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PUBLIC TRANSIT MANAGEMENT AND OPERATION DATABASE DEVELOPMENT

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1. BUSINESS NEEDS

1.1. Context

The project herein constitutes a scenario of the development of a database to serve plausible needs of managers and operators of public transit services such as those in the Montreal metropolitan area. Within that area:

- The ARTM (Agence régionale the transport métropolitain) has the mandate to manage public transit, and are therefore the oversight entity; and
- The STM (Société de transport de Montréal), STL (Société de transport de Laval), RTL (Société de transports de Longueuil), EXO (Réseau de transport métropolitain) and REM (Réseau express métropolitain) operate public transit infrastructure and equipment, and are therefore the operators.

Public transit is fundamental to ensuring population mobility within the Montreal metropolitan area. The offer of services by public transit operators in that area has recently allowed 340 million of user movements per year.[1] Services are supported by operational infrastructure (e.g. stations and dedicated roadways and railways) and equipment (e.g., trains and buses) valued at 11 billion of dollars.[2]

The recent budget established by the oversight entity indicate that fare revenues reach approximately 800 million dollars, representing about 27% of the total revenues of approximately 3 billion dollars collected for the operation of public transit within the Montreal metropolitan area.[3]

1.2. Objectives

To ensure efficient management of the offer of services, infrastructure and equipment, and to assist in developing a viable economic model for public transit, a comprehensive monitoring of revenues from and movements by users are essentials.

As a support to web services for the managers and operators, the objective herein is to develop a database structured around two forms of transactions: fare purchases and fare usages.

Fare purchases are the actions of buying a fare product for the purpose of accessing public transit services. From that form of transactions, the following plausible managers' needs can be fulfilled:

- Long- and mid-term revenue summaries on yearly and monthly bases globally, online, from buses and by the regions defined by ARTM;
- Monthly and yearly revenue details by fare products; and
- Monthly and yearly revenue details by points of sales.

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[1] From annual reports of public transit operators, accessed on May 20, 2024, at Rapport d-activité 2023 | Société de transport de Montréal (stm.info), Rapport annuel 2023 – EXO, STL_Rapport_activite_2022_FINAL.pdf (stlaval.ca), RA_2022_Web_FINAL_3aout.pdf (rtl-longueuil.qc.ca).

[2] From financial statements of public transit operators, accessed on May 20, 2024, at rf2023.pdf (stm.info), Rapport annuel 2023 – EXO, STL-etats-financiers-2023.pdf (stlaval.ca), RA_2022_Web_FINAL_3aout.pdf (rtl-longueuil.qc.ca).

[3] From the 2024 budget report by ARTM, accessed on May 30, 2024, at: 2567_ARTM_Budget_2024_final_page_WEB.pdf.

Fare usages are the actions of validating a fare product to be granted access to public transit services. From that form of transactions, the following plausible operators' needs from operators can be fulfilled:

- Long and mid term fare user traffic on annual, monthly bases on all services individually (i.e., each bus and train lines); and
- Shrot term fare user traffic on and hourly bases on all services individually (i.e., each bus and train lines).

2. DESCRIPTION

The core of the business needs is transit fare management, as it relates to fare processing through purchase and validation transactions. As such, transit fare management constitutes the central concept of the mind map below:

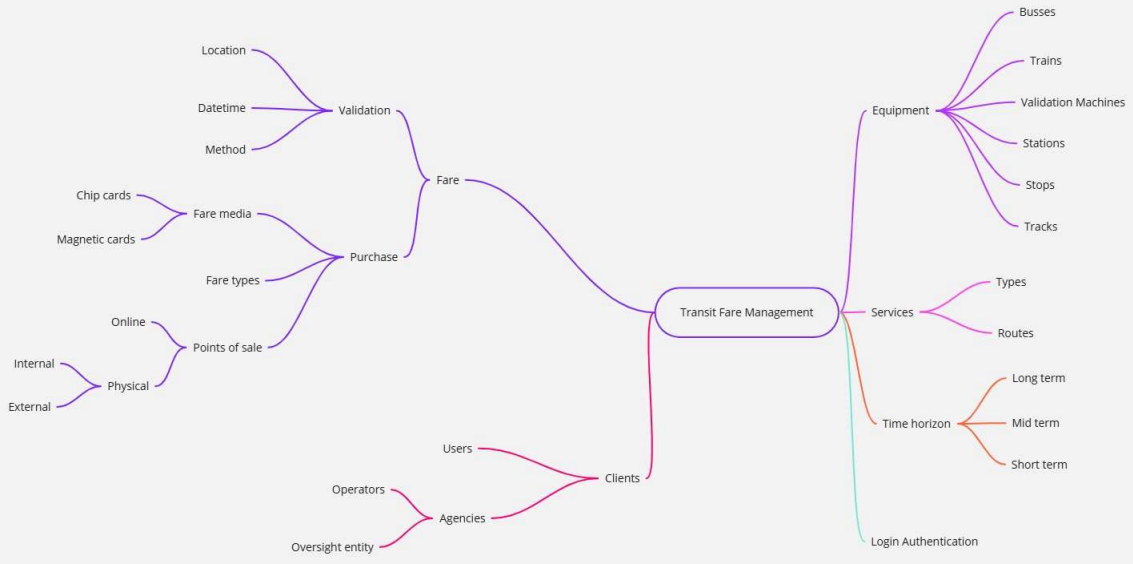


Figure 1. Transit Fare Management Mind Map

Radiating to the left are the fundamental blocks of the central concept, whereby:

- The oversight entity answers their business needs by making requests for key performance indicators derived from the fare purchase data; and
- The operators answer their business needs by making requests for key performance indicators derived from the fare validation data.

Radiating to the right are supporting blocks of the central concept, whereby:

- They provide data to articulate key performance indicators (KPI) requested by the oversight entity and operators; and
- Supports the login authentication required to confirm the identity of the oversight entity and operator employees authorized to access the transit fare management.

The users of public transit are the contributors to fare purchase and validation transactions data. Under the current business needs, the users are not clients, given that they are not entitled to make

request for data or derived KPI from fare purchase and validation transactions. Users are nevertheless defined as clients for transit fare management.

As ulterior development to transit fare management, users could be allowed to create an account allowing them to make purchase of any possible fare types, register their fare media and credit card information, view transaction and validation history, and register to message streams and theft alert. Under such a development, users can then become clients.

3. REQUIREMENTS

3.1. Functional Requirements

Figure 2 illustrates the overview of functional requirements for fare transit management. These requirements are divided into three general categories:

- Transactional requirements, which are intended to insert records of fare purchases and validations into a database;
- Administrative requirements, which are intended to manage access by clients to requests to the database; and
- Data processing requirements, which are requests to the database to process data and send results of the data processing into a key performance indicator dashboard accessible to the clients.

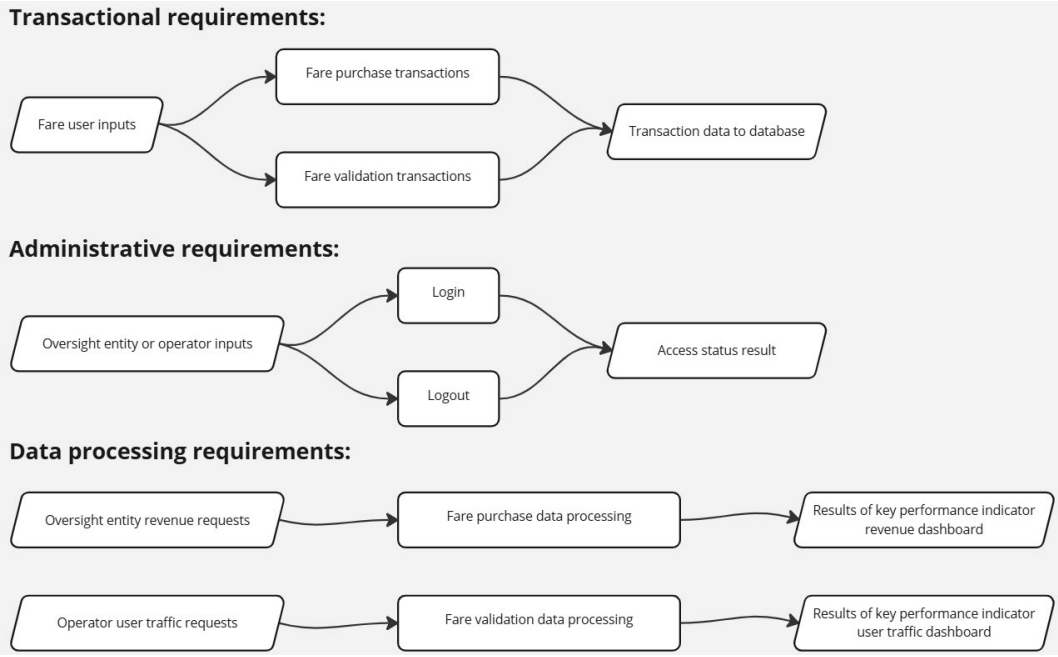


Figure 2. Transit Fare Management Functional Requirements

Details on the functional requirements in figure 2 are provided in Table 1. The Fare purchase (FR01) and Fare transaction (FR02) entail automatic updates to tables in a database, from inputs generated in the field at points of sales and at validators on buses and at train stations. Within this

project, these functionalities are simulated by artificially generating data for the database through coding, and therefore are not integrated in the use case scenarios (Section 5).

Table 1. Description of Functional Requirements

Requirement ID	Requirement statement	Comment
Transactional requirements:		
FR01	Fare purchases	Inputs generated in the field at points of sales, simulated herein by an input generator described in Section 6.
FR02	Fare transactions	Inputs generated in the field validators on buses and at train stations, simulated herein by an input generator described in Section 6.
Administrative requirements:		
FR03	Client signup	The system administrator must signup new users so that they can sign in (use case UC01, Section 5).
FR04	Client login	The employee of a client must login to access the revenue or user traffic KPI dashboard (use case UC02, Section 5).
FR05	Reset password	The employee of a client has lost access or had their password compromised and must reset their password (use case UC03, Section 5).
Data processing requirements:		
FR06	Process long term revenue summary	Long term revenue summaries on a yearly basis, for a selected period of years, ending with a selected year, globally, online, from buses and by the regions defined by ARTM (use case UC04, Section 5). The results are sent to the revenue KPI dashboard (use case UC11, Section 5).
FR07	Process mid term revenue summary	Mid term revenue summaries on a monthly basis for a selected year, globally, online, from buses and by the regions defined by ARTM (use case UC05, Section 5). The results are sent to the revenue KPI dashboard (use case UC11, Section 5).
FR08	Process revenue details by fare products	Revenue details for a selected year, on a yearly and monthly bases, by fare products (use case UC06, Section 5). The results are sent to the revenue KPI dashboard (use case UC11, Section 5).
FR09	Process revenue details by points of sale	Revenue details for a selected year, on a yearly and monthly bases, by points of sales (use case UC07, Section 5). The results are

Requirement ID	Requirement statement	Comment
		sent to the revenue KPI dashboard (use case UC11, Section 5).
FR10	Process mid term user traffic by service	Fare user traffic on yearly and monthly basis, for a selected year and service, that is, each bus and train lines, in both directions (use case UC08, Section 5). The results are sent to the revenue KPI dashboard (use case UC12, Section 5).
FR11	Process short term user traffic by service	Fare user traffic on daily and hourly periods on all services individually, that is, each bus and train lines, in both directions (use case UC09, Section 5). The results are sent to the revenue KPI dashboard (use case UC12, Section 5).
FR12	Process long term user traffic by service	Fare user traffic on yearly and monthly basis, for a selected period of years, ending with a selected year, a service, that is, each bus and train lines, and a direction (use case UC10, Section 5). The results are sent to the revenue KPI dashboard (use case UC12, Section 5).

3.2. Non-Functional Requirements

Table 2 lists summarily the system behaviours, features, and general characteristics the database must possess to produce an adequate user experience.

Table 2. Description of Non-Functional Requirements

Requirement ID	Requirement statement	Comment
NFR01	Usability	Clients will need a portal to access analysis tools.
NFR02	Reliability	Data must be collected 24/7 or whenever transit is running.
NFR03	Reliability	Improvements and maintenance must be done on the fly with no downtime.
NFR04	Scalability	Service must be able to scale to handle new transit offers of service.
NFR05	Scalability	Service must be able to add new providers that clients may want to add.
NFR06	Performance	Collection of data must be able to keep up with reporting of data from fare validators and points of sale.
NFR07	Performance	Analysis of data must be fast enough to provide data at regular intervals as requested by clients.
NFR08	Supportability	Support will be provided by in house helpdesk.
NFR09	Security	Database must securely protect client's credentials and non-publicly available data.

4. ANALYSIS MODELS

The structure and functionalities of the transit fare management database have been established in two main steps. In the first step, the relations between the clients and the database are established through the functional requirements described in Table 2. These relations, referred to as use cases are illustration in Figure 3 and described in greater details in Section 5.

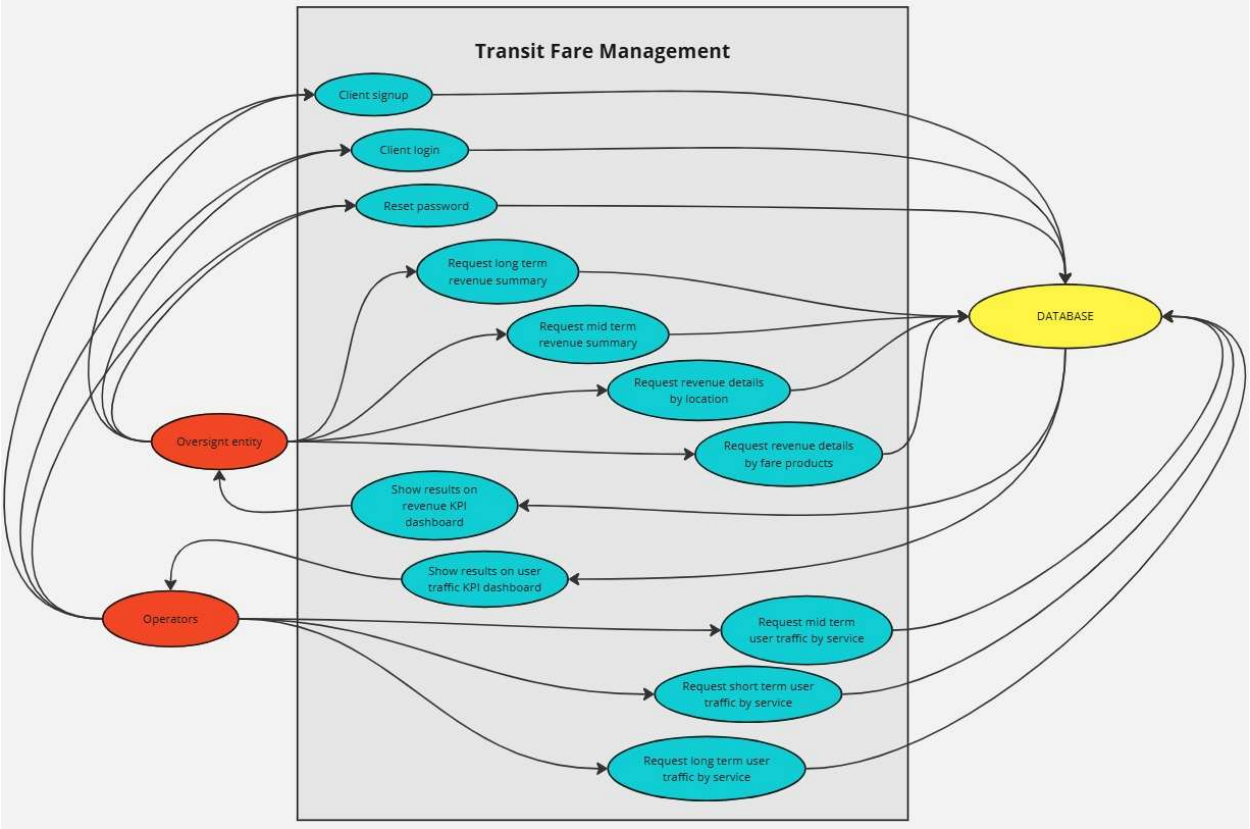


Figure 3. Transit Fare Management Use Case Diagram

In the second step, the entities and related variables required to support the functional requirements of the database are established. The results of that steps are illustrated in the class and database diagrams, shown in Figures 4 and 5, respectively.

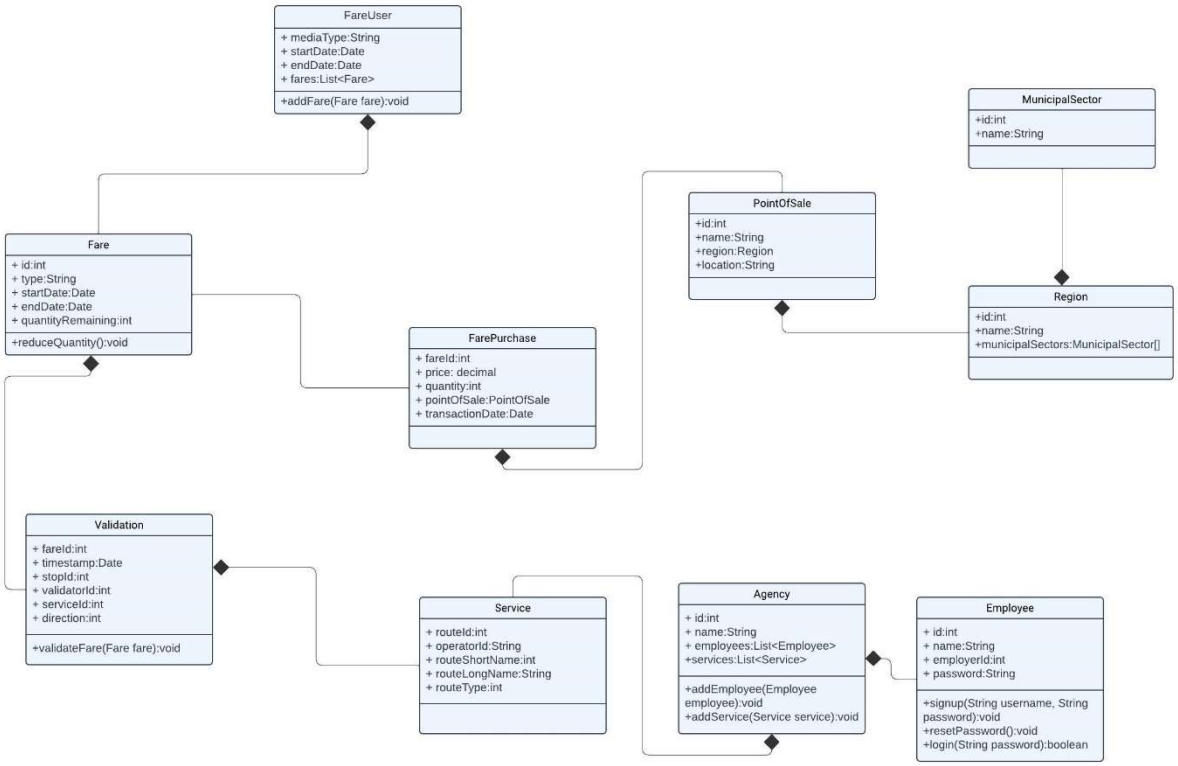


Figure 4. Transit Fare Management Class Diagram

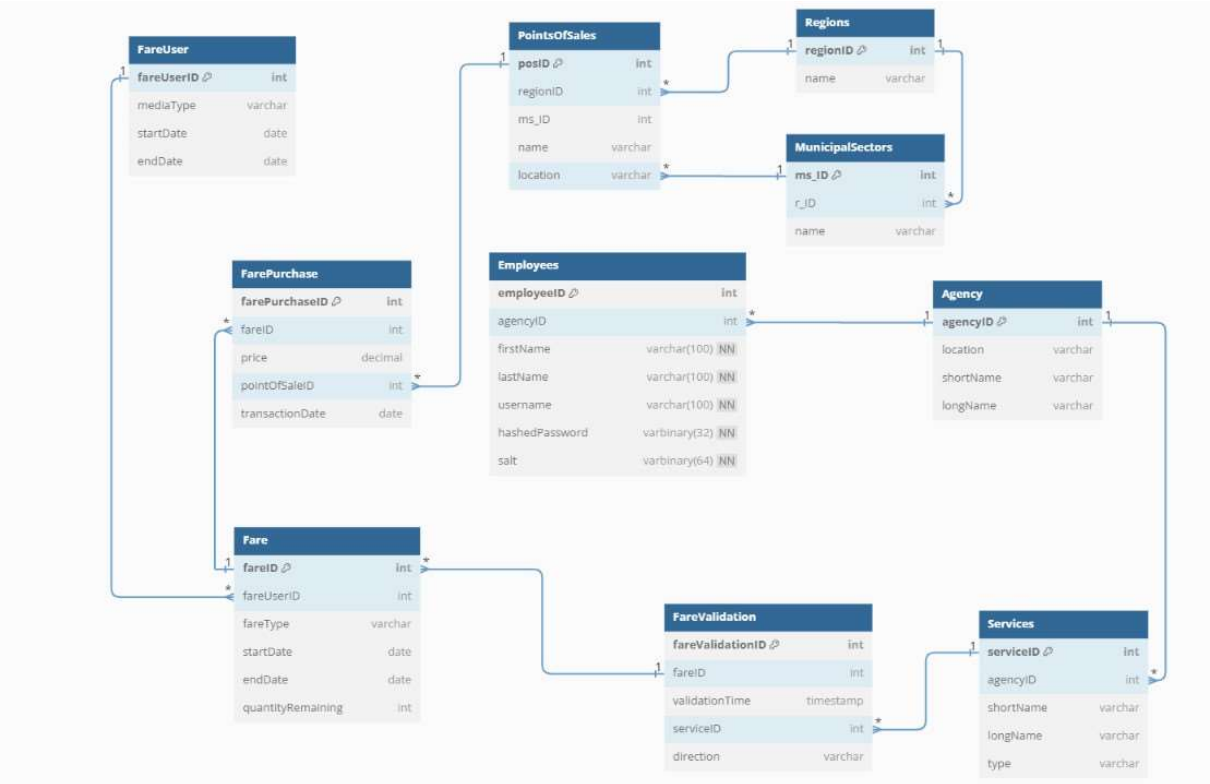


Figure 5. Transit Fare Management Database Diagram

5. USE CASE SCENARIOS

On the basis of the use case diagram in Figure 3, a total of 11 use cases, described in Tables 3 to 13 respectively. These use cases have been programmed in the database and their results are discussed in Section 6.

Table 3. Signup New User

Use case ID	UC01
Use case name	Client signup
Description	The system administrator must signup new users so that they can sign in.
Actor	System administrator with privileges to signup new users.
Pre-conditions	
Post-conditions	The system administer will receive confirmation that the user has been registered or that there was an error.
Triggering event	The system administrator triggers a signup from their dashboard.
Flow of events	• The process takes a username and password, as well as information about the employee being signed up. • The process searches for the username in the database and returns error code 0 if it already exists. • A salt is created which is hashed together with the password. • A new record is created in the Employees table, storing the employee's details along with the hashed password.
Alternate flow	None
Exceptional flow	A user already exists with the chosen username.

Table 4. Login

Use case ID	UC02
Use case name	Client login
Description	The employee of a client must login to access the revenue or user traffic KPI dashboard.
Actor	Employees of the operators or oversight entity who are pre-registered.
Pre-conditions	The employees must be registered by the system administrator.
Post-conditions	The employees are directed to their allowed dashboard.
Triggering event	The employee accesses the login page from the front-end web application.
Flow of events	• The process accepts as username and password. • If the username does not exist in the database, an error code of -1 is returned. • The password is hashed along with the salt from the record from the employees table corresponding to the provided username. • The result of the hash is compared against the hashedPassword stored in the Employees table. • If the hashed result does not match the hashedPassword, an error code of 0 is returned. • A success code of 1 is returned.
Alternate flow	None
Exceptional flow	No access is granted for a wrong user account or password.

Table 5. Reset Password

Use case ID	UC03
Use case name	Reset Password
Description	The employee of a client has lost access or had their password compromised and must reset their password.
Actor	The employee of a client who must reset their password.
Pre-conditions	The employee must receive a reset password link in their email or from the system administrator.
Post-conditions	The employee's password is reset.
Triggering event	The employee clicks the provided link to reset their password.
Flow of events	• The process accepts as username and password. • If the username does not exist in the database, an error code of 0 is returned. • A salt is created which is hashed together with the password. • The record in the employees table corresponding to the provided username is updated with the new hashedPassword and salt.
Alternate flow	None
Exceptional flow	No employee is found with the username provided to the procedure and an error code is returned.

Table 6. Request long term revenue summary

Use case ID	UC04
Use case name	Request long term revenue summary.
Description	Long term revenue summaries on a yearly basis, for a selected period of years, ending with a selected year, globally, online, from buses and by the regions defined by ARTM.
Actor	Oversight entity
Pre-conditions	The employee must be logged-in to gain access.
Post-conditions	The results are called by use case UC10, powering the KPI for fare purchase analyses.
Triggering event	The employee makes a request, entering the number of years and the end year of the summary.
Flow of events	• The process iterates through all sources of sales (online, buses, regions), one by one. • With each iteration by sources of sales, the process iterates through all years of the period covered by the summary. • With each iteration by years, the process calculates the revenue for the given sources of sales and year.
Alternate flow	None
Exceptional flow	None

Table 7. Request mid term revenue summary

Use case ID	UC05
Use case name	Request mid term revenue summary.
Description	Mid term revenue summaries on a monthly basis for a selected year, globally, online, from buses and by the regions defined by ARTM.
Actor	Oversight entity
Pre-conditions	The employee must be logged-in to gain access.
Post-conditions	The results are called by use case UC10, powering the KPI for fare purchase analyses.
Triggering event	The employee makes a request, entering the year for which the summary is required.
Flow of events	• The process iterates through all sources of sales (online, buses, regions), one by one. • With each iteration by sources of sales, the process iterates through all the months. • With each iteration by months, the process calculates the revenue for the given sources of sales and month.
Alternate flow	None
Exceptional flow	None

Table 8. Request revenue details by fare product

Use case ID	UC06
Use case name	Request revenue details by fare product.
Description	Revenue details for a selected year, on a yearly and monthly bases, by fare products.
Actor	Oversight entity
Pre-conditions	The employee must be logged-in to gain access.
Post-conditions	The results are called by use case UC10, powering the KPI for fare purchase analyses.
Triggering event	The employee makes a request, entering the year for which the details are required.
Flow of events	• The process iterates through all fare products (two tickets, ten tickets, monthly pass), one by one. • With each iteration by fare products, the process iterates through all the months and the full year. • With each iteration by months or full year, the process calculates the revenue for the given fare products and time period.
Alternate flow	None
Exceptional flow	None

Table 9. Request revenue details by location

Use case ID	UC07
Use case name	Request revenue details by location.
Description	Revenue details for a selected year, on a yearly and monthly bases, by points of sales.
Actor	Oversight entity
Pre-conditions	The employee must be logged-in to gain access.
Post-conditions	The results are called by use case UC10, powering the KPI for fare purchase analyses.
Triggering event	The employee makes a request, entering the year for which the details are required.
Flow of events	• The process iterates through all points of sales, one by one. • With each iteration by points of sales, the process iterates through all the months and the full year. • With each iteration by months or full year, the process calculates the revenue for the given point of sales and time period.
Alternate flow	None
Exceptional flow	None

Table 10. Request long to mid-term user traffic by service

Use case ID	UC08
Use case name	Request mid-term user traffic by service.
Description	Fare user traffic on yearly and monthly basis, for a selected year and service (i.e., each bus and train lines, in both directions).
Actor	Operators
Pre-conditions	The employee must be logged-in to gain access.
Post-conditions	The results are called by use case UC11, powering the KPI for user traffic analyses.
Triggering event	The employee makes a request, entering the year and service for which the details are required.
Flow of events	• The process iterates through all the months and the full year, one by one. • With each iteration by time period, the process iterates through all traffic direction possibility (both together and each one separately). • With each iteration by direction possibility, the process calculates sum of fare validation for the requested service, for the given time period and direction possibility.
Alternate flow	None
Exceptional flow	None

Table 11. Request short term user traffic by service

Use case ID	UC09
Use case name	Request short term user traffic by service.
Description	Fare user traffic on daily, hourly and peak periods on all services individually (i.e., each bus and train lines, in both directions).
Actor	Operations
Pre-conditions	The employee must be logged-in to gain access.
Post-conditions	The results are called by use case UC11, powering the KPI for user traffic analyses.
Triggering event	The employee makes a request, entering the date of the day and service for which the details are required.
Flow of events	• The process iterates through all the hours and the full day, one by one • With each iteration by time period, the process iterates through all traffic direction possibility (both together and each one separately) • With each iteration by direction possibility, the process calculates sum of fare validation for the requested service, for the given time period and direction possibility.
Alternate flow	None
Exceptional flow	None

Table 12. Request current year user traffic with long term statistics by service

Use case ID	UC10
Use case name	Request long-term user traffic by service.
Description	Fare user traffic on yearly and monthly basis, for a selected year, a period of years, ending with the selected year, service and direction of traffic (i.e., each bus and train lines).
Actor	Operators
Pre-conditions	The employee must be logged-in to gain access.
Post-conditions	The results are called by use case UC11, powering the KPI for user traffic analyses.
Triggering event	The employee makes a request, entering the number of years, the end year of the summary, the service and direction for which the details are required.
Flow of events	• The process iterates through the year and all months, one by one. • With each iteration by year and months, the process iterates through all years of the period covered by the summary. • With each iteration by years, the process calculates user traffic for the year and the months of that year.
Alternate flow	None
Exceptional flow	None

Table 13. Show results on revenue KPI dashboard

Use case ID	UC11
Use case name	Show results on revenue KPI dashboard.
Description	Collect and show results deriving from requests made by the actor through use case UC04 to UC07.
Actor	Oversight entity
Pre-conditions	The employee must be logged-in to gain access.
Post-conditions	The results from that use case are intended to be transferred to a front-end web application.
Triggering event	The employee makes a request on fare purchase revenues (UC04 to UC07).
Flow of events	The request calls either the procedure for long-term revenue summary, mid-term revenue summary, revenue details by fare products, or revenue details by points of sales, in line with the request made by the employee.
Alternate flow	None
Exceptional flow	None

Table 14. Show results on user traffic KPI dashboard

Use case ID	UC12
Use case name	Show results on revenue KPI dashboard.
Description	Collect and show results deriving from requests made by the actor through use case UC08 to UC10.
Actor	Operators
Pre-conditions	The employee must be logged-in to gain access.
Post-conditions	The results from that use case are intended to be transferred to a front-end web application.
Triggering event	The employee makes a request on user traffic by service from fare validation (UC08 to UC10).
Flow of events	The request calls either the procedure for long-term user traffic by service, mid-term user traffic by service, or short-term user traffic by service, in line with the request made by the employee.
Alternate flow	None
Exceptional flow	None

6. TESTING

6.1. Creation of the Tables in the Database

The tables shown in Figure 5 can be created for the fare transit management database from SQL statements developed as part of the project. These statements are stored in SQL query files and should be executed in the following order:

- 01_AgencyTable.sql, which creates and populates the Agency table;
- 02_EmployeesTable.sql, which creates and populates the Employees table;
- 03_ServicesTable.sql, which creates and populates the Services table;
- 04_RegionsTable.sql, which creates and populates the Regions table;
- 05_MunicipalSectorsTable.sql, which creates and populates the MunicipalSectors table;
- 06_PointsOfSalesTable.sql, which creates and populates the PointsOfSales table;
- 07to10_FareAndValidationTables.sql, which creates the FareUser, Fare, FarePurchase and FareValidation tables, in that order.

The agencies included in the Agency table, identify all public transit corporations operating in the Montreal metropolitan area, all known as a matter of public notoriety. That table includes:

- The Autorité régionale de transport (ARTM), the oversight entity (ARTM website);
- The Société de transport de Montréal (STM), an operator covering the Montreal Island (STM website);
- The Réseau de transport métropolitain (EXO), an operator covering suburban areas (EXO website);
- The Société de transport de Longueuil (RTL), an operator covering the south shore region that encompasses Longueuil, Brossard, Boucherville, etc. (RTL website);
- The Société de transport de Laval (STL), the operator covering the city of Laval (STL website); and
- The Réseau express métropolitain (REM), an operator covering western parts of the Montreal metropolitan areas (REM website).

The data included in the Employees table are entirely fictious, and just intended to assign one employee for each of the agencies in the Agency table.

The data in the Services tables have represent all metro, trains and bus services in operation in the Montreal metropolitan areas. These data have been extracted from General Transit Feed Specifications (GTFS) data available online from the websites of the STM, EXO, RTL and STL operators.

The data for the Regions and MunicipalSectors tables have been obtained from the ARTM free data depot for the 2018 origin-destination study (Portail données mobilité de l'ARTM). The regions divide the Montreal metropolitan area into eight parts: 1) the Montréal Centre-ville region, 2) the Montréal centre region, 3) the Montréal est region, 4) the Montréal ouest region, 5) the Rive-sud (south shore) region, 6) the Laval region, 7) the Couronne Nord (north crown suburbs) region, and 8) the Couronne Sud (south crown suburbs) regions. The municipal sectors are further sub-division within regions, and are approximately illustrated in Figure 6.

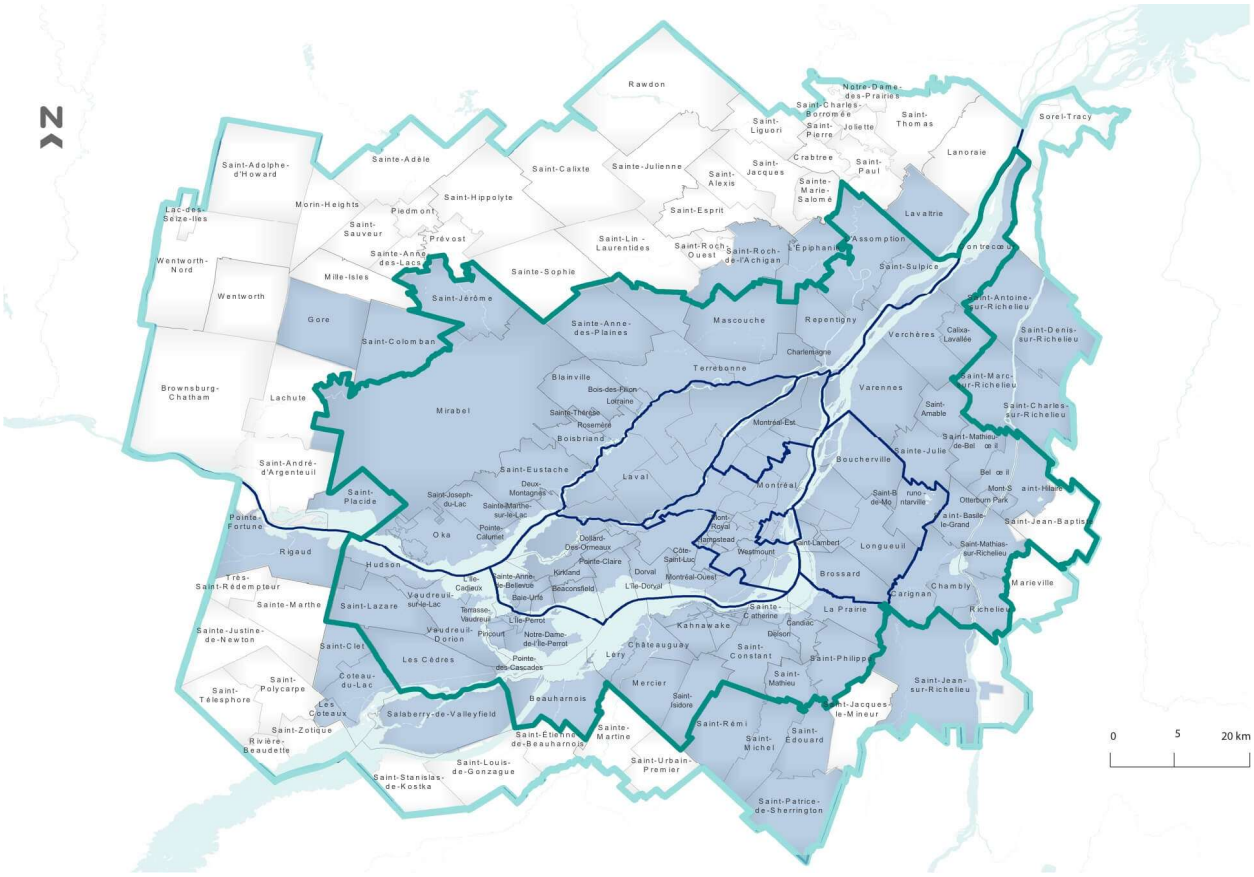


Figure 6. ARTM Regions and Municipal Sectors

The data for the PointsOfSales table are part real and part fictious. The ARTM catalogs 775 points of sales within the Montreal metropolitan area (Points de vente ARTM)). Metro and trains stations are well points of sales and constitutes the real data included in the PointsOfSales table. All other points of sales in that table were artificially generated, at a count:

- Nine points of sales in municipal sectors within the Montreal Island (regions 1 to 4);
- Seven points of sales in municipal sectors within the south shore and Laval (regions 5 and 6); and
- Three points of sales in municipal sectors within the suburban crowns (regions 7 and 8).

The points of sales included in the PointsOfSales table totals 783, which is closed to the actual number catalogued by ARTM.

There is no readily available data to populate the FareUser, Fare, FarePurchase and FareValidation tables, and therefore they have been populated by a data generator specifically developed for this project.

The data generator simulates in a simplified manor the use of the transit system. Several variables are defined including the number of users to be created, the length of time to simulate, and various behaviours for the users. For our purposes we are creating 1000 users over a period of 5 years. For each user that is created, the program steps day by day through each day in the simulation period for which the user is valid. The user purchases a fare if necessary and then has a chance of taking transit based on predefined probabilities. Each user is assigned a service which they are most likely to use, although they have a chance of using a different service on any given day. The result is data that while simplified, is sufficient for testing procedures.

6.2. Application of the Use Cases

The functions and procedures developed for the used cases described in Section 5 have been tested after creating and populating the tables in the database. The following presents results obtained from functions and procedures.

From UC1 (client signup), UC2 (client login) and UC3 (reset password), the possible outcomes are summarized in Table 15.

Table 15. Possible Results from Use Cases UC01, UC02 and UC03

Use case	Possible results
UC01	• Code 0 – Username already exists in database. • Code 1 – User successfully added to database.
UC02	• Code -1 – Username not found in database. • Code 0 – Password incorrect for user. • Code 1 – User successfully logged in.
UC03	• Code 0 – Username not found in database. • Code 1 – Password successfully reset.

Figures 7 to 10 illustrates examples of using the functionalities of use case UC04 to UC07. As well:

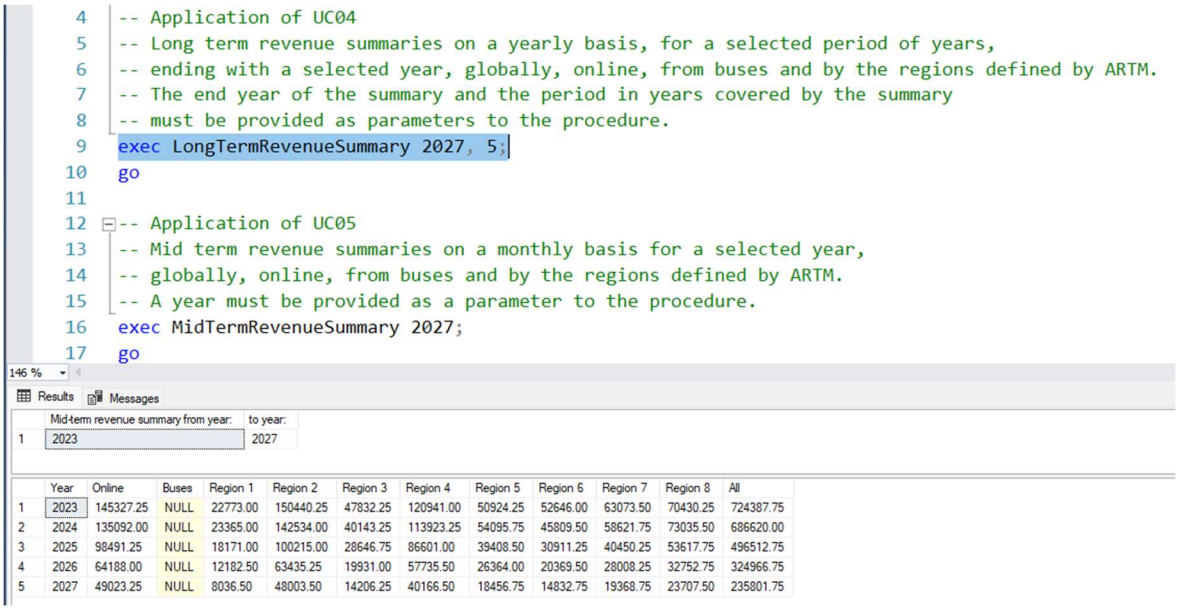
- Figures 11 and 12 illustrate the use of use case UC08;
- Figures 13 and 14 illustrate the use of use case UC09; and
- Figures 15, 16 and 17 illustrate the use of use case UC10.

In order to limit the database to a reasonable size, the generation of data has been limited to only a few years and transit services. As such, the database covers only:

- The years 2023 to 2027 in full;
- The transit services identified by serviceID 1, 2, 3, and 4, for the metro lines; and
- The transit service identified by serviceID 13, 16, 40, 51, 77, 89, 102, 110 and 191, corresponding the busiest bus line in Montreal (bus numbers 18, 24, 51, 67, 105, 121, 141, 165 and 439).

It must be understood as well that user traffic on buses is divided into two directions, 0 and 1. One of these two integer must be provided for applying use case UC10. Alternatively, the value null adds the results of both directions. Unlike bus lines, it is not possible to assign a specific direction of traffic during fare validation for the metro lines. Using direction 0 and 1 results in no user traffic; however, using null provides total user traffic.

Despite its very modest size by the standard of a normal fare transit management, the database in use for this project does possess a certain volume. The FareValidation table alone contains nearly one million entries. As a consequence, executing the use cases may take a noticeable amount of time.



```
-- Application of UC04
-- Long term revenue summaries on a yearly basis, for a selected period of years,
-- ending with a selected year, globally, online, from buses and by the regions defined by ARTM.
-- The end year of the summary and the period in years covered by the summary
-- must be provided as parameters to the procedure.
exec LongTermRevenueSummary 2027, 5;
go

-- Application of UC05
-- Mid term revenue summaries on a monthly basis for a selected year,
-- globally, online, from buses and by the regions defined by ARTM.
-- A year must be provided as a parameter to the procedure.
exec MidTermRevenueSummary 2027;
go
```

Results | Messages

	Mid-term revenue summary from year:	to year:
1	2023	2027

	Year	Online	Buses	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8	All
1	2023	145327.25	NULL	22773.00	150440.25	47832.25	120941.00	50924.25	52646.00	63073.50	70430.25	724387.75
2	2024	135092.00	NULL	23365.00	142534.00	40143.25	113923.25	54095.75	45809.50	58621.75	73035.50	686620.00
3	2025	98491.25	NULL	18171.00	100215.00	28646.75	86601.00	39408.50	30911.25	40450.25	53617.75	496512.75
4	2026	64188.00	NULL	12182.50	63435.25	19931.00	57735.50	26364.00	20369.50	28008.25	32752.75	324966.75
5	2027	49023.25	NULL	8036.50	48003.50	14206.25	40166.50	18456.75	14832.75	19368.75	23707.50	235801.75

Figure 7. Example of UC04 Use – Long Term Revenue Summary

```
12 -- Application of UC05
13 -- Mid term revenue summaries on a monthly basis for a selected year,
14 -- globally, online, from buses and by the regions defined by ARTM.
15 -- A year must be provided as a parameter to the procedure.
16 exec MidTermRevenueSummary 2027;
17 go
18
19 -- Application of UC06
20 -- Revenue details for a selected year, on a yearly and monthly bases, by fare products.
```

146 %

Results | Messages

	Mid-term revenue summary for year:
1	2027

	Region	January	February	March	April	May	June	July	August	September	October	November	December
1	Buses	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
2	Online	3660.00	4394.00	3995.50	4471.25	4223.25	4558.00	3628.25	4007.25	4521.25	3668.50	3559.00	4337.00
3	Region 1	741.50	794.25	694.50	497.75	734.25	294.50	454.00	761.00	794.25	1015.00	768.00	487.50
4	Region 2	3275.00	3091.75	3319.75	3946.25	4377.25	4520.50	3788.00	4552.25	4340.75	4245.75	3953.50	4592.75
5	Region 3	1309.50	1194.25	1236.00	1276.50	1248.25	1516.50	1115.00	1175.00	955.25	1369.00	1436.00	375.00
6	Region 4	3540.00	2813.50	3533.00	3325.25	2683.00	3398.50	4299.00	3821.00	2745.25	3874.50	2713.75	3419.75
7	Region 5	1596.75	1166.00	1642.75	1476.25	1509.50	1117.00	1730.00	1576.25	1596.75	1422.00	1442.00	2181.50
8	Region 6	1296.00	1162.25	1335.75	1502.50	1022.25	762.50	1222.00	1716.25	930.50	950.00	1830.25	1102.50
9	Region 7	2024.25	2282.50	1969.00	1284.75	2083.50	1516.25	1590.00	1183.25	1269.25	1356.50	1535.25	1274.25
10	Region 8	2456.50	2270.25	1712.50	1670.50	1982.75	1751.25	2325.00	1348.25	2405.50	1779.25	2137.00	1868.75
11	Total	19899.50	19168.75	19438.75	19451.00	19864.00	19435.00	20151.25	20140.50	19558.75	19680.50	19374.75	19639.00

Figure 8. Example of UC05 Use – Mid Term Revenue Summary

```
19 -- Application of UC06
20 -- Revenue details for a selected year, on a yearly and monthly bases, by fare products.
21 -- A year must be provided as a parameter to the procedure.
22 exec RevenueDetailsFareProducts 2027;
23 go
24
25 -- Application of UC07
26 -- Revenue details for a selected year, on a yearly and monthly bases, by points of sales.
```

146 %

Results | Messages

	Sales by fare products for year:
1	2027

	Product	January	February	March	April	May	June	July	August	September	October	November	December	TotalYear
1	twoTrips	1078.00	980.00	1050.00	1162.00	910.00	1246.00	1064.00	987.00	1071.00	1127.00	1120.00	952.00	12747.00
2	tenTrips	4721.50	4488.75	4488.75	4389.00	5054.00	4389.00	5087.25	5253.50	4887.75	5253.50	4754.75	5187.00	57954.75
3	monthly	14100.00	13700.00	13900.00	13900.00	13900.00	13800.00	14000.00	13900.00	13600.00	13300.00	13500.00	13500.00	165100.00

Figure 9. Example of UC06 Use – Revenue Details by Fare Products

```
25 -- Application of UC07
26 -- Revenue details for a selected year, on a yearly and monthly bases, by points of sales.
27 -- A year must be provided as a parameter to the procedure.
28 exec RevenueDetailsPOS 2027;
29 go
30
```

146 %

Results | Messages

	Sales at points of sale for year:
1	2027

	Name	PointOfSaleID	January	February	March	April	May	June	July	August	September	October	November	December	TotalYear
1	Online	1	3660.00	4394.00	3995.50	4471.25	4223.25	4558.00	3628.25	4007.25	4521.25	3668.50	3559.00	4337.00	49023.25
2	Bus	2	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL
3	Gare Brossard	3	NULL	NULL	7.00	NULL	NULL	NULL	NULL	NULL	133.25	NULL	NULL	NULL	140.25
4	Gare Du Quartier	4	NULL	NULL	NULL	NULL	NULL	NULL	66.50	NULL	NULL	NULL	33.25	NULL	99.75
5	Gare Panama	5	100.00	NULL	NULL	NULL	NULL	NULL	NULL	100.00	NULL	NULL	NULL	100.00	300.00
6	Gare Île-des-sœurs	6	NULL	NULL	7.00	NULL	33.25	233.25	NULL	NULL	NULL	NULL	NULL	NULL	273.50
7	Gare centrale	7	NULL	NULL	NULL	NULL	33.25	NULL	NULL	NULL	100.00	NULL	NULL	NULL	133.25
8	Métro Angrignon	8	NULL	NULL	100.00	NULL	233.25	NULL	NULL	100.00	33.25	NULL	NULL	NULL	466.50
9	Métro Monk	9	NULL	NULL	100.00	NULL	73.50	NULL	NULL	NULL	NULL	NULL	NULL	NULL	173.50
10	Métro Jolicoeur	10	NULL	33.25	NULL	NULL	33.25	NULL	NULL	NULL	NULL	NULL	NULL	NULL	66.50
11	Métro Verdun	11	107.00	NULL	NULL	7.00	NULL	NULL	33.25	NULL	NULL	100.00	NULL	7.00	254.25
12	Métro De L'Église	12	NULL	NULL	NULL	NULL	133.25	NULL	100.00	133.25	NULL	NULL	33.25	100.00	499.75
13	Métro LaSalle	13	NULL	NULL	73.50	NULL	100.00	33.25	7.00	100.00	NULL	7.00	33.25	NULL	354.00
14	Métro Charlevoix	14	NULL	100.00	NULL	NULL	NULL	73.50	NULL	NULL	NULL	NULL	NULL	NULL	173.50
15	Métro Lionel-Groulx	15	NULL	7.00	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	107.00	114.00

Figure 10. Example of UC07 Use – Revenue Details by Points of Sales

```
4  -- Application of UC08
5  -- Fare user traffic on yearly and monthly basis,
6  -- for a selected year and service (i.e., each bus and train lines, in both directions)
7  -- A year and a service ID must be provided as parameters to the procedure.
8  exec MidTermTraffic 2027, 1;
9  go
10
11 -- Application of UC09
12 -- Request Short Term User Traffic by Service; daily and hourly
13 -- on all services individually (i.e., each bus and train lines, in both directions)
14 -- A date ('yyyy-mm-dd') and a service ID must be provided as parameters to the procedure.
15 exec ShortTermTrafficProc '2023-02-25', 33;
16 go
17
```

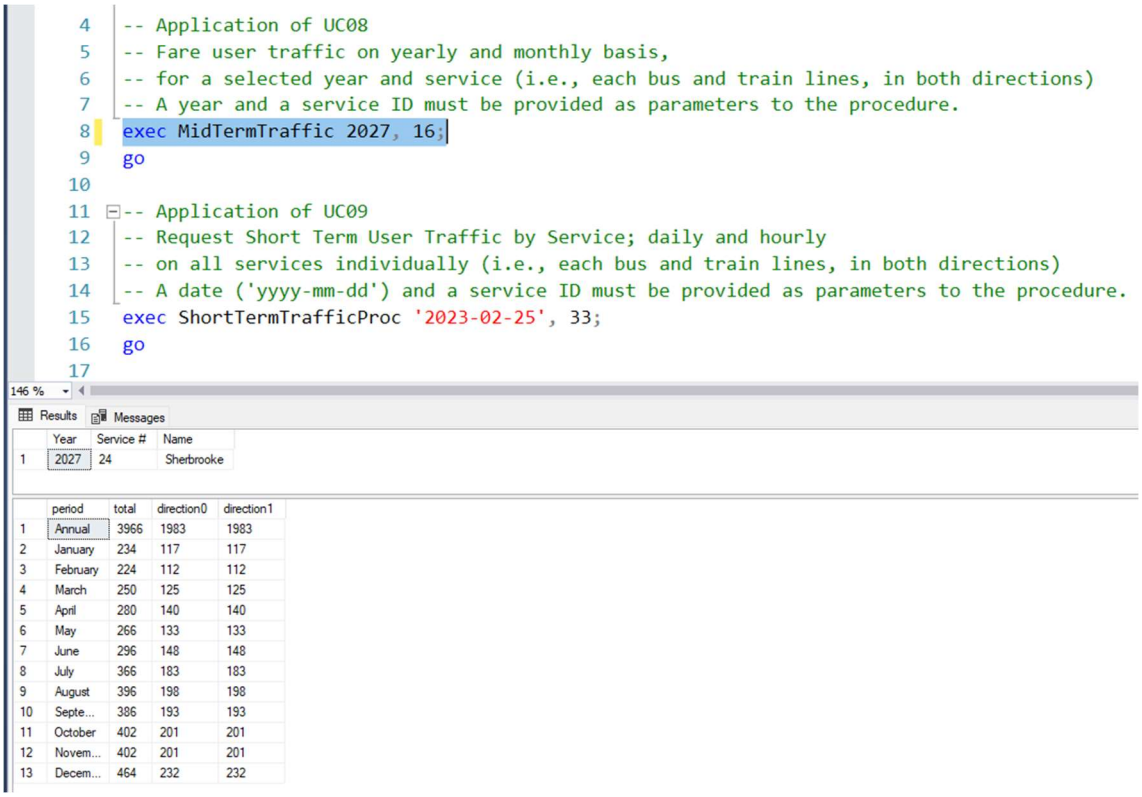
146 %

Results | Messages

	Year	Service #	Name
1	2027	1	Ligne 1 - Verte

	period	total	direction0	direction1
1	Annual	14148	0	0
2	January	1130	0	0
3	February	1098	0	0
4	March	1186	0	0
5	April	1198	0	0
6	May	1234	0	0
7	June	1238	0	0
8	July	1310	0	0
9	August	1216	0	0
10	Septe...	1166	0	0
11	October	1128	0	0
12	Novem...	1104	0	0
13	Decem...	1140	0	0

Figure 11. First Example of UC08 Use – Mid Term User Traffic (Metro)



```
4  -- Application of UC08
5  -- Fare user traffic on yearly and monthly basis,
6  -- for a selected year and service (i.e., each bus and train lines, in both directions)
7  -- A year and a service ID must be provided as parameters to the procedure.
8  exec MidTermTraffic 2027, 16;
9  go
10
11 -- Application of UC09
12 -- Request Short Term User Traffic by Service; daily and hourly
13 -- on all services individually (i.e., each bus and train lines, in both directions)
14 -- A date ('yyyy-mm-dd') and a service ID must be provided as parameters to the procedure.
15 exec ShortTermTrafficProc '2023-02-25', 33;
16 go
17
```

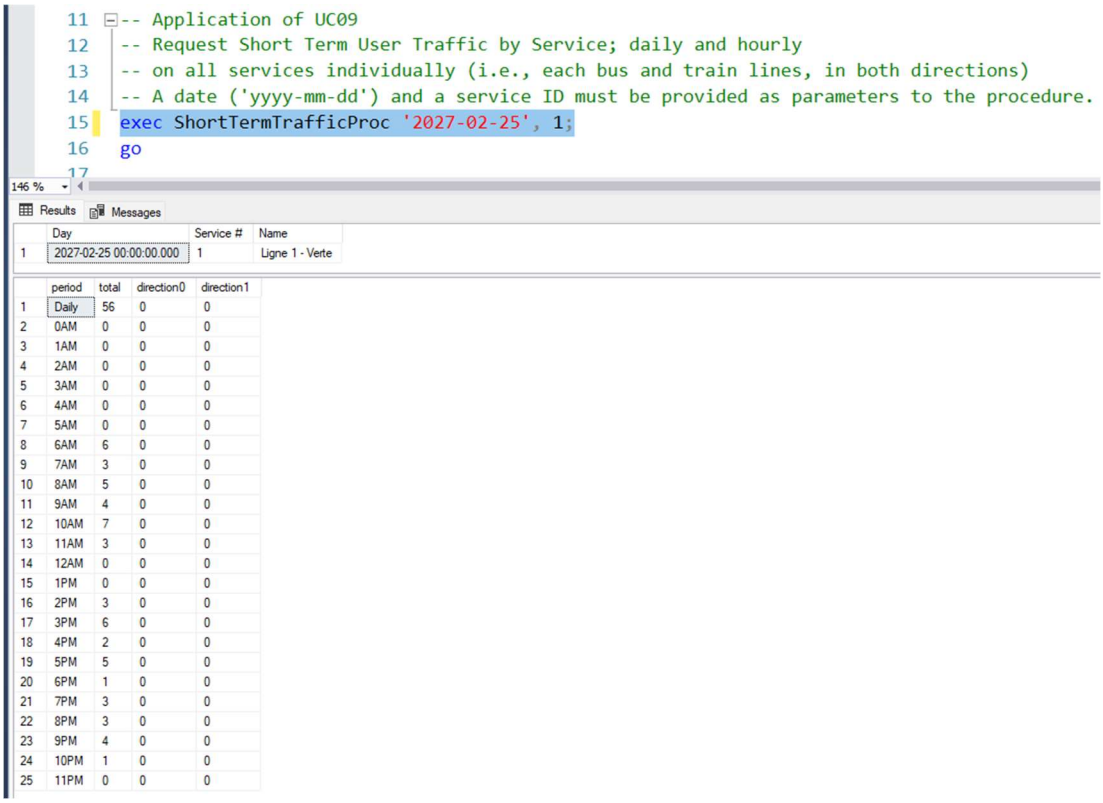
146 %

Results | Messages

	Year	Service #	Name
1	2027	24	Sherbrooke

	period	total	direction0	direction1
1	Annual	3966	1983	1983
2	January	234	117	117
3	February	224	112	112
4	March	250	125	125
5	April	280	140	140
6	May	266	133	133
7	June	296	148	148
8	July	366	183	183
9	August	396	198	198
10	Septe...	386	193	193
11	October	402	201	201
12	Novem...	402	201	201
13	Decem...	464	232	232

Figure 12. Second Example of UC08 Use – Mid Term User Traffic (Bus)



```
11 -- Application of UC09
12 -- Request Short Term User Traffic by Service; daily and hourly
13 -- on all services individually (i.e., each bus and train lines, in both directions)
14 -- A date ('yyyy-mm-dd') and a service ID must be provided as parameters to the procedure.
15 exec ShortTermTrafficProc '2027-02-25', 1;
16 go
17
```

146 %

Results | Messages

	Day	Service #	Name
1	2027-02-25 00:00:00.000	1	Ligne 1 - Verte

	period	total	direction0	direction1
1	Daily	56	0	0
2	0AM	0	0	0
3	1AM	0	0	0
4	2AM	0	0	0
5	3AM	0	0	0
6	4AM	0	0	0
7	5AM	0	0	0
8	6AM	6	0	0
9	7AM	3	0	0
10	8AM	5	0	0
11	9AM	4	0	0
12	10AM	7	0	0
13	11AM	3	0	0
14	12AM	0	0	0
15	1PM	0	0	0
16	2PM	3	0	0
17	3PM	6	0	0
18	4PM	2	0	0
19	5PM	5	0	0
20	6PM	1	0	0
21	7PM	3	0	0
22	8PM	3	0	0
23	9PM	4	0	0
24	10PM	1	0	0
25	11PM	0	0	0

Figure 13. First Example of UC09 Use – Short Term User Traffic (Metro)

```
11 -- Application of UC09
12 -- Request Short Term User Traffic by Service; daily and hourly
13 -- on all services individually (i.e., each bus and train lines, in both directions)
14 -- A date ('yyyy-mm-dd') and a service ID must be provided as parameters to the procedure.
15 exec ShortTermTrafficProc '2027-02-25', 16;
16 go
```

146 %

Results | Messages

	Day	Service #	Name
1	2027-02-25 00:00:00.000	24	Sherbrooke

	period	total	direction0	direction1
1	Daily	10	0	0
2	0AM	0	0	0
3	1AM	0	0	0
4	2AM	0	0	0
5	3AM	0	0	0
6	4AM	0	0	0
7	5AM	0	0	0
8	6AM	0	0	0
9	7AM	1	1	0
10	8AM	1	1	0
11	9AM	1	0	1
12	10AM	0	0	0
13	11AM	2	1	1
14	12AM	0	0	0
15	1PM	0	0	0
16	2PM	0	0	0
17	3PM	0	0	0
18	4PM	0	0	0
19	5PM	2	0	2
20	6PM	0	0	0
21	7PM	2	1	1
22	8PM	0	0	0
23	9PM	1	1	0
24	10PM	0	0	0
25	11PM	0	0	0

Figure 14. Second Example of UC09 Use – Short Term User Traffic (Bus)

```
18 -- Application of UC10
19 -- Fare user traffic on yearly and monthly basis, for a selected year, a period of years, ending with the selected year,
20 -- service and direction of traffic (i.e., each bus and train lines)
21 -- The end year of the summary and the period in years covered by the summary,
22 -- along with the service ID and direction of traffic must be provided as parameters to the procedure.
23 -- The direction of traffic is either 0, 1 or null, the latter combining both directions 0 and 1.
24 exec LongTermTrafficProc 2027, 5, 1, null;
25 go
```

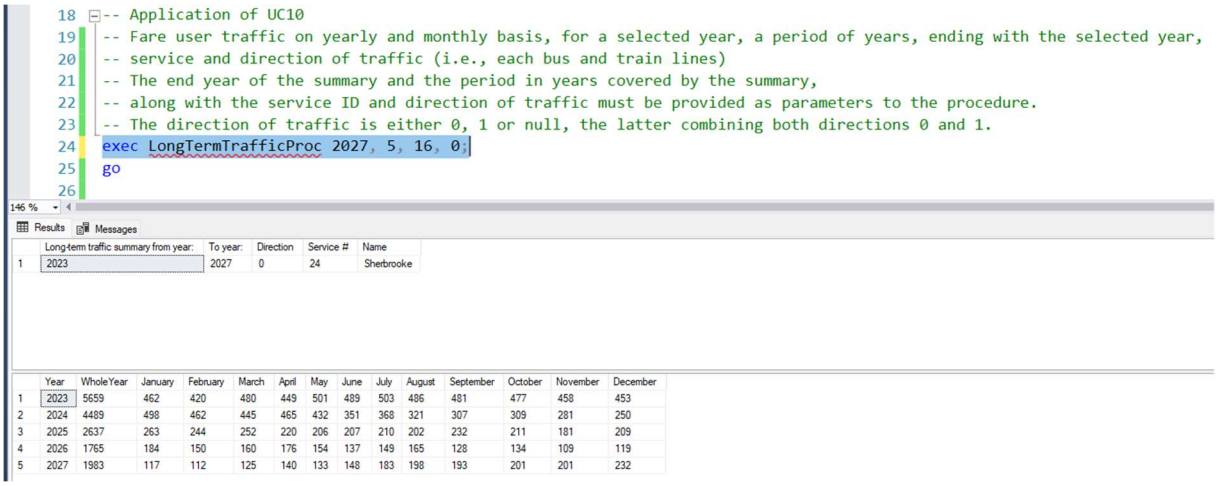
146 %

Results | Messages

	Long-term traffic summary from year:	To year:	Direction	Service #	Name
1	2023	2027	NULL	1	Ligne 1 - Verte

	Year	Whole Year	January	February	March	April	May	June	July	August	September	October	November	December
1	2023	38940	3292	2926	3352	2938	3210	3156	3234	3374	3318	3428	3428	3284
2	2024	37768	3522	3130	3154	3288	3342	3122	3314	3210	2984	3016	2790	2896
3	2025	26932	2838	2332	2330	2258	2270	2128	2346	2178	2108	2146	1934	2064
4	2026	20224	2010	1780	1864	1874	1842	1838	1834	1662	1526	1420	1322	1252
5	2027	14148	1130	1098	1186	1198	1234	1238	1310	1216	1166	1128	1104	1140

Figure 15. First Example of UC10 Use – Long Term User Traffic (Metro)



```
18  -- Application of UC10
19  -- Fare user traffic on yearly and monthly basis, for a selected year, a period of years, ending with the selected year,
20  -- service and direction of traffic (i.e., each bus and train lines)
21  -- The end year of the summary and the period in years covered by the summary,
22  -- along with the service ID and direction of traffic must be provided as parameters to the procedure.
23  -- The direction of traffic is either 0, 1 or null, the latter combining both directions 0 and 1.
24  exec LongTermTrafficProc 2027, 5, 16, 0;
25  go
26
```

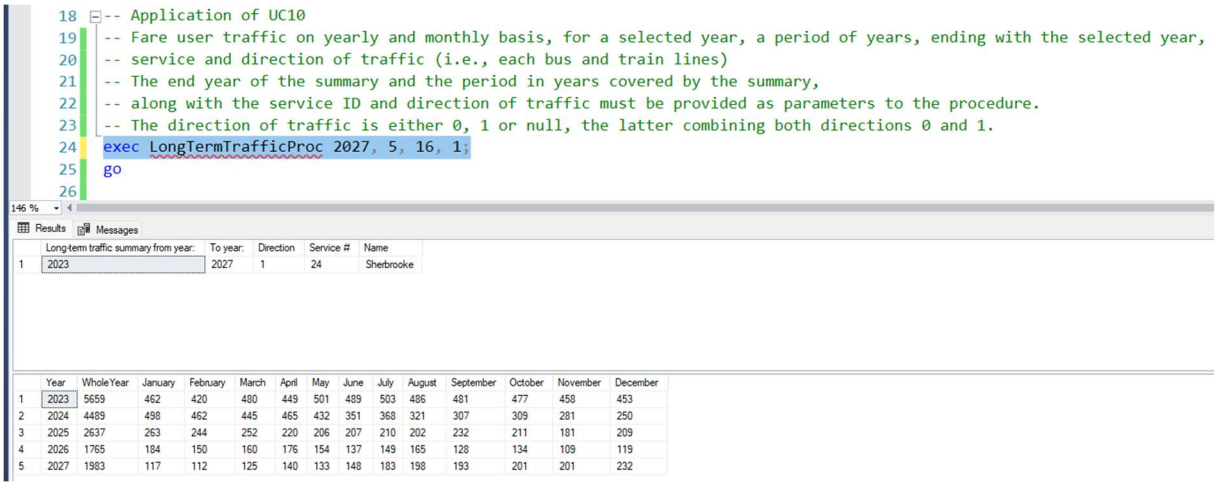
146 %

Results | Messages

	Long-term traffic summary from year:	To year:	Direction	Service #	Name
1	2023	2027	0	24	Sherbrooke

	Year	Whole Year	January	February	March	April	May	June	July	August	September	October	November	December
1	2023	5659	462	420	480	449	501	489	503	486	481	477	458	453
2	2024	4489	498	462	445	465	432	351	368	321	307	309	281	250
3	2025	2637	263	244	252	220	206	207	210	202	232	211	181	209
4	2026	1765	184	150	160	176	154	137	149	165	128	134	109	119
5	2027	1983	117	112	125	140	133	148	183	198	193	201	201	232

Figure 16. Second Example of UC10 Use – Long Term User Traffic (Bus, Direction 0)



```
18  -- Application of UC10
19  -- Fare user traffic on yearly and monthly basis, for a selected year, a period of years, ending with the selected year,
20  -- service and direction of traffic (i.e., each bus and train lines)
21  -- The end year of the summary and the period in years covered by the summary,
22  -- along with the service ID and direction of traffic must be provided as parameters to the procedure.
23  -- The direction of traffic is either 0, 1 or null, the latter combining both directions 0 and 1.
24  exec LongTermTrafficProc 2027, 5, 16, 1;
25  go
26
```

146 %

Results | Messages

	Long-term traffic summary from year:	To year:	Direction	Service #	Name
1	2023	2027	1	24	Sherbrooke

	Year	Whole Year	January	February	March	April	May	June	July	August	September	October	November	December
1	2023	5659	462	420	480	449	501	489	503	486	481	477	458	453
2	2024	4489	498	462	445	465	432	351	368	321	307	309	281	250
3	2025	2637	263	244	252	220	206	207	210	202	232	211	181	209
4	2026	1765	184	150	160	176	154	137	149	165	128	134	109	119
5	2027	1983	117	112	125	140	133	148	183	198	193	201	201	232

Figure 17. Second Example of UC10 Use – Long Term User Traffic (Bus, Direction 1)

7. SUBSEQUENT DEVELOPMENTS

7.1. Additional Data to the Database

For the purpose of limiting the development of a data generator for the FareUser, Fare, FarePurchase and FareValidation tables to a reasonable task within the scope of this project, some data typically present in a transit fare management database have been ignored. In subsequent developments of the database aiming at constructing a more exhaustive and realistic transit fare management, such data could be incorporated in the database and support the functions and procedures extracting results for the key performance indicator dashboards.

Such data include:

- Fare media types: only two generic chip cards have been considered in the data generator (card and occasional), while the ARTM actually manage a total of 24 different Opus cards, plus the occasional chip card.

- Fare types: only three types of fares have been considered in the data generator (twoTrips, tenTrips and monthly), while the ARTM actually list nearly 100 different regular fare types, this in addition to special fare types offered by each operator.
- Locations of train and metro stations and bus stops: these data would allow a more granular analyses of user traffic along the length of any given service, which would be an improvement from the aggregate user traffic extracted in this project.

7.2. Front-End Web Application

Currently, the key performance indicator dashboards are restricted to the console on the SQL Server Management Studio. Developing a front-end web application to show the results extracted from the database on web pages constitute a natural subsequent development to that project, in order to improve the clients' experience.