Industrial and Systems Engineering- Systems Design Project

Train Captain Duty Redesign for Optimal Manpower Utilization

I.Overview

Problem Description

Determine the crew scheduling parameters for the driver-operated North-South and East-West MRT Lines so as to ensure efficient utilization of the train captains. Additionally, a location for installing a new Intermediate Relief Crew Point (IRCP) will have to be selected.

Project Objective

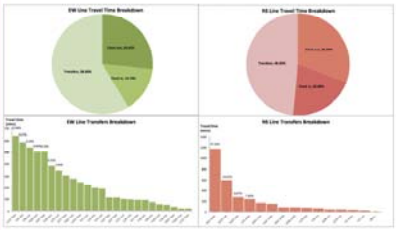
Review and redesign the current Train Captain (TC) duty allocation in consideration of numerous constraints.

NSEW Line Network Map

LINE	NS	EW	SHARED
Train Depot	Bishan Depot	Changi Depot	Ulu Pandan Depot
Crew Point	Ang Mo Kio Crew Point	Tanah Merah Crew Point	Jurong Crew Point

II. Implementation

1. Current Schedule Analysis



Travel Time Classification

Clock In: TC travels to another station to start his first driving piece after clock in

Clock Out: TC travels to another station after his last driving piece to clock out

Transfers: TC travels to another station in between driving pieces

Issue 1: Large amount of clock in and clock out travelling times

Cause: TC must clock-in and clock-out at the same station which causes many unnecessary travelling

Recommendation: Allowing Train Captains to clock in and clock out at different stations to alleviate Issue 1

Issue 2: Excessive travelling time between a Crew Point and Train Depot pair e.g. AMK and BSD

Cause: Travelling between a Crew Point and Train Depot pair (e.g. AMK & BSD) by public transport is inconvenient and time-consuming

Recommendation: Introduce a shuttle bus service to ferry TCs within each Crew Point and Train Depot pair

Issue 3: Large amount of travelling time between crew points and terminal stations

Cause: Many TCs have to travel to the terminal stations to meet the higher demand during the peak hours

Recommendations: Install an IRCP point between (1) JKN and JUR for EW Line (2) AMK and JUR for NS Line. This will address Issue 1 and 2 too.

Methodology

2. Scheduling Model

Greedy Algorithm

Pseudo Code

```
for each schedule:
    if train of this schedule has a driver:
        if any constraint is violated if driver continues driving:
            if exceeds maximum working time
                set driver to be off work
            else
                set driver to be temporarily unavailable and update his next available time
    if train of this schedule has no driver:
        find the best available driver according to criteria
        allocate this schedule with this driver
```

Constraint Examples

Explicit Constraints

(1) Maximum working hour per TC is 8.5 hours per day

(2) Meal Break must be taken within the first 5.5 hours of working time

(3) Cannot drive a train continuously for more than 4 hours

(4) Maximum of 5 driving pieces a day

Implicit Constraints

(1) TCs cannot have a meal break at terminal stations

(2) At terminal stations during peak hours, TCs who step out can only step in the 2nd next subsequent train onwards

(3) TC needs to clock in and clock out at the same station.

Hungarian Algorithm

1. Select a list of schedules

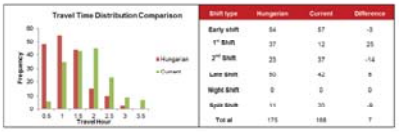
2. Select available drivers

3. Assign cost to each pair

4. Use Hungarian algorithm to find maximum match with lowest cost

5. Process drivers and mark off schedules

3. Model Validation



Shift type	Hungarian	Current	Difference
Early shift	54	57	-3
1st Shift	37	12	25
2nd Shift	23	37	-14
Late Shift	50	42	8
Night Shift	0	0	0
Split Shift	11	35	-6
Total	175	168	7

- Schedule produced by the model has comparable performance with the current schedule
- Improvements
  - Fewer people with long travelling time
  - Fewer split shift, early shift and 2nd shift (with additional allowance)
- Limitations
  - More TCs required

4. Solution Evaluation

Recommendation 1: Relax clock-in and clock-out limitation

- Reduce TC number by 4 for EW line
- High administration cost incurred
  - TC personal belongings storage
  - TC personal vehicles storage
  - May need to provide transportation for TC to return to original clock-in station for them to collect their belongings and vehicles

Recommendation 2: Shuttle Bus

Train Depot	Train Station Pair	Current Travel Time / min	Shuttle Service Travel / min	Number of Travellers	Proposed Timing for Buses	Travel Time Saved / mins
BSD	AMK	40	10	36	10:10; 11:06; 16:20*	400
UPD	JUR	40	15	9		-
CHD	TNM	40	6	36	10:06; 11:01; 16:03*; 17:03*; 23:08	360

- Most feasible location: between BSD and AMK
- 2 buses at each depot can save us more than 700 minutes of travelling time
- This slack time give us more flexibility for planning TC schedule

Recommendation 3: IRCP

EW Line	
IRCP	Crew number reduction
PSR	2
JKN	1

- IRCP tested for EW line
- Marginal improvement
  - there is an existing IRCP in operation
  - Crew points and IRCP spread evenly
- Expected larger impact if NS line
- Practical limitation
  - Administration cost for IRCP installation
  - Limited space within MRT stations
  - No nearby eateries for meal break at certain stations

III. Future Direction

1. Continue developing the Hungarian algorithm

- Current algorithm is locally optimum.
- The next direction should be an improvement towards the globally optimum solution

2. Verify the IRCP analysis on Hastus

- The HASTUS software takes a long time to generate a feasible output
- Input our proposed IRCP point to verify if it produces a significantly more efficient output
- Perform cost-benefit analysis for installing this new IRCP

3. Perform a Survey on TCs to determine their perception towards certain guidelines

- Should clock in and clock out stations be allowed to be different?
- Are you fine with having shorter meal breaks but shorter working time?

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