General Description of the Problem:

The Santiago Metro is a rail network that serves the Chilean capital, Santiago. It provides transportation for approximately 2.241 million people per day across seven different lines, covering a total of 136 stations with a length of 140 km.

Line 1, also known as the red line, carries the highest number of passengers, with an average of 717,730 daily trips, accounting for 35.1% of the total. It runs along the main corridor of the city, which is the commercial hub of the city, and is therefore a critical component of the network. This line has 27 stations, starting from the west at the San Pablo station (where it connects with Line 5) and ending in the east at Los Dominicos station. It covers a distance of 20 km, which takes a little over 38 minutes on average. There are six stations on this line that intersect with other lines of the Metro network. It also has two stations that connect with intercity bus terminals (Pajaritos and Universidad de Santiago) and one station (Estación Central) that connects with the railway station, offering train services to/from the southern periphery of Santiago and connecting to cities in the south of Chile.

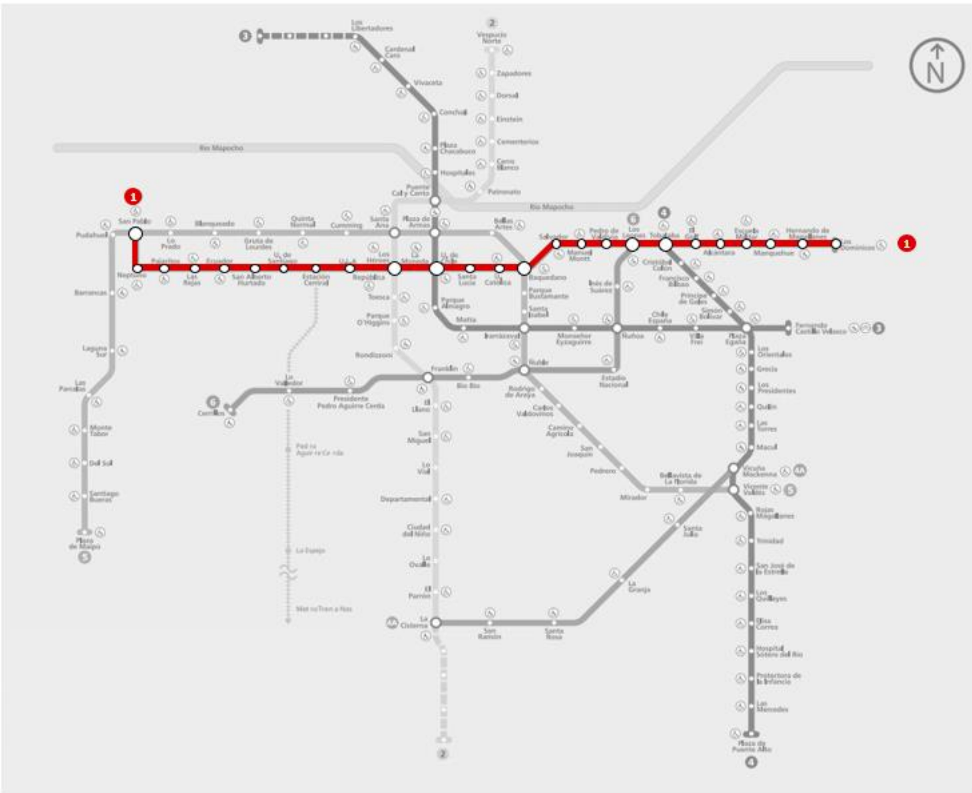

Figure 1 – Line 1, Metro Santiago

STATION DATA

ID	Code	Line	Name	Type
1	SP	1	San Pablo L1	Transfer
2	NP	1	Neptuno	Intermediate
3	PJ	1	Pajaritos	Intermediate
4	LR	1	Las Rejas	Intermediate
5	EC	1	Ecuador	Intermediate
6	AH	1	San Alberto Hurtado	Intermediate

7	US	1	Universidad de Santiago	Intermediate
8	EL	1	Estación Central	Intermediate
9	LA	1	Unión Latinoamericana	Intermediate
10	RP	1	República	Intermediate
11	LH	1	Los Héroes L1	Transfer
12	LM	1	La Moneda	Intermediate
13	CH	1	Universidad de Chile L1	Transfer
14	SL	1	Santa Lucía	Intermediate
15	UC	1	Universidad Católica	Intermediate
16	BA	1	Baquedano L1	Transfer
17	SA	1	Salvador	Intermediate
18	MM	1	Manuel Montt	Intermediate
19	PV	1	Pedro de Valdivia	Intermediate
20	LE	1	Los Leones L1	Transfer
21	TB	1	Tobalaba L1	Transfer
22	GO	1	El Golf	Intermediate
23	AL	1	Alcántara	Intermediate
24	EM	1	Escuela Militar	Intermediate
25	MQ	1	Manquehue	Intermediate
26	HM	1	Hernando de Magallanes	Intermediate
27	LD	1	Los Dominicos	Intermediate

During peak hours on a working day, Line 1 operates with 44 trains, with an interval (time between consecutive trains in the same direction) of 103 seconds and 141,425 scheduled car-kilometers (CKM). The entire line is equipped with the Communication-Based Train Control (CBTC) system, which optimizes train services and provides better service to passengers. This line operates with a loop system in order to provide more trains in the sections of the line that have higher demand. There are two possible shorter loops that trains can serve: San Pablo – Manquehue, and Pajaritos – Los Dominicos (see Figure 2).

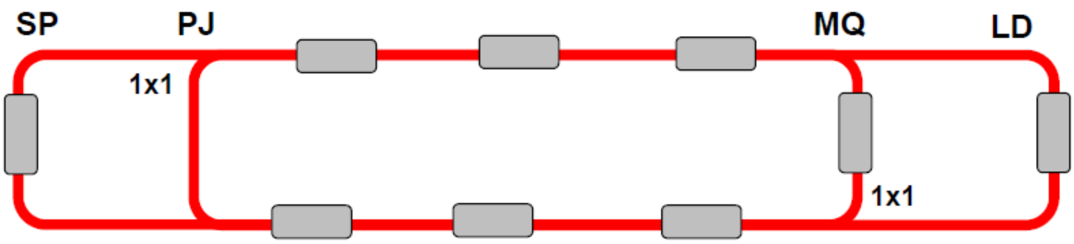

Ilustración 2 - Esquema de Operación Línea 1

Additionally, when there is a significant level of demand due to contingencies or operational events, empty trains are sent to the stations that require them, usually the high-flow transfer stations such as Estación Central and Los Héroes during peak morning hours, and Tobalaba during peak afternoon hours. In addition, other flow management actions may be taken, such as congestion control in mezzanines or corridors in transfer stations, to prevent an excess of demand on platforms, or to deviate demand to adjacent stations.

Line 1 is constantly challenged due to its high demand and criticality for the city's transportation. Any disruption, especially during peak hours, has a high impact on operational variables such as interval and frequency, decreasing the level of service and generating significant media exposure. Congestion causes increase in waiting times in mezzanines or transfer corridors, and once they are cleared or the train frequency normalizes, the recovery speed of the usual service level is slow, leading to an increase in passenger complaints and dissatisfaction.

The objective of this challenge is to create a timetable for the operation of Line 1 during a typical weekday. The timetable must take into account various technical constraints such as minimum headway, dwelling times, turnaround times, positioning of trains for the next day's operation, and maximum station capacity. The proposed timetable must provide sufficient capacity to cater to the demand of the entire day without exceeding the maximum capacity of the stations.

Participants must explore different operational schemes that include (but are not limited to):

- Injecting or removing trains at intermediate stations (in Manquehue towards San Pablo or in Pajaritos towards Los Dominicos).
- Deadheading, which involves moving a train from a terminal or injection station to a different station where it starts providing service.
- Stop skipping, which allows trains to skip stations to improve service times, thus increasing train rotation and system capacity. However, since there are no places for overtaking in Line 1, stop skipping is restricted to specific operational schemes, such as "A-B" stop skipping patterns with some common stations.

Participants must design three different timetables based on the following criteria:

1. Reducing operational costs: what is the cheapest way to cater to the demand of Line 1? Assume that operational costs are proportional to the total CKM of the proposed solution. For this part, user travel time and waiting time may be ignored, but it is important to note that passengers cannot be forced to behave as the planner decides (i.e., the optimization of their routes cannot be forced).
2. Maximizing the quality of service: how can we minimize the average travel time of users on Line 1? It can be assumed that time spent waiting on the platform is perceived as twice as costly as in-vehicle time, and that time waiting in the mezzanine (whenever a platform reaches capacity) costs four times the in-vehicle time.
3. Propose a solution that balances the two criteria above, while also taking into consideration other realistic aspects of the problem, such as the comprehensibility of the solution (i.e., the complexity of the services and their operation times), the robustness of the plan (i.e., how it behaves when passenger demand is more variable), or any other aspects of the problem that the participants deem important.

Evaluation Criteria:

The criteria that judges will use to evaluate a solution include the following:

- Feasibility of the proposed solutions.
- The quality of the proposed solutions for the given objective function values (see the full problem description for additional details).

- The soundness of the reasoning for the additional solution(s) proposed by the participants (see the full problem description for additional details).
- The tractability of the solution approach adopted.
- The usability/reproducibility of the solution approach.
- The performance of the solution approach, e.g., its computational time.
- The quality and clarity of the paper describing the model and the solution approach considered for the problem.
- Submissions must comply with the specified format for solution files (see the full problem description for additional details).
- The quality of the presentation, to be given by three finalist teams at the Rail Applications Section Meeting at the 2023 INFORMS conference.

The finalists will make a presentation at the 2023 INFORMS Annual Meeting. Aside from the previous factors, the judging panel will take into consideration the clarity of the presentation to make a final decision about the first, second and third places for the competition. Note that being among the finalists and presenting at the Annual Meeting does not guarantee a finalist will receive first, second or third place. The decision of the judges is final.

Awards:

First Prize: $2,000

Second Prize: $1,000

Third Prize: $750

In addition to the cash prizes, the first prize winners' contribution to this competition will also be considered for publication in the journal *Networks*. The paper still needs to go through the journal's refereeing process; however, it will receive an expedited refereeing and publication process.

Eligibility:

Practitioners of operations research and management science who are interested in solving problems in the railroad domain using Operations Research and Analytics tools are welcome to participate. Registration is open to all with the exception of RAS officers and organizing committee members. Likewise, members of the organizing committee may NOT help nor guide any participating team.

Teams of up to five members can participate. At least one member of each finalist team must be available in-person or virtually for questions/answers at the 2023 INFORMS Annual Meeting. Winners will be announced after the session.

Registration:

Participation in the RAS Problem Solving Competition requires **registration by June 15th**. Every team must register by the due date to participate in the contest. To register, please send the following information to railwayapplicationssection@gmail.com by the deadline.

- For each team member: Name, Email, Organization, Position.
- Brief statement describing what motivated you to participate.

After submitting your registration email, you will receive an email confirming your team's successful registration and eligibility, and you will be added to the competition's channel in Slack.

Can I publish?

Yes, you can. In fact, RAS encourages you to do so. Anyone can use the RAS competition problem and provided datasets in their publication. References to year-specific problem competitions are given in the URL, and as such you can reference the year-specific competition URL which will not be changed.

Important dates:

- Release of Full Problem and Datasets: April 21st, 2023
- Registration Deadline: June 15th, 2023
- Q&A Period: Open from May 1st, until August 15th 2023.
- Solution Submission Deadline (Paper + Results): **August 1st, 2023**. **Submissions must be sent to rasproblemsolving2023@gmail.com**
- Announcement of Finalists: **August 31st, 2023**
- Finalists' Presentations: **October 15-18, 2023**, at INFORMS Annual Meeting, Washington, DC.
- Winner Announced: **October 15-18, 2023**, at INFORMS Annual Meeting, Washington, DC.

Competition chairs:

Marcella Sama, Roma Tre University, Italy
Homero Larrain, Pontificia Universidad Católica de Chile, Chile

Problem owner:

Marcela Munizaga, Universidad de Chile/ Santiago Metro, Chile
Robert Sprätz Demaria, Santiago Metro, Chile