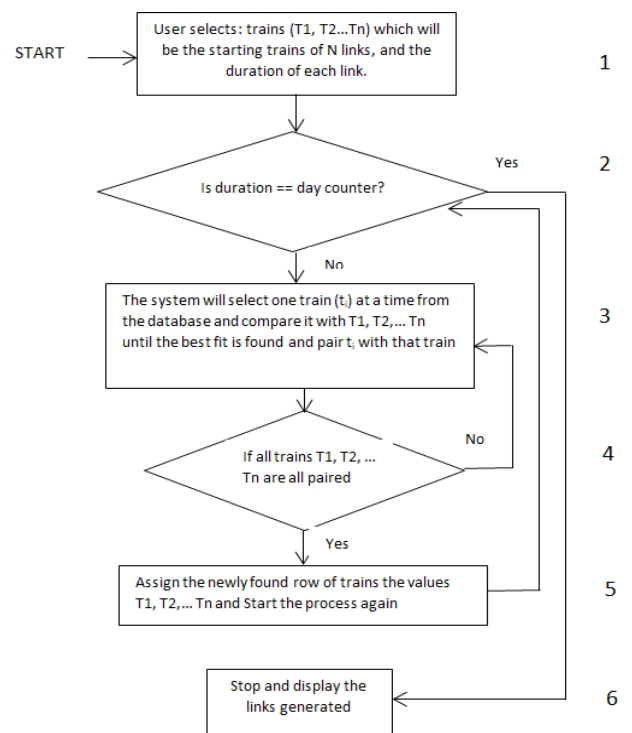

Fig -7: Overall flow of control diagram

The pictorial representation of this explanation is shown in Fig -8. In this case, train T5 is the best fit for train T3. And the searching and comparing continues till T8, when all 4 trains find a pair. System stops when the Day Counter matches the Duration entered by the crew controller.

Overall Algorithm is shown in Fig -9. Step 2 is further divided into Outstation Algorithm [Section 3.2.2] and Headquarter Algorithm [Section 3.2.3].

3.2.2 Outstation Module Algorithm

The Outstation Module is called when the source, of the train we are trying to find a pair for, is not the headquarter. The Flow of Control of this module is shown in Fig. -10.
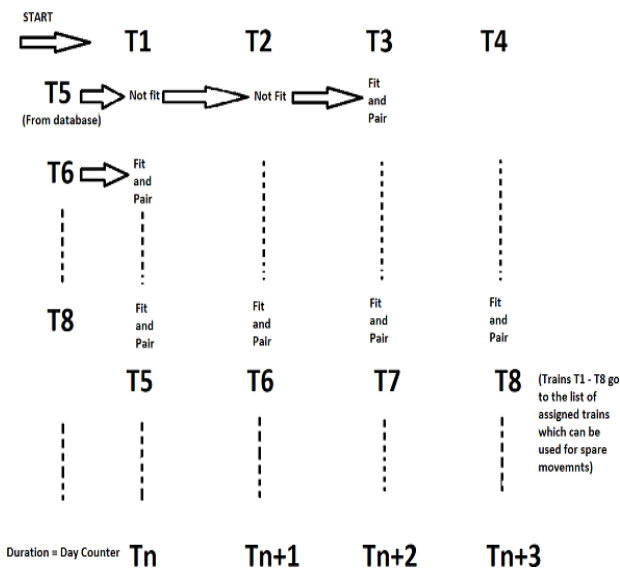
Fig -8: Structure of the system

Fig -10: Flow of Control of the Outstation Module

ALGORITHM – OVERALL MODEL

Step 1: Take start trains as input from user; T1, T2.... Tn (for n links).

Step 2: **While** (T1, T2.... Tn find pairing duty)

    for (i =0; i<=m; i++)

      for (j=0;j<=n; j++)

        Select train Ti from database/assigned list and compare with train Tj;

          if ((Ti,Tj) == legal and valid pair)

          \\ To check if legal and valid use Outstation and Headquarter algorithm

            Assign Ti to Tj;

        else

            goto for loop;

Step 3: The new row of trains will become the new T1, T2.... Tn

Step 4: Repeat Steps 2 and 3 while incrementing the Day Counter.

Step 5: Stop and Display the 'n' links when Day Counter == Duration (input from the user).

Fig -9: Overall Algorithm

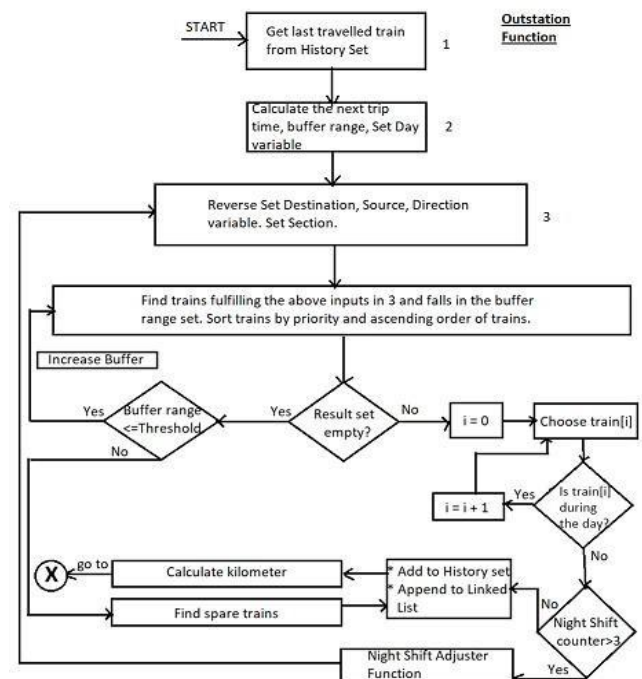From the history list, the last Ds information is read and the destination of the last Ds is now converted to the origin station from which the LPs/ALPs have to return back to their Headquarters. The next Ds is calculated after addition of appropriate outstation rest from Ds sign off time. The new Result set is generated by searching trains in the history set where departing time lies between the buffer range (Br) calculated, from the new origin and whose destination will be their headquarters on the given day. Also if the new Result set is empty then increase the right limit of buffer range till the right threshold is reached. If the buffer range exceeds the threshold then decrease the left limit of buffer range till the left threshold is reached. If still Result set is found to be empty then (a)assign a train from the History set as spare movement or (b)keep on increasing the right threshold till Result set is obtained and choose the earliest trains as spare movement.

The Result set is ordered by priority followed by ascending order of departing time. If the chosen train does not violate the constraints mentioned in section 2.1 append that train to the History set and if violated then choose the next train from Resultset. Update night counter,day counter,day and calculate the kilometer coverage. Check if the duration of the TLS is satisfied then pass on the control to Overall Module Algorithm Step 2.

Algorithm for outstation module is shown in Fig -11.

Let Assigned list be At

Let Unassigned list be Ut

If (At && Ut) != φ

Ti,Tj ε Ut

If((At!=φ)&&(Ut=φ))

Ti,Tj ε At

If ((At = φ)&&(Ut = φ))

IncreaseBufferandRepeatStep2.

ALGORITHM – OUTSTATION MODULE

Step 1: Consider train Tj. Render its source, destination and reverse it.

Step 2: Compare trains Tj and Ti

//Tj is the train we need to find a pair for. Ti is the train from the database/assigned/history list.

Check if this pair satisfies the rest, work hours, night duty etc. constraints

//

if (satisfies)

Assign Ti to Tj;

Copy Ti to ASSIGNED LIST;

Pass Control Back to OVERALL ALGORITHM;

else

Check if Ti satisfies for the other T(j-1) trains // Step 2

if (satisfies)

Assign;

else

Add Ti to UNASSIGNED LIST;

Pass Control back to OVERALL ALGORITHM;

Fig -11: Algorithm of the Outstation Module

3.2.3 Headquarter Module Algorithm

Fig -12 shows the Flow Control of the Headquarter Module which is called when the source of the train is headquarter. It reads the last Ds from the History set, and checks the number of duty shifts stored in the set. The periodical rest is assigned depending on the number of weeks the TLS is designed for. For example, if the number of weeks is 11, then there must be a minimum of 11 periodical rests assigned. If no periodical rest is assigned, then calculate the next Ds by adding the headquarter rest with the previous Ds sign off time at the headquarter.

The new Result set is filled after the search is completed by adjusting the Buffer range like done in the outstation module. The search done for a train at headquarters module is different because not one specific destination/section is provided, as from the headquarter the LP/ALP has to cover all the routes in the given TLS.
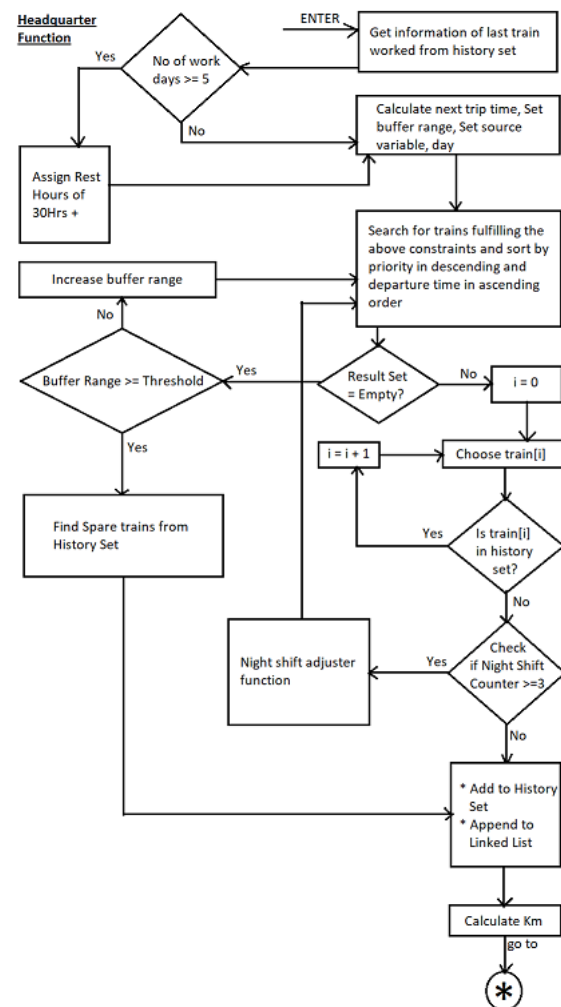
Fig -12: Flow of Control of the Headquarter Module

Again the new Result set is sorted according to priority and departure time from the source and the earliest train is chosen. Before appending the next node to History set and updating the variables it should be verified if the constraints mentioned in section 2.1 are not violated. Night Shift can be of two type (A) and type (B). Type A is

encountered when the program is executed for the first time and the train departure time lies between 00:00 to 6:00.Type B is encountered when the control is bounced back and forth between the outstation and headquarters module where the train departure time lies between 22:00 to 6:00.

Algorithm is shown in Fig -13. After the execution the control passes to the overall algorithm.

```
ALGORITHM – HEADQUARTER MODULE

Step 1: Consider train Tj.

Step 2: Compare trains Tj and Ti

        //Tj is the train we need to find a pair for. Ti is the train from the database/assigned/history list.

        Check if this pair satisfies the rest, work hours, night duty etc. constraints

        //

            if (satisfies)

                Assign Ti to Tj;

                Copy Ti to ASSIGNED LIST;

                Pass Control Back to OVERALL ALGORITHM;

            else

                Check if Ti satisfies for the other T(j-1) trains  // Step 2

                if (satisfies)

                    Assign;

                else

                    Add Ti to UNASSIGNED LIST;

                    Pass Control back to OVERALL ALGORITHM;

Step 3: Let  d = number of work days

        while (Day Counter != Duration)

            switch (d)

                Case 5:

                    6:

                    7:

                    8:

                    9: Assign REST;

            if ( d == 9)

                Set d = 5;
```

Fig -13: Algorithm of the Headquarter Module

4. CONCLUSIONS

The Train Link System uses a multilevel linked list for efficient storing and accessing of data. The start train is selected from the first level and the corresponding train pairs form the corresponding lower levels. Using this process we generate N links simultaneously. The Train Link System follows divide and conquer strategy as we subdivide the problem in to smaller sections for ease of creation of the link and efficient distribution of spare trains. The output generated best serves circular routes where in the crew booking depot acts as a mid point and the TLS should begin and end at this point (headquarter). This proposed algorithm is applicable for the given constraints for a circular route.

4.0.1 Advantages and Future Scope of the Project

This automated Link system can be extended to the 900+ Crew Booking depots all over the Indian Railways. Upon its implementation, the Indian Railways can benefit tremendously from :

1. The High speed generation (within minutes) of the link (which otherwise takes weeks to create).
2. Immediate and Prompt generation of the crew links as and when required (especially in cases of link failure due to unavoidable circumstances, when the timings of trains are updated, when regular trains are cancelled or when new trains are imposed by the Ministry of Railways etc.).
3. The system will not require more than one employee to operate as compared to the manual method of generation (which requires at least 3-5 Loco Pilots, few Assistants and 1 or 2 Superior Employee(s) to guide them).
4. Since the Automated Link generating system strictly abides by the rules and regulations of the Indian Railway, the link generated cannot be disputed or argued by the Loco Pilots or Administration (which might occur in case of manual generation of the link due to biasing or manipulation of the rules).
5. Working style and strategy followed by each crew booking depot is different. This system facilitates these types of alterations locally.

REFERENCES

[1] Aggarwal, Divyam Saxena, Dhish Emmerich, Michael Paulose, Saaju. (2018). On Large-Scale Airline Crew Pairing Generation.10.1109/SSCI.2018.8628699.

[2] Ernst, Andreas T., Houyuan Jiang, Mohan Krishnamoorthy and David Sier. "Staff scheduling and rostering: A review of applications, methods and models." European Journal of Operational Research 153 (2004): 3-27.

[3] Kasirzadeh, Atoosa, Mohammed Saddoune and François Soumis."Airline crew scheduling: models, algorithms, and data sets." EURO Journal on Transportation and Logistics 6 (2014): 111-137.

[4] Chen, Mingming and Huimin Niu. "A Model for Bus Crew Scheduling Problem with Multiple Duty Types." (2012).