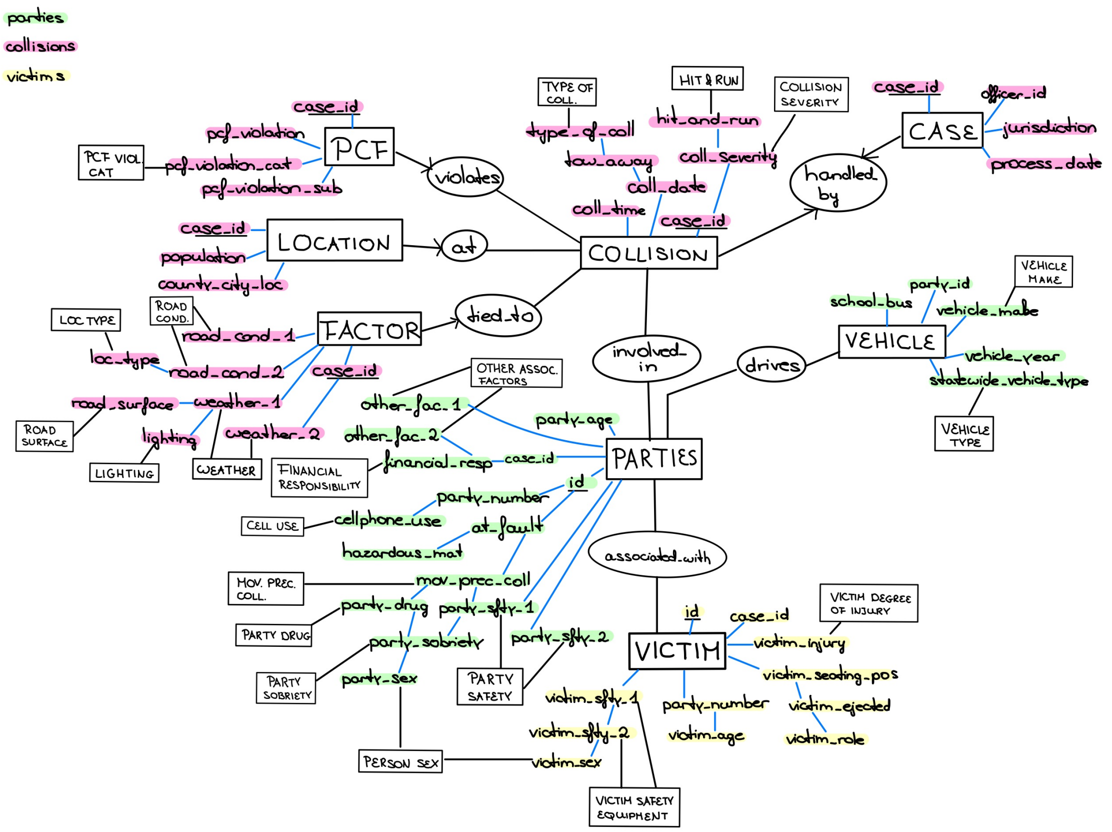
ER Model



Data constraints

Participation constraints

Collisions

- Every `Collision` has a `Case`, a `PCF`, a `Location` and a `Factor`.
- Conversely, each `Case`, a `PCF`, a `Location` and a `Factor` is tied back to a unique collision.

Parties

- Every `Party` is involved in a `Collision`, but not every `Collision` has a `Party` by design.
- Every `Party` has a unique `Vehicle` and conversely.

Victims

- Some `Party` have no `Victim`, and a `Victim` cannot be identified as a particular `Party`: there is no participation constraint between `Parties` and `Victims`.

Additional constraints

- In the project description, each attribute that is nullable is clearly stated:

  ```
  > Blank or - - Not Stated
  ```

  Hence we can mark as `NOT NULL` every other attribute, except for `PRIMARY KEY`s, which are implicitely so.

- Since we are using a star schema, we cannot express the following constraints in the SQL code: every collision has a location, a factor, a pcf and a case. Likewise, every party has a vehicle.

Design choices

Star schema

We decided to cluster attributes into separate entities following a star schema. Some groups are obvious, others are debatable.

The obvious groups are:

- For the `Collision` entity, some attributes form the logical groups `Pcf`, `Location`, `Factor`, `Case`.
- Similarly, for the `Victim` entity, the only logical group is `Vehicle`.

Attribute types in the SQL code

- In the project description, some attributes are enums: they can only take on specific pre-defined values. Therefore, we can let them be `INTEGER`, and store their actual value in what we call sattelite tables. Such tables are highlighted to be entities on the ER schema. For example: `PcfViolation` is stored in such a sattelite table. It will become apparent in the SQL code.

- `case_id` is a `VARCHAR(19)` and not a `NUMERIC(19)` as it sometimes possesses leading zeros in the `.csv`. Not making the distinction would have meant multiple collisions would've been dropped for having the same `case_id`.

- The rest of the attributes are clearly `INTEGER` from the project description as well as upon inspection of the values in the `.csv` files.

SQL code

Collision

Main Tables

```sql
CREATE TABLE Collisions(case_id VARCHAR(19),
                        collision_date DATE NOT NULL,
                        collision_time TIME,
                        type_of_collision INTEGER,
```

```
                        collision_severity INTEGER NOT NULL,
                        hit_and_run INTEGER NOT NULL,
                        tow_away BIT,
                        FOREIGN KEY(type_of_collision) REFERENCES
TypeOfCollision(id),
                        FOREIGN KEY(collision_severity) REFERENCES
CollisionSeverity(id),
                        FOREIGN KEY(hit_and_run) REFERENCES HitAndRun(id),
                        PRIMARY KEY(case_id))
```

```
CREATE TABLE Pcfs(case_id VARCHAR(19) NOT NULL,
                    pcf_violation INTEGER,
                    pcf_violation_category INTEGER,
                    pcf_violation_subsection CHAR(1),
                    FOREIGN KEY(pcf_violation_category) REFERENCES
PcfViolationCategory(id),
                    FOREIGN KEY(case_id) REFERENCES Collisions(case_id))
```

```
CREATE TABLE Locations(case_id VARCHAR(19) NOT NULL,
                        population INTEGER,
                        county_city_location INTEGER NOT NULL,
                        FOREIGN KEY(case_id) REFERENCES
Collisions(case_id))
```

```
CREATE TABLE Factors(case_id VARCHAR(19) NOT NULL,
                        location_type INTEGER,
                        lighting INTEGER,
                        road_condition_1 INTEGER,
                        road_condition_2 INTEGER,
                        road_surface INTEGER,
                        weather_1 INTEGER,
                        weather_2 INTEGER,
                        FOREIGN KEY(location_type) REFERENCES
LocationType(id),
                        FOREIGN KEY(lighting) REFERENCES Lighting(id),
                        FOREIGN KEY(road_condition_1) REFERENCES
RoadCondition(id),
                        FOREIGN KEY(road_condition_2) REFERENCES
RoadCondition(id),
                        FOREIGN KEY(road_surface) REFERENCES
RoadSurface(id),
                        FOREIGN KEY(weather_1) REFERENCES Weather(id),
                        FOREIGN KEY(weather_2) REFERENCES Weather(id),
                        FOREIGN KEY(case_id) REFERENCES
Collisions(case_id))
```

```
CREATE TABLE Cases(case_id VARCHAR(19) NOT NULL,
                    process_date DATE NOT NULL,
                    officer_id VARCHAR(8),
                    jurisdiction INTEGER,
                    FOREIGN KEY(case_id) REFERENCES Collisions(case_id))
```

Satelite Enum Tables

```
CREATE TABLE CollisionSeverity(id INTEGER AUTO_INCREMENT,
                   description VARCHAR(25) NOT NULL UNIQUE,
                   PRIMARY KEY(id))
```

```
CREATE TABLE HitAndRun(id INTEGER AUTO_INCREMENT,
            description VARCHAR(20) NOT NULL UNIQUE,
            PRIMARY KEY(id))
```

```
CREATE TABLE Lighting(id INTEGER AUTO_INCREMENT,
               description VARCHAR(39) NOT NULL UNIQUE,
               PRIMARY KEY(id))
```

```
CREATE TABLE LocationType(id INTEGER AUTO_INCREMENT,
               description VARCHAR(20) NOT NULL UNIQUE,
               PRIMARY KEY(id))
```

```
CREATE TABLE PcfViolationCategory(id INTEGER AUTO_INCREMENT,
                   description VARCHAR(70) NOT NULL UNIQUE,
                   PRIMARY KEY(id))
```

```
CREATE TABLE PrimaryCollisionFactor(id INTEGER AUTO_INCREMENT,
                     description VARCHAR(25) NOT NULL UNIQUE,
                     PRIMARY KEY(id))
```

```
CREATE TABLE RoadCondition(id INTEGER AUTO_INCREMENT,
                description VARCHAR(20) NOT NULL UNIQUE,
                PRIMARY KEY(id))
```

```
CREATE TABLE RoadSurface(id INTEGER AUTO_INCREMENT,
              description VARCHAR(15) NOT NULL UNIQUE,
              PRIMARY KEY(id))
```

```
CREATE TABLE TypeOfCollision(id INTEGER AUTO_INCREMENT,
                  description VARCHAR(15) NOT NULL UNIQUE,
                  PRIMARY KEY(id))
```

```
CREATE TABLE Weather(id INTEGER AUTO_INCREMENT,
              description VARCHAR(10) NOT NULL UNIQUE,
              PRIMARY KEY(id))
```

Party

Main Tables

```
CREATE TABLE Parties(id INTEGER,
                        case_id VARCHAR(19) NOT NULL,
                        party_number INTEGER NOT NULL,
                        party_type INTEGER,
                        finanicial_responsibility INTEGER,
                        party_age INTEGER,
                        party_sex INTEGER,
                        at_fault BIT NOT NULL,
                        cellphone_use INTEGER,
                        hazardous_materials CHAR(1),
                        movement_preceding_collision INTEGER,
                        other_associate_factor_1 INTEGER,
                        other_associate_factor_2 INTEGER,
                        party_drug_physical INTEGER,
                        party_safety_equipment_1 INTEGER,
                        party_safety_equipment_2 INTEGER,
                        party_sobriety INTEGER,
                        PRIMARY KEY(id, case_id),
                        FOREIGN KEY(party_type) REFERENCES PartyType(id),
                        FOREIGN KEY(finanicial_responsibility) REFERENCES
FinancialResponsability(id),
                        FOREIGN KEY(party_sex) REFERENCES PersonSex(id),
                        FOREIGN KEY(cellphone_use) REFERENCES
CellphoneUse(id),
                        FOREIGN KEY(movement_preceding_collision)
REFERENCES MovementPrecedingCollision(id),
                        FOREIGN KEY(other_associate_factor_1) REFERENCES
OtherAssociatedFactors(id),
                        FOREIGN KEY(other_associate_factor_2) REFERENCES
OtherAssociatedFactors(id),
```

```
                        FOREIGN KEY(party_drug_physical) REFERENCES
PartyDrugPhysical(id),
                        FOREIGN KEY(party_safety_equipment_1) REFERENCES
PartySafetyEquipement(id),
                        FOREIGN KEY(party_safety_equipment_2) REFERENCES
PartySafetyEquipement(id),
                        FOREIGN KEY(party_sobriety) REFERENCES
PartySobriety(id),
                        FOREIGN KEY(case_id) REFERENCES
Collisions(case_id))
```

```
CREATE TABLE Vehicles(party_id INTEGER NOT NULL,
                        school_bus_related BIT,
                        statewide_vehicle_type INTEGER,
                        vehicle_make INTEGER,
                        vehicle_year INTEGER,
                        FOREIGN KEY(statewide_vehicle_type) REFERENCES
StatewideVehiculeType(id),
                        FOREIGN KEY(vehicle_make) REFERENCES
VehiculeMake(id),
                        FOREIGN KEY(party_id) REFERENCES Parties(id))
```

Satelite Enum Tables

```
CREATE TABLE CellphoneUse(id INTEGER AUTO_INCREMENT,
               description CHAR(1) NOT NULL UNIQUE,
                CHECK (description BETWEEN 'B' AND 'D'),
               PRIMARY KEY(id))
```

```
CREATE TABLE FinancialResponsibility(id INTEGER AUTO_INCREMENT,
                      description CHAR(1) NOT NULL UNIQUE,
                                      CHECK (description IN ('N', 'Y',
'O', 'E')),
                          PRIMARY KEY(id))
```

```
CREATE TABLE MovementPrecedingCollision(id INTEGER AUTO_INCREMENT,
                     description VARCHAR(100) NOT NULL UNIQUE,
                     PRIMARY KEY(id))
```

```
CREATE TABLE OtherAssociatedFactors (id INTEGER AUTO_INCREMENT,
    description CHAR(1) NOT NULL UNIQUE,
```

```
    CHECK (description BETWEEN 'A' AND 'Z'),
    PRIMARY KEY(id))
```

```
CREATE TABLE PartyDrugPhysical(id INTEGER AUTO_INCREMENT,
                   description CHAR(1) NOT NULL UNIQUE,
                            CHECK (description IN ('E', 'F', 'H', 'I')),
                   PRIMARY KEY(id))
```

```
CREATE TABLE PartySafetyEquipement(id INTEGER AUTO_INCREMENT,
                   description CHAR(1) NOT NULL UNIQUE,
                                   CHECK (description BETWEEN 'A' AND
'Y'),
                   PRIMARY KEY(id))
```

The following can store `victim_sex` and `party_sex`

```
CREATE TABLE PersonSex(id INTEGER AUTO_INCREMENT,
               description VARCHAR(6) NOT NULL UNIQUE,
                       CHECK (description in ('male', 'female')),
               PRIMARY KEY(id))
```

```
CREATE TABLE PartySobriety(id INTEGER AUTO_INCREMENT,
                description CHAR(1) NOT NULL UNIQUE,
                           CONSTRAINT sobriety_check CHECK (description
IN ('A', 'B', 'C', 'D', 'G', 'H')),
                PRIMARY KEY(id))
```

```
CREATE TABLE PartyType(id INTEGER AUTO_INCREMENT,
            description VARCHAR(14) NOT NULL UNIQUE,
            PRIMARY KEY(id))
```

```
CREATE TABLE StatewideVehiculeType(id INTEGER AUTO_INCREMENT,
                    description VARCHAR(35) NOT NULL UNIQUE,
                    PRIMARY KEY(id))
```

```
CREATE TABLE VehiculeMake(id INTEGER AUTO_INCREMENT,
               description VARCHAR(28) NOT NULL,
               PRIMARY KEY(id))
```

Victim

Main Table

```
CREATE TABLE Victims(id INTEGER,
                        case_id VARCHAR(19) NOT NULL,
                        party_number INTEGER NOT NULL,
                        victim_age INTEGER,
                        victim_sex INTEGER,
                        victim_degree_of_injury INTEGER,
                        victim_ejected INTEGER,
                        victim_role INTEGER NOT NULL,
                        victim_safety_equipment_1 INTEGER,
                        victim_safety_equipment_2 INTEGER,
                        victim_seating_position INTEGER,
                        PRIMARY KEY(id, case_id),
                        FOREIGN KEY(victim_sex) REFERENCES PersonSex(id),
                        FOREIGN KEY(victim_safety_equipment_1) REFERENCES
VictimSafetyEquipment(id),
                        FOREIGN KEY(victim_safety_equipment_2) REFERENCES
VictimSafetyEquipment(id),
                        FOREIGN KEY(victim_degree_of_injury) REFERENCES
VictimDegreeOfInjury(id),
                        FOREIGN KEY(case_id) REFERENCES
Collisions(case_id))
```

Satelite Enum Tables

```
CREATE TABLE VictimSafetyEquipment(id INTEGER AUTO_INCREMENT,
                   description CHAR(1) NOT NULL UNIQUE,
                                CHECK(description BETWEEN 'A' AND 'Z'),
                   PRIMARY KEY(id))
```

```
CREATE TABLE VictimDegreeOfInjury(id INTEGER AUTO_INCREMENT,
                   description VARCHAR(30) NOT NULL UNIQUE,
                   PRIMARY KEY(id))
```

The following can store `victim_sex` and `party_sex`.

```
CREATE TABLE PersonSex(id INTEGER AUTO_INCREMENT,
               description VARCHAR(6) NOT NULL UNIQUE,
                       CHECK (description in ('male', 'female')),
               PRIMARY KEY(id))
```

Design modifications

Justifications

We made certain design modifications to respond to the feedback that we got after the last deliverable.

> Think about the repeated information stored in rows of your table with your current entity modeling. As a thought experiment, if 1000 accidents took place in the same county_city_location "Lausanne", it would not be efficient to repeatedly store "Lausanne" 1000 times in the rows of our collision table. We'd prefer to store it only once as a single row in a separate location entity, and reference it. Apply this logic to your modeling structure, starting with the feedback below.

Firstly, to avoid having to store certain strings over and over again, we created satellite enum tables to which we reference from within our main entities.

> Consider modeling "other_associated_factors" as a separate entity. Consider modeling road conditions and weather as separate entities.

The satellite table modeling also responded to this point of the feedback by making weather, road conditions and other_associated_factors a separate entity.

To be consistant throughout the columns, we had to model any column like the ones mentioned as separate entities. There are too much of these to mention here.

> There is no strong benefit to creating "Party Contexts" and "Victim Contexts" entities separate from your Party and Victim entities, because all this requires is more joining at query time

We removed the Party Context and Victim Context entities and simply merged their attributes to the ones in the Party and Victim entities.

> Please justify your decision to model safety equipment-related information as fields of victims and party instead of migrating them to a separate 'Safety Equipment' entity.

We decided to keep safety equipment related attributes inside the Party and Victim entities instead of migrating them to a separate safety equipment entity. This is because since these attributes exist individually for victims and parties, it seemed more logical to us to keep them with those entities rather than creating a new entity that would hold information for different types of participants in the collision.

> Strong vs. weak entities: consider converting currently-modeled-as-strong, non-uniquely identifiable entities to weak ones. For example, parties can be modeled as a weak entity, as they only exist in the context of a collision.

We noticed that both Victim and Party entities were modeled as strong entities. In order to turn these into weak entities, as suggested, we added a foreign key : the case id.

How we did the import

The following is implementation details that we inserted for completion.

The database server

We decided to run `MySQL` locally after failing to get acceptable performances on AWS/GCP.

The method to dump data

- After having declared every table, we simply performed a row-wise import, using `pd.iterrows` and `INSERT INTO` commands.
- Sattelite tables were populated on the fly.
- `id`s from such Sattelite tables were cached during import for performance.

Data cleaning choices

Collisions

- `Collisions` has three columns with dirty values.
- The columns are `hit_and_run`, `pcf_violation_category` and `road_surface`. The corresponding values are `D`, `21804` and `H`.
- The above anomalies each occur once in the table.
- Droping a collision means dropping the associated parties and victims. In our case, we dropped 1 victim and 2 parties.
- Surprisingly, it was a single row combining the above three anomalies. The corresponding `case_id` was `2816618`.

Parties

- `Parties` has two columns with dirty values.
- In `party_drug_physical` there is an undefined `G` which is converted into a `NULL` in the table. Even if this value is the most prevalant in the table, we decided to replace with `NULL` as we cannot interpret it.
- In `cellphone_use`, undefined values `1`, `2` and `3` are converted into `B`, `C` and `D` respectively. We made this choice because of similar frequency as well as similar order.

Victims

- In the table `Victims`, `victim_degree_of_injury` has an undefined `7` which is replaced by `NULL`. This occurs once throughout the table.

Miscellaneous

From our checks, it seems like every victim and party in the `.csv` files has an attached `case_id` that exists in `collisions.csv`.

Disclaimer

There was arguably more data cleaning that we could have done: replacing enum values that are no expressive with their full description, like `VictimSafetyEquipment` having values like `C`, `E` and `G`, which we could have replaced with `Lap Belt Used`, `Shoulder Harness Used`, `Lap/Shoulder Harness Used`.

This is something Vinitria warned us about. Unfortunately, we ran out of time knowing that we would have to replace each enum value by our own in the data cleaning process.

Therefore we placed `CASE` in queries where the data stored in the sattelite table was no expressive. For example for query 6 of deliverable 2, we replaced `weather` by its meaning with a `CASE WEATHER WHEN 1 THEN 'clear'...`.

Queries - Deliverable 2

As asked, we only included the first 20 rows or less.

Query 1

List the year and the number of collisions per year. Suppose there are more years than just 2018.

Command

```
SELECT
  EXTRACT(
    YEAR
    FROM
      c.collision_date
  ) as year,
  COUNT(*) as collisions_count
FROM
  Collisions c
GROUP BY
  EXTRACT(
    YEAR
    FROM
      c.collision_date
  )
```

Result

year	collisions_count
2002	544741
2003	538953
2004	538294
2005	532724

year	collisions_count
2006	498849
2007	501908
2017	7
2018	21
2001	518985

Query 2

Find the most popular vehicle make in the database. Also list the number of vehicles of that particular make.

Command

```
CREATE VIEW MostPopularVehicle AS (
  SELECT
    COUNT(p.id) as number_of_vehicles,
    v.vehicle_make as brand_id
  FROM
    Parties p,
    Vehicles v
  WHERE
    p.id = v.party_id
  GROUP BY
    v.vehicle_make
  ORDER BY
    number_of_vehicles DESC
  LIMIT
    1
)

SELECT
  vm.description as brand,
  vp.number_of_vehicles as vehicle_count
FROM
  VehiculeMake vm,
  MostPopularVehicle vp
WHERE
  vm.id = 1
```

Result

brand	vehicle_count
FORD	1129719

Query 3

Find the fraction of total collisions that happened under dark lighting conditions.

Command

```
SELECT
  (
    SELECT
      COUNT(*)
    FROM
      (
        SELECT
          c.case_id
        FROM
          Collisions c,
          Factors f,
          Lighting l
        WHERE
          c.case_id = f.case_id
          AND f.lighting = l.id
          AND l.description LIKE 'dark%'
      ) AS DarkCols
  ) / (
    SELECT
      COUNT(*)
    FROM
      Collisions
  )
```

Result

fraction
0.2802

Query 4

Find the number of collisions that have occurred under snowy weather conditions.

Command

```
SELECT
  COUNT(snowy.case_id)
FROM
  Collisions snowy,
  Factors f,
```

```
  Weather w
WHERE
  snowy.case_id = f.case_id
  AND (
    f.weather_1 = w.id
    OR f.weather_2 = w.id
  )
  AND w.description LIKE 'snowing'
```

Result

count
8542

Query 5

Compute the number of collisions per day of the week, and find the day that witnessed the highest number of collisions. List the day along with the number of collisions.

Command

```
SELECT
  CASE DAYOFWEEK(collision_date)
    WHEN 1 THEN 'Sunday'
    WHEN 2 THEN 'Monday'
    WHEN 3 THEN 'Tuesday'
    WHEN 4 THEN 'Wednesday'
    WHEN 5 THEN 'Thursday'
    WHEN 6 THEN 'Friday'
    ELSE 'Saturday'
  END as day,
  COUNT(*) as counts
FROM   Collisions
GROUP BY day
ORDER BY counts desc
LIMIT 1
```

Result

day	count
Friday	614143

Query 6

List all weather types and their corresponding number of collisions in descending order of the number of collisions.

Command

```
SELECT
  CASE weather
    WHEN 1 THEN 'clear'
    WHEN 2 THEN 'cloudy'
    WHEN 3 THEN 'fog'
    WHEN 4 THEN 'other'
    WHEN 5 THEN 'raining'
    WHEN 6 THEN 'snowing'
    ELSE 'wind'
  END AS weather_type,
  SUM(counts) as count
FROM
  (
    SELECT
      f.weather_1 as weather,
      COUNT(*) as counts
    FROM
      Factors f
    GROUP BY
      f.weather_1
    UNION ALL
    SELECT
      f.weather_2 as weather,
      COUNT(*) as counts
    FROM
      Factors f
    GROUP BY
      f.weather_2
  ) AS WeatherList
GROUP BY
  weather
ORDER BY
  counts DESC
```

Result

weather_type	count
wind	3592379
clear	2941042
cloudy	548250
snowing	223752

weather_type	count
fog	21259
wind	13952
other	8530
raining	6960

Query 7

Find the number of at-fault collision parties with financial responsibility and loose material road conditions.

Command

```
SELECT
  COUNT(*)
FROM
  Parties p,
  Factors f
WHERE
  p.at_fault = 1
  AND p.financial_responsibility IN (
    SELECT
      id
    FROM
      FinancialResponsibility
    WHERE
      description = 'Y'
  )
  AND f.case_id = p.case_id
  AND (
    f.road_condition_1 IN (
      SELECT
        id
      FROM
        RoadCondition
      WHERE
        description = 'loose material'
    )
    OR f.road_condition_2 IN (
      SELECT
        id
      FROM
        RoadCondition
      WHERE
        description = 'loose material'
    )
  )
```

Result

count
4818

Query 8

Find the median victim age and the most common victim seating position.

Command

```
CREATE INDEX index_victim_age ON Victims(victim_age)

SET @rowindex := -1;

SELECT b.seating_position as seating_position, a.median as median
FROM
  (SELECT
    AVG(d.age) as median
  FROM
    (SELECT @rowindex:=@rowindex + 1 AS rowindex,
            v.victim_age AS age
      FROM Victims v
      ORDER BY v.victim_age) AS d
  WHERE
  d.rowindex IN (FLOOR(@rowindex / 2), CEIL(@rowindex / 2))) a,
  (SELECT
    victim_seating_position as seating_position
  FROM
    Victims
  GROUP BY
    victim_seating_position
  ORDER BY
    COUNT(*) DESC
  LIMIT
    1) b
```

Result

seating_position	median
3	24

Query 9

What is the fraction of all participants that have been victims of collisions while using a belt?

Command

```
SELECT
  (
    (
      SELECT
        COUNT(V.case_id)
      FROM
        Victims V,
        VictimSafetyEquipment S
      WHERE
        (
          V.victim_safety_equipment_1 = S.id
          OR V.victim_safety_equipment_2 = S.id
        )
        AND S.description IN ('C', 'E', 'G')
    ) / ((SELECT COUNT(*) FROM Victims) + (SELECT COUNT(*) FROM Parties))
  )
```

Result

fraction
0.2691

Query 10

Compute and the fraction of the collisions happening for each hour of the day (for example, x% at 13, where 13 means period from 13:00 to 13:59). Display the ratio as percentage for all the hours of the day.

Command

```
SELECT
   TIME_FORMAT(collision_time, "%h%p") AS hour_ranges
   count(1) * 100.0 / (SELECT COUNT(*) FROM Collisions) as percents
 FROM
   Collisions
 GROUP BY
   hour_ranges
```

Result

hour_ranges	percents
03PM	7.74805

hour_ranges	percents
07PM	4.42864
07AM	5.17068
11AM	4.89138
05PM	7.90707
04PM	7.33087
08AM	5.23360
06AM	2.62328
12PM	5.77554
11PM	2.38452
10PM	2.86186
10AM	4.22712
02AM	1.80804
02PM	6.54758
01AM	1.82982
09AM	4.08810
06PM	6.30052
01PM	5.77527
09PM	3.28186
08PM	3.48964
05AM	1.44671
12AM	1.90845
None	0.80600
03AM	1.15409
04AM	0.98130

Queries - Deliverable 3

Query 1

For all the designated age groups, find the percentage of cases where the driver was the party at fault.

Comand

```
SELECT
  q1.AgeGroup as age_group,
  q2.Count * 100.0 / q1.Count AS percentage
FROM
  (
    SELECT
      CASE WHEN party_age BETWEEN 0
      AND 18 THEN 'Underage' WHEN party_age BETWEEN 19
      AND 21 THEN 'Young I' WHEN party_age BETWEEN 22
      AND 24 THEN 'Young II' WHEN party_age BETWEEN 24
      AND 60 THEN 'Adult' WHEN party_age BETWEEN 61
      AND 64 THEN 'Elder I' ELSE 'Elder II' END AS AgeGroup,
      count(1) AS Count
    FROM
      Parties
    GROUP BY
      AgeGroup
  ) q1
  INNER JOIN (
    SELECT
      CASE WHEN p.party_age BETWEEN 0
      AND 18 THEN 'Underage' WHEN p.party_age BETWEEN 18
      AND 21 THEN 'Young I' WHEN p.party_age BETWEEN 21
      AND 24 THEN 'Young II' WHEN p.party_age BETWEEN 24
      AND 60 THEN 'Adult' WHEN p.party_age BETWEEN 60
      AND 64 THEN 'Elder I' ELSE 'Elder II' END AS AgeGroup,
      count(1) AS Count
    FROM
      Parties p
    WHERE
      p.at_fault = true
      AND p.party_type IN (SELECT id FROM PartyType WHERE
description='driver')
    GROUP BY
      AgeGroup
  ) q2 ON q1.AgeGroup = q2.AgeGroup
```

Result

age_group	percentage
Young I	56.28855
Underage	56.44656
Adult	40.01389
Elder II	43.00967
Young II	50.83931
Elder I	38.93744

Conclusion

We notice that in general, young and underage people should have to pay more for their insurance since they are more often the party at fault when a collision happens and they were driving, whilst elders should have to pay less.

Query 2

Find the top 5 vehicle types that were involved in collisions on roads with holes, as well as the associated number of collisions.

Command

```
SELECT vt.description , COUNT(*)
FROM(
    SELECT p.id
    FROM Collisions c, Factors f, RoadCondition r, Parties p
    WHERE c.case_id = f.case_id AND(
        r.id = f.road_condition_1 OR
        r.id = f.road_condition_2) AND
        r.description = 'holes' AND
        c.case_id = p.case_id ) AS parties_holes , Vehicles v ,
StatewideVehiculeType vt
WHERE parties_holes.id = v.party_id AND
      vt.id = v.statewide_vehicle_type
GROUP BY v.statewide_vehicle_type
ORDER BY COUNT(*) DESC
LIMIT 5
```

Result

vehicule_type	count
passenger car	10662
pickup or panel truck	2263
motorcycle or scooter	450
bicycle	430
truck or truck tractor with trailer	369

Query 3

Find the top 10 vehicle makes that were involved in collisions with victims suffering either a severe injury or who died, as well as the associated number of victims.

Command

```
SELECT
  make.description,
  COUNT(*)
FROM
  Vehicles v,
  Victims vict,
  Parties p,
  VehiculeMake make,
  VictimDegreeOfInjury injury
WHERE
  v.party_id = p.id
  AND vict.case_id = p.case_id
  AND v.vehicle_make = make.id
  AND vict.victim_degree_of_injury = injury.id
  AND (
    injury.description = 'Killed'
    OR injury.description = 'Severe Injury'
  )
GROUP BY
  v.vehicle_make
ORDER BY
  COUNT(*) DESC
LIMIT 10
```

Result

vehicule_make	number_of_collisions
FORD	31727
CHEVROLET	22835
TOYOTA	22292
HONDA	20212
DODGE	9028
NISSAN	8070
GMC	4696
NOT STATED	4172
HARLEY-DAVIDSON	3810
MISCELLANEOUS	3753

Query 4

Find the safest and least safe seating position, where safety is defined by the safety index calculated as the percentage of collisions where the victim in the corresponding seating position suffered no injury.

Command

Part 1: computing the safety index for each.

```
SELECT
  q1.SeatingPosition,
  q2.Count / q1.Count AS SafetyIndex
FROM
  (
    SELECT
      CASE WHEN victim_seating_position BETWEEN 1
      AND 1 THEN 'Driver' WHEN victim_seating_position BETWEEN 2
      AND 6 THEN 'Passenger' WHEN victim_seating_position BETWEEN 7
      AND 7 THEN 'Station Wagon Rear' WHEN victim_seating_position BETWEEN
8
      AND 8 THEN 'Rear Occupant of Truck or Van' WHEN
victim_seating_position BETWEEN 9
      AND 9 THEN 'Position Unknown' WHEN victim_seating_position BETWEEN 0
      AND 0 THEN 'Other Occupants' WHEN victim_seating_position BETWEEN
'A'
      AND 'Z' THEN 'Bus Occupants' ELSE 'Not Stated' END AS
SeatingPosition,
      count(1) AS Count
    FROM
      Victims
    GROUP BY
      SeatingPosition
  ) q1
  INNER JOIN (
    SELECT
      CASE WHEN victim_seating_position BETWEEN 1
      AND 1 THEN 'Driver' WHEN victim_seating_position BETWEEN 2
      AND 6 THEN 'Passenger' WHEN victim_seating_position BETWEEN 7
      AND 7 THEN 'Station Wagon Rear' WHEN victim_seating_position BETWEEN
8
      AND 8 THEN 'Rear Occupant of Truck or Van' WHEN
victim_seating_position BETWEEN 9
      AND 9 THEN 'Position Unknown' WHEN victim_seating_position BETWEEN 0
      AND 0 THEN 'Other Occupants' WHEN victim_seating_position BETWEEN
'A'
      AND 'Z' THEN 'Bus Occupants' ELSE 'Not Stated' END AS
SeatingPosition,
      count(1) AS Count
    FROM
      Victims
    WHERE
      victim_degree_of_injury IN (SELECT id FROM VictimDegreeOfInjury
WHERE description='no injury')
    GROUP BY
```

```
      SeatingPosition
  ) q2 ON q1.SeatingPosition = q2.SeatingPosition
```

Part 2: Retrieving the min and the max.

```
CREATE VIEW SafetyIndexes AS
  (SELECT
    q1.SeatingPosition,
    q2.Count / q1.Count AS SafetyIndex
  FROM
  (
    SELECT
    CASE WHEN victim_seating_position BETWEEN 1
    AND 1 THEN 'Driver' WHEN victim_seating_position BETWEEN 2
    AND 6 THEN 'Passenger' WHEN victim_seating_position BETWEEN 7
    AND 7 THEN 'Station Wagon Rear' WHEN victim_seating_position BETWEEN 8
    AND 8 THEN 'Rear Occupant of Truck or Van' WHEN
victim_seating_position BETWEEN 9
    AND 9 THEN 'Position Unknown' WHEN victim_seating_position BETWEEN 0
    AND 0 THEN 'Other Occupants' WHEN victim_seating_position BETWEEN 'A'
    AND 'Z' THEN 'Bus Occupants' ELSE 'Not Stated' END AS SeatingPosition,
    count(1) AS Count
    FROM
    Victims
    GROUP BY
    SeatingPosition
  ) q1
  INNER JOIN (
    SELECT
    CASE WHEN victim_seating_position BETWEEN 1
    AND 1 THEN 'Driver' WHEN victim_seating_position BETWEEN 2
    AND 6 THEN 'Passenger' WHEN victim_seating_position BETWEEN 7
    AND 7 THEN 'Station Wagon Rear' WHEN victim_seating_position BETWEEN 8
    AND 8 THEN 'Rear Occupant of Truck or Van' WHEN
victim_seating_position BETWEEN 9
    AND 9 THEN 'Position Unknown' WHEN victim_seating_position BETWEEN 0
    AND 0 THEN 'Other Occupants' WHEN victim_seating_position BETWEEN 'A'
    AND 'Z' THEN 'Bus Occupants' ELSE 'Not Stated' END AS SeatingPosition,
    count(1) AS Count
    FROM
    Victims
    WHERE
    victim_degree_of_injury IN (SELECT id FROM VictimDegreeOfInjury WHERE
description='no injury')
    GROUP BY
    SeatingPosition
  ) q2 ON q1.SeatingPosition = q2.SeatingPosition)

SELECT
  *
FROM
  SafetyIndexes
```

```
WHERE
  SafetyIndex IN (
    (SELECT MIN(SafetyIndex) FROM SafetyIndexes),
    (SELECT MAX(SafetyIndex) FROM SafetyIndexes)
  )
```

Result

Part 1:

seating_position	safety_index
Passenger	0.7548
Position Unknown	0.3440
Other Occupants	0.6244
Rear Occupant of Truck or Van	0.8177
Station Wagon Rear	0.8251
Not Stated	0.1822
Driver	0.0090

Part 2:

seating_position	safety_index
Station Wagon Rear	0.8251
Driver	0.0090

Query 5

Find how many vehicle types have participated in at least 10 collisions in at least half of the cities.

Command

```
SELECT COUNT(*)
FROM (SELECT statewide_vehicle_type  ,COUNT(Parties.case_id) as collisions
,COUNT(DISTINCT county_city_location) as city
      FROM (Vehicles   INNER JOIN Parties ON Parties.id =
Vehicles.party_id
                       INNER JOIN Locations ON Locations.case_id =
Parties.id)
GROUP BY statewide_vehicle_type
) A
WHERE A.collisions > 10 AND
      A.city > (
```

```
SELECT COUNT(DISTINCT county_city_location)
FROM Locations)/2
```

Result

14

Query 6

For each of the top-3 most populated cities, show the city location, population and the bottom-10 collisions in terms of average victim age.

Command

```
SELECT
  cities.location_id,
  l.population,
  l.case_id,
  AVG(v.victim_age) as victim_mean
FROM
  (SELECT
  l.county_city_location as location_id
FROM
  Locations l
WHERE
  l.population != 9
  AND l.population != 0
GROUP BY
  l.county_city_location,
  l.population
ORDER BY
  l.population DESC
LIMIT
  1 OFFSET 0) cities,
  Locations l,
  Victims v
WHERE
  (l.county_city_location = cities.location_id)
  AND v.case_id = l.case_id
GROUP BY
  v.case_id,
  l.case_id,
  l.county_city_location,
  l.population
ORDER BY
  case when AVG(v.victim_age) is null then 1 when AVG(v.victim_age) then 1
else 0 end,
  AVG(v.victim_age)
LIMIT
```

```
    10) UNION

    (SELECT
    cities.location_id,
    l.population,
    l.case_id,
    AVG(v.victim_age) as victim_mean
  FROM
    (SELECT
    l.location_id as location_id
  FROM
    (
      SELECT
        l.county_city_location as location_id,
        l.population as pop
      FROM
        Locations l
      WHERE
        l.population != 9
        AND l.population != 0
      GROUP BY
        l.county_city_location,
        l.population
      ORDER BY
        l.population DESC
      LIMIT
        2 OFFSET 1
    ) l
  ORDER BY
    l.pop ASC
  LIMIT
    1) cities,
    Locations l,
    Victims v
  WHERE
    (l.county_city_location = cities.location_id)
    AND v.case_id = l.case_id
  GROUP BY
    v.case_id,
    l.case_id,
    l.county_city_location,
    l.population
  ORDER BY
    case when AVG(v.victim_age) is null then 1 when AVG(v.victim_age) then 1
  else 0 end,
    AVG(v.victim_age)
  LIMIT
    10) UNION


    (SELECT
    cities.location_id,
    l.population,
    l.case_id,
```

```
  AVG(v.victim_age) as victim_mean
FROM
  (SELECT
  l.county_city_location as location_id
FROM
  Locations l
WHERE
  l.population != 9
  AND l.population != 0
GROUP BY
  l.county_city_location,
  l.population
ORDER BY
  l.population DESC
LIMIT
  1 OFFSET 3) cities,
  Locations l,
  Victims v
WHERE
  (l.county_city_location = cities.location_id)
  AND v.case_id = l.case_id
GROUP BY
  v.case_id,
  l.case_id,
  l.county_city_location,
  l.population
ORDER BY
  case when AVG(v.victim_age) is null then 1 when AVG(v.victim_age) then 1
else 0 end,
  AVG(v.victim_age)
LIMIT
  10)
```

Result

city_location	description	collision_id	average_age
3711	7	0060439	0.0000
3711	7	0162669	0.0000
3711	7	0382996	0.0000
3711	7	0347879	0.0000
3711	7	0695315	0.0000
3711	7	0568761	0.0000
3711	7	0186147	0.0000
3711	7	1034588	0.0000
3711	7	0197188	0.0000

city_location	description	collision_id	average_age
3711	7	0066852	0.0000
1005	7	2048203	0.0000
1005	7	2376747	0.0000
1005	7	0682784	0.0000
1005	7	1837508	0.0000
1005	7	2399236	0.0000
1005	7	0644343	0.0000
1005	7	0800448	0.0000
1005	7	0457868	0.0000
1005	7	0360320	0.0000
1005	7	1186635	0.0000
3019	7	2072101	0.0000
3019	7	2674015	0.0000
3019	7	2138547	0.0000
3019	7	1170908	0.0000
3019	7	2412373	0.0000
3019	7	1994820	0.0000
3019	7	2942932	0.0000
3019	7	2715062	0.0000
3019	7	1825689	0.0000
3019	7	2637212	0.0000

Query 7

Find all collisions that satisfy the following: the collision was of type pedestrian and all victims were above 100 years old. For each of the qualifying collisions, show the collision id and the age of the eldest collision victim.

Command

```
SELECT
  old_people_collisions.id,
  old_people_collisions.max_age
FROM(
    SELECT
```

```
        v.case_id AS id,
        MAX(v.victim_age) AS max_age
      FROM
        Victims v
      GROUP BY
        v.case_id
      HAVING
        MIN(v.victim_age) > 99
    ) AS old_people_collisions,
    Collisions c,
    TypeOfCollision tc
  WHERE(
      c.case_id = old_people_collisions.id
      AND c.type_of_collision = tc.id
      AND tc.description = 'pedestrian'
    )
```

Result

case_id	age
0036446	110
0069198	101
0415838	100
0439197	102
0445265	101
0486529	100
0566220	102
0621752	100
0644226	103
0784061	102
0817210	102
0820619	101
0828116	102
0851026	106
0868472	103
0885420	100
1209166	101
1213340	121

case_id	age
1347636	101
1373664	101
1548445	102
1847678	104
2290129	100
2427260	100
2472739	103
2531557	103
3388544	105
3485436	101

Query 8

Find the vehicles that have participated in at least 10 collisions. Show the vehicle id and number of collisions the vehicle has participated in, sorted according to number of collisions (descending order).

Command

```
SELECT
  makes.description,
  v.vehicle_year,
  type.description,
  COUNT(*) AS num_of_collisions
FROM
  Vehicles v,
  Parties p,
  Collisions c,
  VehiculeMake makes,
  StatewideVehiculeType type
WHERE
  v.party_id = p.id AND v.vehicle_make != 'None'
  AND p.case_id = c.case_id AND
  v.vehicle_make = makes.id AND
  v.statewide_vehicle_type = type.id
GROUP BY v.vehicle_make,
  v.vehicle_year,
  v.statewide_vehicle_type
HAVING(COUNT(*) > 9)
ORDER BY
  num_of_collisions DESC
```

Result

vehicule_make	year	type	number_of_collisions
TOYOTA	2000	passenger car	52504
FORD	2000	passenger car	51943
HONDA	2000	passenger car	50284
FORD	1998	passenger car	49182
TOYOTA	2001	passenger car	47232
HONDA	2001	passenger car	45277
FORD	2001	passenger car	45236
TOYOTA	1999	passenger car	42941
HONDA	1998	passenger car	42091
FORD	1999	passenger car	41948
FORD	1995	passenger car	40246
HONDA	1997	passenger car	39210
FORD	1997	passenger car	38885
HONDA	1999	passenger car	38556
TOYOTA	2002	passenger car	38427
TOYOTA	1998	passenger car	38012
TOYOTA	1997	passenger car	37158
TOYOTA	2003	passenger car	35943
HONDA	2002	passenger car	35785
FORD	2002	passenger car	35460

Conclusions

We notice that mostly Toyota, Honda and Ford cars participate in collisions, which is not surprising as they are among the most popular car manufacturers in the USA.

Query 9

Find the top-10 (with respect to number of collisions) cities. For each of these cities, show the city location and number of collisions.

Command

```
SELECT
  l.county_city_location,
  COUNT(*)
FROM
  Collisions c,
  Locations l
WHERE
  (c.case_id = l.case_id)
GROUP BY
  (l.county_city_location)
ORDER BY
  COUNT(*) DESC
LIMIT
  10
```

Result

county_city_location	count
1942	399582
1900	118446
3400	80191
3711	76867
109	72995
3300	61453
3404	58068
4313	57852
1941	53565
3801	48450

Query 10

Are there more accidents around dawn, dusk, during the day, or during the night ? Display the number of accidents, and to which group it belongs, and make your conclusion based on absolute number of accidents in the given 4 periods.

Command

```
SELECT
  CASE WHEN l.description = 'daylight'
  OR (
    f.lighting = NULL
```

```
      AND c.collision_time BETWEEN '00:08:00'
      AND '17:59:00'
    ) THEN 'day' WHEN (
      f.lighting = NULL
      AND c.collision_time BETWEEN '00:06:00'
      AND '07:59:00'
    )
    OR (
      l.description = 'dusk or dawn'
      AND (
        c.collision_time BETWEEN '00:06:00'
        AND '07:59:00'
      )
    ) THEN 'dawn' WHEN (
      f.lighting = NULL
      AND c.collision_time BETWEEN '00:18:00'
      AND '19:59:00'
    )
    OR (
      l.description = 'dusk or dawn'
      AND (
        c.collision_time BETWEEN '00:18:00'
        AND '19:59:00'
      )
    ) THEN 'dusk' ELSE 'night' END AS time_of_day,
    count(1) as num
  FROM
    Factors f,
    Lighting l,
    Collisions c
  WHERE
    f.case_id = c.case_id
    AND (
      f.lighting = l.id
      OR f.lighting = NULL
    )
  GROUP BY
    time_of_day
```

Result

day_time	count
night	1039682
day	2496938
dusk	74906
dawn	40756

Conclusions

We notice that most collisions happen during the day, which makes sense since there is a lot more traffic during that time. Dusk and dawn having much less collisions also makes sense as they only span two hours (despite those two hours being rush hour) whilst the other periods span ten hours.

Optimization Part

We decided to optimize the 5 following queries : 2,3,7,8 and 10. Our approach consists of checking the cost of the query by inspecting the Plan Analysis, then we optimize the latter by adding the appropriate indexes and we compare to the new cost after optimization.

Query 2

The unoptimised version of this query leads the database to only make full scans and hash joins. The hash joins is what takes the most time, and the total cost is 1901541074130.96.

```
+------------------------------------------------------------------------------------------------------------------------------------------+
|EXPLAIN
|
+------------------------------------------------------------------------------------------------------------------------------------------+
|-> Limit: 5 row(s)  (actual time=17361.284..17361.285 rows=5 loops=1)
|
|-> Sort: `COUNT(vm.id)` DESC, limit input to 5 row(s) per chunk  (actual time=17361.283..17361.284 rows=5 loops=1)
|
|-> Table scan on <temporary>  (actual time=0.002..0.022 rows=109 loops=1)
|
|-> Aggregate using temporary table  (actual time=17361.214..17361.247 rows=109 loops=1)
|
|-> Inner hash join (vm.id = v.vehicle_make)  (cost=1901541264398.97 rows=1495201) (actual time=17315.241..17352.695 rows=16732 loops=1)
|
|-> Table scan on vm  (cost=0.00 rows=215) (actual time=0.786..0.830 rows=217 loops=1)
|
|-> Hash
|
|-> Inner hash join (v.party_id = p.id)  (cost=1901509115641.82 rows=1495201) (actual time=11795.607..17285.357 rows=17942 loops=1)
|
|-> Table scan on v  (cost=23.77 rows=7106966) (actual time=0.977..3661.512 rows=7286604 loops=1)
|
|-> Hash
|
|-> Inner hash join (p.case_id = f.case_id)  (cost=838839052968.67 rows=1495201) (actual time=6156.822..11756.979 rows=17942 loops=1)
|
|-> Table scan on p  (cost=31.10 rows=7116413) (actual time=3.072..2213.091 rows=7286604 loops=1)
|
|-> Hash
|
|-> Inner hash join (c.case_id = f.case_id)  (cost=269506531216.49 rows=799992) (actual time=3587.501..6127.144 rows=9985 loops=1)
|
|-> Table scan on c  (cost=6.81 rows=3368797) (actual time=0.418..902.211 rows=3678062 loops=1)
|
|-> Hash
|
|-> Filter: ((f.road_condition_1 = r.id) or (f.road_condition_2 = r.id))  (cost=352965.07 rows=799991) (actual time=3.976..3557.020 rows=9985 loops=1)
|
|-> Inner hash join (no condition)  (cost=352965.07 rows=799991) (actual time=3.529..3189.574 rows=3678062 loops=1)
|
|-> Table scan on f  (cost=91632.87 rows=3413295) (actual time=0.702..2610.780 rows=3678062 loops=1)
|
|-> Hash
|
|-> Filter: (r.`description` = 'holes')  (cost=1.80 rows=1) (actual time=2.804..2.807 rows=1 loops=1)
|
|-> Table scan on r  (cost=1.80 rows=8) (actual time=2.799..2.803 rows=8 loops=1)
|
+------------------------------------------------------------------------------------------------------------------------------------------+
```

```sql
CREATE INDEX index_collision_id ON Collisions(case_id) USING HASH;
CREATE INDEX index_parties_case_id ON Parties(case_id) USING HASH;
CREATE INDEX index_victims_party_id ON Victims(party_id) USING HASH;
CREATE INDEX index_vehicle_make_id ON VehicleMake(id) USING HASH;
```

The total cost dropped to 108691.43, reducing it by 17494926% . Most of the decrease came from taking advantages of index when joining, as you can see on the figure below.

```
+------------------------------------------------------------------------------------------------------------------------------------------------------------+
|EXPLAIN
|
+------------------------------------------------------------------------------------------------------------------------------------------------------------+
|-> Limit: 5 row(s)  (actual time=773.240..773.241 rows=5 loops=1)
|
|-> Sort: `COUNT(*)` DESC, limit input to 5 row(s) per chunk  (actual time=773.239..773.240 rows=5 loops=1)
|
|-> Table scan on <temporary>  (actual time=0.001..0.003 rows=15 loops=1)
|
|-> Aggregate using temporary table  (actual time=773.220..773.223 rows=15 loops=1)
|
|-> Nested loop inner join  (cost=134184.86 rows=33489) (actual time=2.863..756.759 rows=15274 loops=1)
|
|-> Nested loop inner join  (cost=97346.86 rows=33489) (actual time=2.332..740.784 rows=15274 loops=1)
|
|-> Nested loop inner join  (cost=60508.86 rows=33489) (actual time=1.174..448.970 rows=17942 loops=1)
|
|-> Nested loop inner join  (cost=39086.24 rows=17918) (actual time=0.772..267.565 rows=9985 loops=1)
|
|-> Filter: ((f.road_condition_1 = '5') or (f.road_condition_2 = '5'))  (cost=19376.44 rows=17918) (actual time=0.611..153.510 rows=9985 loops=1)
|
|-> Index range scan on f using union(road_condition_1,road_condition_2)  (cost=19376.44 rows=17918) (actual time=0.606..150.129 rows=9985 loops=1)
|
|-> Single-row index lookup on c using PRIMARY (case_id=f.case_id)  (cost=1.00 rows=1) (actual time=0.011..0.011 rows=1 loops=9985)
|
|-> Index lookup on p using case_id (case_id=f.case_id)  (cost=1.01 rows=2) (actual time=0.017..0.018 rows=2 loops=9985)
|
|-> Filter: (v.statewide_vehicle_type is not null)  (cost=1.00 rows=1) (actual time=0.015..0.016 rows=1 loops=17942)
|
|-> Index lookup on v using party_id (party_id=p.id)  (cost=1.00 rows=1) (actual time=0.015..0.016 rows=1 loops=17942)
|
|-> Single-row index lookup on vt using PRIMARY (id=v.statewide_vehicle_type)  (cost=1.00 rows=1) (actual time=0.001..0.001 rows=1 loops=15274)
|
+------------------------------------------------------------------------------------------------------------------------------------------------------------+
```

The runtime of the query is:

- Unoptimised: 14s700ms
- Optimised: 1s337ms

Query 3

The unoptimised version of this query leads the database to only make full scans and hash joins. The hash joins is what takes the most time, and the total cost is 3092626926820.33.

```
+------------------------------------------------------------------------------------------------------------------------------------------------------------+
|EXPLAIN
|
+------------------------------------------------------------------------------------------------------------------------------------------------------------+
|-> Limit: 10 row(s)  (actual time=12410.577..12410.578 rows=10 loops=1)
|
|-> Sort: `COUNT(vm.description)` DESC, limit input to 10 row(s) per chunk  (actual time=12410.576..12410.577 rows=10 loops=1)
|
|-> Table scan on <temporary>  (actual time=0.001..0.016 rows=117 loops=1)
|
|-> Aggregate using temporary table  (actual time=12410.521..12410.547 rows=117 loops=1)
|
|-> Inner hash join (vm.id = v.vehicle_make)  (cost=3092627035006.38 rows=2833356) (actual time=12346.335..12390.496 rows=41309 loops=1)
|
|-> Table scan on vm  (cost=0.00 rows=215) (actual time=0.115..0.170 rows=217 loops=1)
|
|-> Hash
|
|-> Inner hash join (v.party_id = p.id)  (cost=3092566117101.97 rows=2833356) (actual time=6609.175..12299.314 rows=47611 loops=1)
|
|-> Table scan on v  (cost=19.29 rows=7106966) (actual time=0.069..3509.661 rows=7286604 loops=1)
|
|-> Hash
|
|-> Inner hash join (p.case_id = c.case_id)  (cost=1078854794607.80 rows=2833356) (actual time=1300.734..6553.819 rows=47611 loops=1)
|
|-> Table scan on p  (cost=23.32 rows=7116413) (actual time=0.320..2075.305 rows=7286604 loops=1)
|
|-> Hash
|
|-> Inner hash join (c.collision_severity = cs.id)  (cost=616806.49 rows=1515959) (actual time=2.612..1264.476 rows=25587 loops=1)
|
|-> Table scan on c  (cost=52578.57 rows=3368797) (actual time=0.093..942.615 rows=3678062 loops=1)
|
|-> Hash
|
|-> Filter: ((cs.`description` = 'Fatal') or (cs.`description` = 'Severe'))  (cost=1.50 rows=2) (actual time=2.012..2.015 rows=1 loops=1)
|
|-> Table scan on cs  (cost=1.50 rows=5) (actual time=2.003..2.009 rows=5 loops=1)
|
+------------------------------------------------------------------------------------------------------------------------------------------------------------+
```

We optimise the query by adding multiple indexes:

```
CREATE INDEX index_collision_id ON Collisions(case_id) USING HASH;
CREATE INDEX index_parties_case_id ON Parties(case_id) USING HASH;
```

```sql
CREATE INDEX index_victims_party_id ON Victims(party_id) USING HASH;
CREATE INDEX index_vehicle_make_id ON VehicleMake(id) USING HASH;
```

The total cost dropped to 6763992.34, reducing it by 457219%. Most of the decrease came from taking advantages of index when joining, as you can see on the figure below.

```
|EXPLAIN
|-> Limit: 10 row(s)  (actual time=3830.303..3830.305 rows=10 loops=1)
|-> Sort: `COUNT(*)` DESC, limit input to 10 row(s) per chunk  (actual time=3830.303..3830.303 rows=10 loops=1)
|-> Table scan on <temporary>  (actual time=0.001..0.042 rows=167 loops=1)
|-> Aggregate using temporary table  (actual time=3830.213..3830.268 rows=167 loops=1)
|-> Nested loop inner join  (cost=8197663.21 rows=2819580) (actual time=5.059..3670.992 rows=198745 loops=1)
|-> Nested loop inner join  (cost=5096124.97 rows=2819580) (actual time=4.558..3352.274 rows=198745 loops=1)
|-> Nested loop inner join  (cost=1994586.72 rows=2819580) (actual time=4.425..1638.316 rows=228853 loops=1)
|-> Nested loop inner join  (cost=231128.57 rows=1508588) (actual time=4.344..683.291 rows=120532 loops=1)
|-> Filter: ((injury.`description` = 'Killed') or (injury.`description` = 'Severe Injury'))  (cost=1.43 rows=2) (actual time=0.108..0.143 rows=2 loops=1)
|-> Index range scan on injury using description  (cost=1.43 rows=2) (actual time=0.105..0.136 rows=2 loops=1)
|-> Index lookup on vict using index_hash_victim_injury (victim_degree_of_injury=injury.id)  (cost=77848.87 rows=754294) (actual time=2.326..335.710 rows=60266 loops=2)
|-> Index lookup on p using case_id (case_id=vict.case_id)  (cost=0.98 rows=2) (actual time=0.007..0.008 rows=2 loops=120532)
|-> Filter: (v.vehicle_make is not null)  (cost=1.00 rows=1) (actual time=0.007..0.007 rows=1 loops=228853)
|-> Index lookup on v using party_id (party_id=p.id)  (cost=1.00 rows=1) (actual time=0.006..0.007 rows=1 loops=228853)
|-> Single-row index lookup on make using PRIMARY (id=v.vehicle_make)  (cost=1.00 rows=1) (actual time=0.001..0.001 rows=1 loops=198745)
```

The runtime of the query is:

- Unoptimised: 10s600ms
- Optimised: 794ms

Query 7

We clearly see here in the figure below that our query is costly (cost : 1888463.62) and this is due to several reasons mainly the lack of indexes to make the joins fast as well as the filter that is applied to TypeOfCollision table to find the 'pedestrian' type and to the Victim table to find age > 99 .

```
+-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------
+
|
EXPLAIN
|
+-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------
+
|-> Nested loop inner join  (cost=1453582.65 rows=0) (actual time=6150.659..7636.421 rows=28
loops=1)
|
|-> Inner hash join (c.type_of_collision = tc.id)  (cost=360713.03 rows=437147) (actual time=0.241..1399.236 rows=89086
loops=1)
|
|-> Table scan on c  (cost=54708.41 rows=3497175) (actual time=0.096..1079.461 rows=3678062
loops=1)
|
|->
Hash
|
|-> Filter: (tc.`description` = 'pedestrian')  (cost=1.80 rows=1) (actual time=0.108..0.112 rows=1
loops=1)
|
|-> Table scan on tc  (cost=1.80 rows=8) (actual time=0.099..0.106 rows=8
loops=1)
|
|-> Index lookup on old_people_collisions using <auto_key0> (id=c.case_id)  (actual time=0.001..0.001 rows=0
loops=89086)
|
|-> Materialize  (cost=0.00..0.00 rows=0) (actual time=0.070..0.070 rows=0
loops=89086)
|
|-> Filter: (min(v.victim_age) > 99)  (actual time=5794.838..6136.153 rows=115
loops=1)
|
|-> Table scan on <temporary>  (actual time=0.004..147.029 rows=2053339
loops=1)
|
|-> Aggregate using temporary table  (actual time=5790.256..6039.239 rows=2053339
loops=1)
|
|-> Table scan on v  (cost=418375.57 rows=4043719) (actual time=0.087..1439.727 rows=4082684
loops=1)
|
+-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------
+
```

Thus, we decide to create the following indexes :

```sql
CREATE INDEX index_victim_age ON Victims(victim_age) USING BTREE;
CREATE INDEX index_collision_id ON Collisions(case_id) USING HASH;
CREATE INDEX index_type_of_collision ON TypeOfCollision(id) USING HASH;
CREATE INDEX index_collision_type ON Collisions(type_of_collision) USING
HASH;
CREATE INDEX index_victim_case_id ON Victims(case_id) USING HASH;
CREATE INDEX index_type_of_collision_description ON
TypeOfCollision(description) USING HASH;
```

Here is what we got after optimization (figure below), and the cost of our query is now : 1578149.12, reducing it by 1% .

```
+----------------------------------------------------------------------------------------------------------------------------------------------------------
+
|
EXPLAIN
|
+----------------------------------------------------------------------------------------------------------------------------------------------------------
+
|-> Nested loop inner join  (cost=1141001.27 rows=0) (actual time=5292.575..5392.641 rows=28
loops=1)
|
|-> Nested loop inner join  (cost=48131.65 rows=437147) (actual time=0.079..26.448 rows=89086
loops=1)
|
|-> Index lookup on tc using index_type_of_collision_description (description='pedestrian')  (cost=0.35 rows=1) (actual time=0.025..0.031 rows=1
loops=1)
|
|-> Index lookup on c using index_collision_type (type_of_collision=tc.id)  (cost=48131.30 rows=437147) (actual time=0.052..22.379 rows=89086
loops=1)
|
|-> Index lookup on old_people_collisions using <auto_key0> (id=c.case_id)  (actual time=0.001..0.001 rows=0
loops=89086)
|
|-> Materialize  (cost=0.00..0.00 rows=0) (actual time=0.060..0.060 rows=0
loops=89086)
|
|-> Filter: (min(v.victim_age) > 99)  (actual time=4996.346..5290.966 rows=115
loops=1)
|
|-> Table scan on <temporary>  (actual time=0.002..125.671 rows=2053339
loops=1)
|
|-> Aggregate using temporary table  (actual time=4993.376..5205.866 rows=2053339
loops=1)
|
|-> Table scan on v  (cost=420684.28 rows=4043719) (actual time=0.138..1207.702 rows=4082684
loops=1)
|
+----------------------------------------------------------------------------------------------------------------------------------------------------------
+
```

The runtime of the query is:

- Unoptimised: 10s287ms
- Optimised: 8.898ms

Query 8

The unoptimised version of this query leads the database to only make full scans and hash joins. The hash joins is what takes the most time (see figure below) and the total cost is : 6447580524489.79 .

```
+----------------------------------------------------------------------------------------------------------------------------------------------------------
EXPLAIN
+----------------------------------------------------------------------------------------------------------------------------------------------------------
+
|-> Sort: num_of_collisions DESC  (actual time=60277.408..60278.029 rows=6270
loops=1)
|
|-> Filter: (count(0) > 9)  (actual time=60242.311..60274.208 rows=6270
loops=1)
|
|-> Table scan on <temporary>  (actual time=0.002..29.752 rows=19866
loops=1)
|
|-> Aggregate using temporary table  (actual time=60242.306..60273.058 rows=19866
loops=1)
|
|-> Inner hash join (c.case_id = p.case_id)  (cost=387139549922.73 rows=372727) (actual time=26606.385..47729.802 rows=6122074
loops=1)
|
|-> Table scan on c  (cost=15.10 rows=3497175) (actual time=8.189..1096.827 rows=3678062
loops=1)
|
|->
Hash
|
|-> Inner hash join (p.id = v.party_id)  (cost=256712573117.05 rows=372681) (actual time=8332.143..24035.562 rows=6122074
loops=1)
|
|-> Table scan on p  (cost=33.65 rows=6883414) (actual time=1.062..2342.543 rows=7286604
loops=1)
|
|->
Hash
|
|-> Inner hash join (makes.id = v.vehicle_make)  (cost=8796041.67 rows=372627) (actual time=6034.723..7239.855 rows=6122074
loops=1)
|
|-> Table scan on makes  (cost=0.00 rows=217) (actual time=0.023..0.062 rows=217
loops=1)
|->
Hash
|
|-> Inner hash join (v.statewide_vehicle_type = `type`.id)  (cost=709070.37 rows=372627) (actual time=3.049..5119.394 rows=6122074
loops=1)
|
|-> Filter: (v.vehicle_make <> 0)  (cost=8628.36 rows=414030) (actual time=0.058..4309.312 rows=6863224
loops=1)
|
|-> Table scan on v  (cost=8628.36 rows=6900506) (actual time=0.055..3850.638 rows=7286604
loops=1)
|->
Hash
|
|-> Table scan on type  (cost=2.50 rows=15) (actual time=2.951..2.958 rows=15
loops=1)
+----------------------------------------------------------------------------------------------------------------------------------------------------------
```

Thus we decide to create the following indexes :

```
CREATE INDEX index_statewide_vehicle ON Vehicles(statewide_vehicle_type)
USING HASH;
CREATE INDEX index_vehicle_make ON Vehicles(vehicle_make) USING HASH;
CREATE INDEX index_vehicle_year ON Vehicles(vehicle_year) USING HASH;
CREATE INDEX index_v_party_id ON Vehicles(party_id) USING HASH;
CREATE INDEX index_p_id ON Parties(id);
CREATE INDEX index_p_caseid ON Parties(case_id) USING HASH;
CREATE INDEX index_collision_id ON Collisions(case_id);
```

Here is what we got after optimization (figure below), and the cost of our query is now : 12899075, reducing it by 499848% .

```
+------------------------------------------------------------------------------------------------------------------------------------------------
+
|
EXPLAIN
|
+------------------------------------------------------------------------------------------------------------------------------------------------
+
|-> Sort: num_of_collisions DESC  (actual time=377467.938..377468.772 rows=6270
loops=1)
|
|-> Filter: (count(0) > 9)  (actual time=377360.634..377462.769 rows=6270
loops=1)
|
|-> Table scan on <temporary>  (actual time=0.002..97.428 rows=19866
loops=1)
|
|-> Aggregate using temporary table  (actual time=377360.630..377460.020 rows=19866
loops=1)
|
|-> Nested loop inner join  (cost=9599952.77 rows=3450254) (actual time=2.394..360548.862 rows=6122074
loops=1)
|
|-> Nested loop inner join  (cost=6516105.21 rows=3450254) (actual time=2.006..304103.417 rows=6122074
loops=1)
|
|-> Nested loop inner join  (cost=2720826.13 rows=3450254) (actual time=1.282..143388.493 rows=6122074
loops=1)
|
|-> Nested loop inner join  (cost=1513237.33 rows=3450254) (actual time=1.257..134777.389 rows=6122074
loops=1)
|
|-> Index scan on type using description  (cost=1.75 rows=15) (actual time=0.392..0.669 rows=15
loops=1)
|
|-> Filter: ((v.vehicle_make <> 0) and (v.vehicle_make is not null))  (cost=56412.45 rows=230017) (actual time=1.069..8945.642 rows=408138
loops=15)
|
|-> Index lookup on v using index_statewide_vehicle (statewide_vehicle_type=`type`.id)  (cost=56412.45 rows=460034) (actual time=1.037..8854.374 rows=426684
loops=15)
|
|-> Single-row index lookup on makes using PRIMARY (id=v.vehicle_make)  (cost=0.25 rows=1) (actual time=0.001..0.001 rows=1
loops=6122074)
|
|-> Single-row index lookup on p using PRIMARY (id=v.party_id)  (cost=1.00 rows=1) (actual time=0.026..0.026 rows=1
loops=6122074)
|
|-> Single-row index lookup on c using PRIMARY (case_id=p.case_id)  (cost=0.79 rows=1) (actual time=0.009..0.009 rows=1
loops=6122074)
|
+------------------------------------------------------------------------------------------------------------------------------------------------
+
```

The runtime of the query is:

- Unoptimised: 11mn20s
- Optimised: 7mn54s

Query 10

The unoptimised version of this query leads the database to only make full scans and hash joins. The hash joins is what takes the most time as well as the filter applied to verify the following condition: ((f.lighting = l.id) or (f.lighting = NULL)).

The total cost is 1153051835865.08 . (see figure below)

```
+----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
+
|
EXPLAIN
|
+----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
+
|-> Table scan on <temporary>  (actual time=0.002..0.003 rows=4
loops=1)
|
|-> Aggregate using temporary table  (actual time=14024.386..14024.387 rows=4
loops=1)
|
|-> Filter: ((l.id = f.lighting) or (f.lighting = NULL))  (cost=1153051069740.34 rows=16487341) (actual time=9026.911..11832.686 rows=3652282
loops=1)
|
|-> Inner hash join (no condition)  (cost=1153051069740.34 rows=16487341) (actual time=9026.907..10647.370 rows=18390310
loops=1)
|
|-> Table scan on l  (cost=0.00 rows=5) (actual time=8.370..8.376 rows=5
loops=1)
|
|->
Hash
|
|-> Inner hash join (c.case_id = f.case_id)  (cost=1153049418954.85 rows=3297468) (actual time=2323.155..8661.600 rows=3678062
loops=1)
|
|-> Table scan on c  (cost=2.77 rows=3497175) (actual time=0.082..732.565 rows=3678062
loops=1)
|
|->
Hash
|
|-> Table scan on f  (cost=341080.10 rows=3297061) (actual time=0.061..1660.814 rows=3678062
loops=1)
|
+----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
+
```

Thus, we decide to create the following indexes :

```sql
CREATE INDEX index_factor_case_id ON Factors(case_id) USING HASH;
CREATE INDEX index_collision_time ON Collisions(collision_time) USING
BTREE;
CREATE INDEX index_collision_caseid ON Collisions(case_id) USING HASH;
CREATE INDEX index_factors_lightening ON Factors(lighting) USING HASH;
CREATE INDEX index_lightening_description ON Lighting(description) USING
HASH;
CREATE INDEX index_lightening_id ON Lighting(id) USING HASH;
```

Here is what we got after optimization (figure below), and the cost of our query is now : 2906812.20, reducing it by 396672%

```
+----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
+
|
EXPLAIN
|
+----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
+
|-> Table scan on <temporary>  (actual time=0.002..0.003 rows=4
loops=1)
|
|-> Aggregate using temporary table  (actual time=39864.798..39864.798 rows=4
loops=1)
|
|-> Nested loop inner join  (cost=2933644.33 rows=4615885) (actual time=2.985..35068.928 rows=3652282
loops=1)
|
|-> Filter: ((f.lighting = l.id) or (f.lighting = NULL))  (cost=1659940.93 rows=4615885) (actual time=0.178..11013.394 rows=3652282
loops=1)
|
|-> Inner hash join (no condition)  (cost=1659940.93 rows=4615885) (actual time=0.168..9050.476 rows=18390310
loops=1)
|
|-> Table scan on f  (cost=20745.33 rows=3297061) (actual time=0.094..7332.926 rows=3678062
loops=1)
|
|->
Hash
|
|-> Index scan on l using index_lightening_description  (cost=1.50 rows=5) (actual time=0.040..0.048 rows=5
loops=1)
|
|-> Single-row index lookup on c using PRIMARY (case_id=f.case_id)  (cost=0.18 rows=1) (actual time=0.006..0.006 rows=1
loops=3652282)
|
+----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
+
```

The runtime of the query is:

- Unoptimised: 37s203ms

- Optimised: 29.467ms