Exam of *Decision Support Systems* / *Decision Support Databases*: Example 1

It is forbidden to consult any material during the test. Duration of written exam is 2h.

1. **(Mandatory)** Let us consider the following database, without null values:

Products

PkP	UnitPrice	...
10	5	...
20	10	...
30	20	...

Sales

FkP	Qty	...
10	50	...
20	10	...
30	20	...
10	30	...
20	100	...
30	10	...
10	30	...

   (a) **(1 point)** Write an SQL query to find the total sales revenue by product.

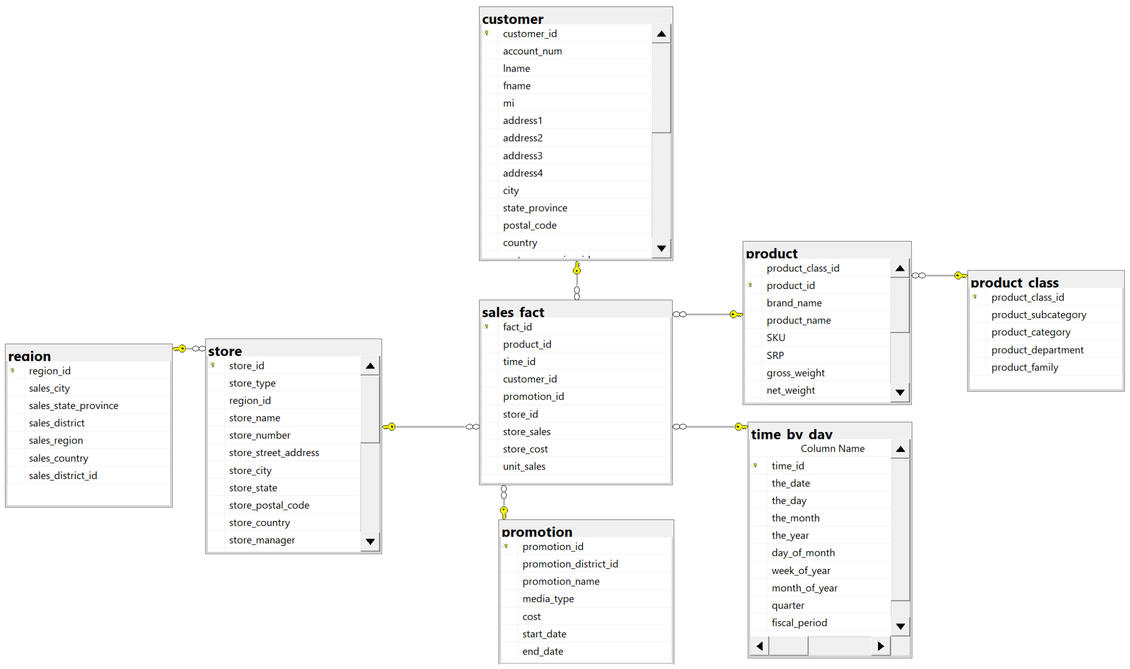
   (b) **(1 point)** Give a logical query plan for the SQL query, the type and the value of the result. Modify the logical query plan to consider only products with UnitPrice > 5 sold each of them more than 5 times.

   (c) **(1 point)** Modify the SQL query to find also the rank of the product total quantity sold (the highest is first)).

   (d) **(1 point)** Show the instance of an index on the attribute FkP.

   (e) **(1 point)** Show the instance of a *Foreign Column Join Index* on the attribute UnitPrice.

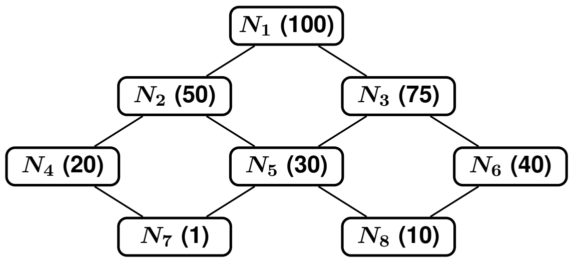
2. **(5 points)** Consider the FoodMart datawarehouse:



Consider a customer *customer_id* in a day *time_id* when she/he has made a purchase. The customer is *occasional* if she/he has made purchases for at most 10 euros in the previous 45 days. Give an analytic SQL query to output for every *customer_id* and *time_id* that are NOT occasional, the total sales in the previous 45 days.

3. See lecture notes Exercise A.4: Inventory.
   With respect to the above business scenario, answer the following questions:
   (a) **(6 points)** Design a conceptual schema for the data mart to support the business questions. Your schema should at least be able to satisfy the above mentioned analysis requirements. You may motivate other suitable attributes for the dimensions. Specify the fact granularity, and for each measure, if it is additive, semi-additive or non-additive, and for each dimensional attribute the type of updates of the attribute.
   (b) **(3 points)** Give a logical data mart design which is able to deal with updates of dimensional attributes.
   (c) **(1 point)** Write an SQL query to answer one business questions of your choice and write a physical query plan for the query using any index of your choice.

4. **(5 points)** Let us consider the following lattice of possible candidate views to materialize. The numbers associated with the nodes represent the view size, measured in terms of the number of tuples in the view. Select 3 views to materialize, different from N_1, with the greedy algorithm HRU.



5. **(5 points)** Let us consider the logical schema of a data mart

   Customer(<u>PkCustPhoneNo</u>, CustName, CustCity)
   CallingPlans(<u>PkPlanId</u>, <u>PlanName</u>)
   Calls(PkCustPhoneNo, FkPlanId, Day, Month, Year, Duration, Charge)

   where PkPlanId e PlanName are two different keys, and the following query

```
Q:  SELECT      Year, PlanName, SUM(Charge) AS TC
    FROM        Calls, CallingPlans
    WHERE       FkPlanId = PkPlanId AND Year >= 2000 AND Year <=2005
    GROUP BY    Year, PlanName
    HAVING      SUM(Charge) > 1000;
```

   Answer **only one** of the following questions:
   (a) Show if and how the GROUP BY can be brought forward on the table Calls.
   (b) Show if and how the query can be rewritten using the materialized view

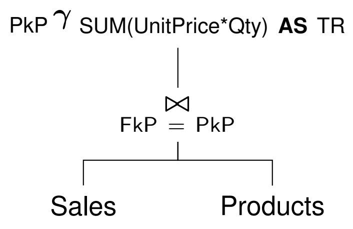
```
V1:  SELECT      FkPlanId, Month, Year, SUM(Charge) AS C
     FROM        Calls
     WHERE       Year >= 2000
     GROUP BY    FkPlanId, Month, Year;
```

Exam of *Decision Support Databases: Solution Example 1 (Hints)*

1. (a) The SQL query is:

```
SELECT      PkP, SUM(UnitPrice*Qty) AS TR
FROM        Sales, Products
WHERE       FkP = PkP
GROUP BY    PkP;
```

(b) The logical query plan is:

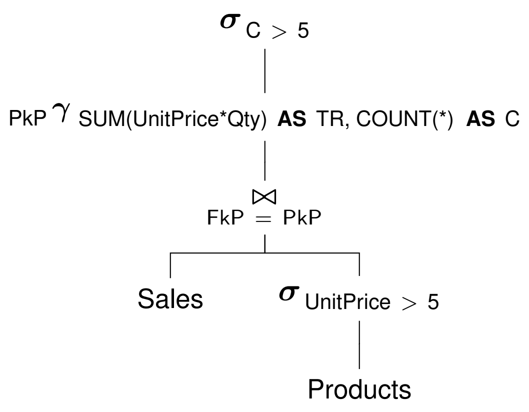


The type of the result is $\{($ PkP:int, TR:int $)\}$. The value of the result is:

Products

PkP	TR
10	550
20	1100
30	600

The modified logical query plan is:



(c) The modified SQL query is:

```
SELECT      PkP, SUM(UnitPrice*Qty) AS TR, RANK() OVER (ORDER BY SUM(Qty) DESC) AS Rk
FROM        Sales, Products
WHERE       FkP = PkP
GROUP BY    PkP;
```

(d) and (e) These are the instances of the indexes:

Index on FkP

FkP	**RID**
10	1
10	4
10	7
20	2
20	5
30	3
30	6

FCJI on UnitPrice

UnitPrice	**RID**
5	1
5	4
5	7
10	2
10	5
20	3
20	6

2.
```
WITH tmp AS (
        SELECT      customer_id, time_id,
                    SUM(SUM(store_sales)) OVER (
                        PARTITION BY customer_id
                        ORDER BY time_id
                        RANGE BETWEEN 45 PRECEDING AND CURRENT ROW ) AS tot
        FROM        sales_fact
        GROUP BY    customer_id, time_id
)
SELECT      *
FROM        tmp
WHERE       tot>10
ORDER BY customer_id, time_id;
```

3. (a) **Requirements specification and the conceptual design of a data mart for the inventory**. See lecture notes solution to Exercise A.4: Inventory.

   (b) **Logical design of the data mart and the SQL queries**. See lecture notes solution to Exercise A.4: Inventory.

   (c) **Physical query plan**. See lecture notes.

4. The application of the HRU algorithm yields:

	First Choice	**Second Choice**	**Third Choice**
$\mathbf{N_2}$	$\mathbf{50 \times 5 = 250}$		
$\mathbf{N_3}$	$25 \times 5 = 125$	$25 \times 2 = 50$	25
$\mathbf{N_4}$	$80 \times 2 = 160$	$30 \times 2 = 60$	$\mathbf{30 \times 2 = 60}$
$\mathbf{N_5}$	$70 \times 3 = 210$	$20 \times 3 = 60$	$20 \times 2 + 10 = 50$
$\mathbf{N_6}$	$60 \times 2 = 120$	$\mathbf{60 + 10 = 70}$	
$\mathbf{N_7}$	$99 \times 1 = 99$	$49 \times 1 = 49$	49
$\mathbf{N_8}$	$90 \times 1 = 90$	$40 \times 1 = 40$	30

5. (a) Show if and how the **GROUP BY** can be brought forward on the table Calls.
   The selection on Year can be pushed on Calls below the join.
   The group-by can be pushed on Calls below the join because the *invariant grouping* property holds: the aggregate function SUM(Charge) uses an attribute from Calls, and (Year, PlanName $\rightarrow$ FkPlanId) because

$$(\text{Year, PlanName})^+ = \{\text{Year, PlanName, PkPlanId, FkPlanId}\}$$

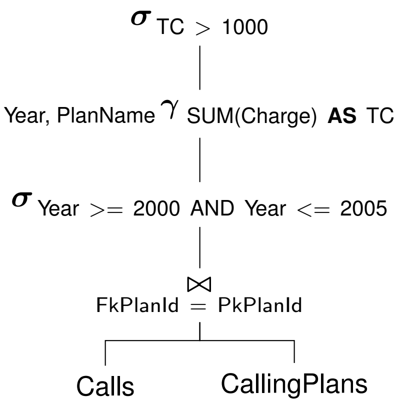

σ TC > 1000
Year, PlanName γ SUM(Charge) AS TC
σ Year >= 2000 AND Year <= 2005
⋈ FkPlanId = PkPlanId
Calls
CallingPlans

Figure 1: Logical query plan

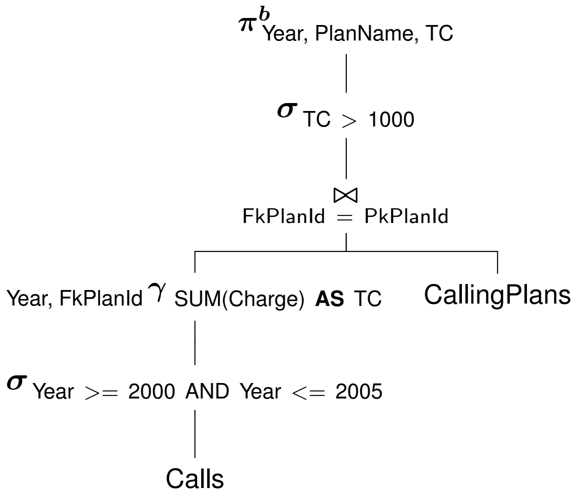


Figure 2: Logical query plan with the group-by pushed below the join

(b) Show if and how the query can be rewritten using the materialized view

```
V1: SELECT     FkPlanId, Month, Year, SUM(Charge) AS C
    FROM       Calls
    WHERE      Year >= 2000
    GROUP BY   FkPlanId, Month, Year;
```

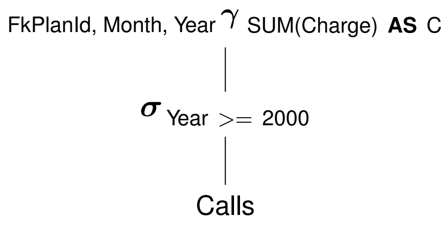
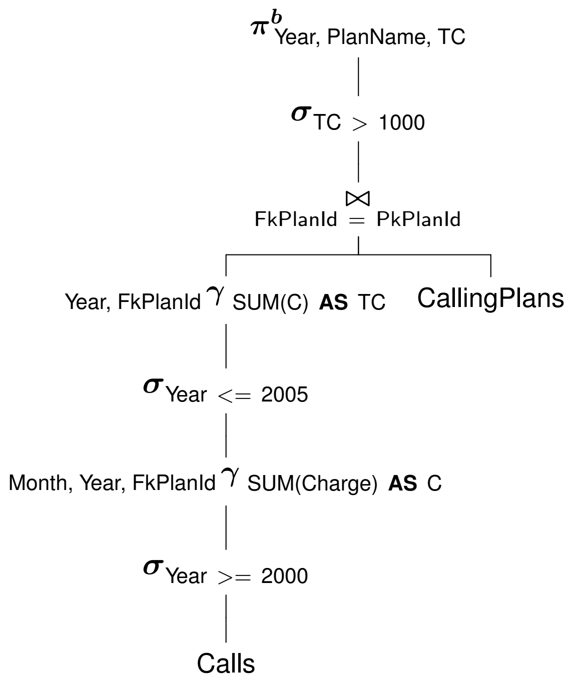


Figure 3: Logical view plan

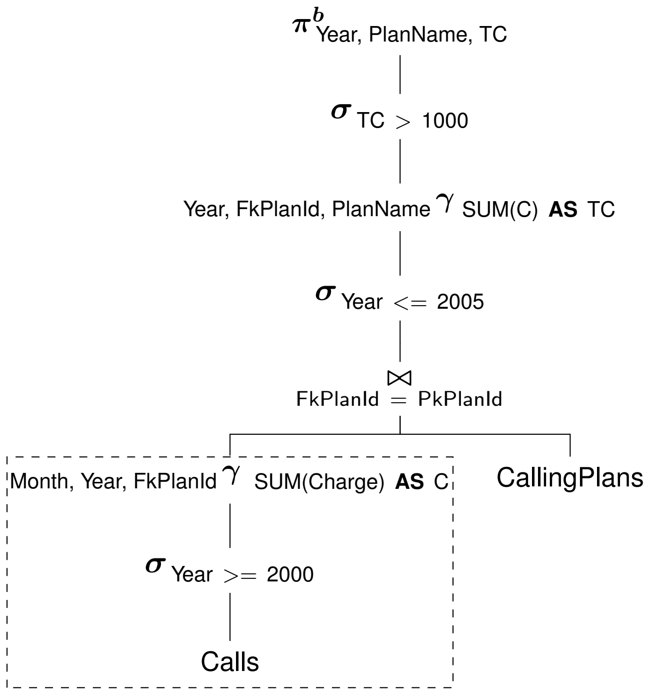
Let us use the approach with a *transformation of the logical query plan* in Figure 2, which can be rewritten as follows with a subtree identical to V:



$\pi^b_{\text{Year, PlanName, TC}}$
$\sigma_{\text{TC} > 1000}$
$\bowtie_{\text{FkPlanId} = \text{PkPlanId}}$
$_{\text{Year, FkPlanId}}\gamma_{\text{SUM(C) AS TC}}$
CallingPlans
$\sigma_{\text{Year} <= 2005}$
$_{\text{Month, Year, FkPlanId}}\gamma_{\text{SUM(Charge) AS C}}$
$\sigma_{\text{Year} >= 2000}$
Calls

Figure 4: Logical query plan with the logical view subplan

The logical query plan with the logical view subplan is then rewritten as follows to translate it in SQL. With the rewriting of the group-by over the join, the attribute PlanName of CallingPlans, used by the projection, can be added to grouping attributes because (FkPlanId = PkPlanId) and PkPlanId $\rightarrow$ PlanName.



$\pi^{b}_{\text{Year, PlanName, TC}}$
$\sigma_{\text{TC} > 1000}$
$_{\text{Year, FkPlanId, PlanName}}\gamma_{\text{SUM(C) AS TC}}$
$\sigma_{\text{Year} <= 2005}$
$\bowtie_{\text{FkPlanId} = \text{PkPlanId}}$
$_{\text{Month, Year, FkPlanId}}\gamma_{\text{SUM(Charge) AS C}}$
CallingPlans
$\sigma_{\text{Year} >= 2000}$
Calls

Figure 5: Final version of the logical query plan with the logical view subplan

So the rewriting of Q succeeds:

```
Q1”: SELECT     Year, PlanName, SUM(C) AS TC
     FROM       V1, CallingPlans
     WHERE      FkPlanId = PkPlanId AND Year <=2005
     GROUP BY   Year, FkPlanId, PlanName
     HAVING     SUM(C) > 1000;
```

Exam of *Decision Support Systems* / *Decision Support Databases*: Example 2

It is forbidden to consult any material during the test. Duration of written exam is 2h.

1. **(Mandatory)** Let us consider the following database, without null values (F(Fk :int, B : int, C :int) and D(Pk :int, E :string)) and the query:

```
SELECT      Fk, COUNT(*) AS Cn
FROM        F, D
WHERE       Fk = Pk AND E <> 'd3'
GROUP BY    Fk
HAVING      SUM(C) < 100;
```

D

Pk	E
1	d1
2	d2
3	d3

F

Fk	B	C
1	10	60
1	20	20
2	30	80
2	20	25
3	30	80

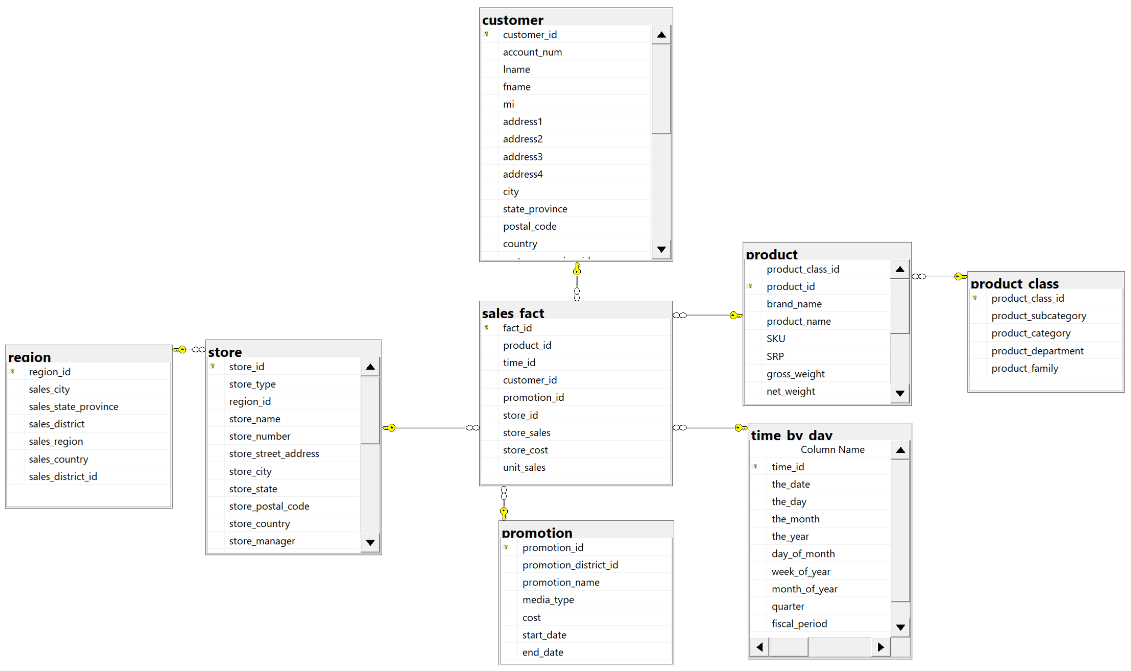
   (a) **(1 point)** Give a logical query plan for the SQL query, the type and the value of the result.

   (b) **(1 point)** Show the instance of a bitmap index on the attribute Fk.

   (c) **(1 point)** Show the instance of a *Bitmap Foreign Column Join Index* on the attribute E.

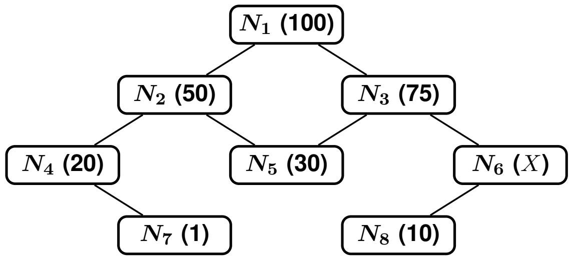
   (d) **(2 points)** Explain the meaning of a "semi-additive" measure. Let F(FkD1, FkD2, M) be a table with the "semi-additive" measure M with respect to the dimension D1. Give a correct and a wrong query on the schema with the aggregation SUM(M).

2. **(5 points)** Consider the FoodMart datawarehouse:



A customer is called a *commuter* if she buys at least 70% of her purchases (total store sales) in stores outside her city. Give an SQL query to find the number of commuters by customer city. The query must return 0 for cities with no commuter.

3. See lecture notes Exercise A.5: Hotels.
   With respect to the above business scenario, answer the following questions:
   (a) **(6 points)** Design a conceptual schema for the data mart to support the business questions. Your schema should at least be able to satisfy the above mentioned analysis requirements. You may motivate other suitable attributes for the dimensions. Specify the fact granularity, and for each measure, if it is additive, semi-additive or non-additive, and for each dimensional attribute the type of updates of the attribute.
   (b) **(3 points)** Give a logical data mart design which is able to deal with updates of dimensional attributes.
   (c) **(1 point)** Write an SQL query to answer one business questions of your choice and write a physical query plan for the query using any index of your choice.
4. **(5 points)** Let us consider the following lattice of possible candidate views to materialize. The numbers associated with the nodes represent the view size, measured in terms of the number of tuples in the view. Select 3 views to materialize, different from N_1, with the greedy algorithm HRU. Determine the various possible results of HRU on the basis of the unknown value X.



5. **(5 points)** Let us consider the database without null values:

   Customer(PKCustomer, CName, CCity)
   Order(PKOrder, FKCustomer, ODate)
   Product(PKProduct, PName, PCost)
   OrderLine(LineNo, FKOrder, FKProduct, Quantity, ExtendedPrice, Discount, Revenue)

   and the query

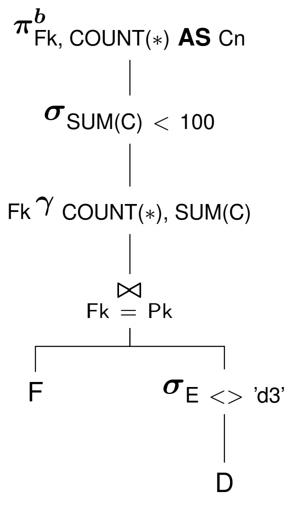
```
Q:  SELECT     CCity, AVG(Revenue) AS avgR
    FROM       OrderLine, Order, Customer
    WHERE      FKOrder = PKOrder AND FKCustomer = PKCustomer
    GROUP BY   CCity, FKCustomer
    HAVING     SUM(Revenue) > 1000;
```

   Answer **only one** of the following questions:
   (a) Show if and how the **GROUP BY** can be pushed on the join
   (OrderLine $\bowtie_{\text{FKOrder = PKOrder}}$ Order),
   and show if and how the **GROUP BY** can be pushed on the relation OrderLine.
   (b) Show if and how the query Q can be rewritten using the materialized view V

```
V:  SELECT     FKCustomer, SUM(Revenue) AS TR, COUNT(*) AS Cnt
    FROM       OrderLine, Order
    WHERE      FKOrder = PKOrder
    GROUP BY   FKCustomer;
```

Exam of *Decision Support Databases: Solution Example 2 (Hints)*

1. (a) The logical query plan is:



$\pi^{b}_{\text{Fk, COUNT}(*)\ \textbf{AS}\ \text{Cn}}$
$\sigma_{\text{SUM(C)} < 100}$
$_{\text{Fk}}\gamma_{\text{COUNT}(*),\ \text{SUM(C)}}$
$\bowtie_{\text{Fk} = \text{Pk}}$
F
$\sigma_{\text{E} <> \text{'d3'}}$
D

The type of the result is $\{($ Fk:int, Cn:int $)\}$. The value of the result is:

Products

Fk	Cn
1	2

(b) and (c) These are the instances of the indexes are:

Bitmap Index on Fk

Fk	Bitmap
1	1 1 0 0 0
2	0 0 1 1 0
3	0 0 0 0 1

BFCJI on E

Fk	Bitmap
d1	1 1 0 0 0
d2	0 0 1 1 0
d3	0 0 0 0 1

(d) A measure M is semi-additive w.r.t. a dimension D when it cannot be summed up for different values of dimension D. E.g., the monthly balance cannot be summed for different months, but it can be summed for different account holder at the same month. Here there are a correct and wrong query:

Correct:
```
SELECT     FkD1, SUM(M)
FROM       F
GROUP BY   FkD1;
```

Wrong:
```
SELECT     FkD2, SUM(M)
FROM       F
GROUP BY   FkD2;
```

2.
```
WITH base AS (
            SELECT     F.customer_id, C.city,
                        CASE WHEN S.store_city=C.city THEN 0 ELSE 1 END AS other,
                       SUM(store_sales) AS purchases
            FROM       sales_fact F, customer C, store S
            WHERE      F.customer_id = C.customer_id AND F.store_id = S.store_id
            GROUP BY   F.customer_id, C.city, CASE WHEN S.store_city=C.city THEN 0 ELSE 1 END )
), tmp AS (
            SELECT     customer_id, city,
                       100*SUM(purchases) OVER (PARTITION BY customer_id, other) /
                              SUM(purchases) OVER (PARTITION BY customer_id) AS Pct
            FROM       base
)
SELECT     city, SUM( CASE WHEN other=1 AND Pct >= 70 THEN 1 ELSE 0 END ) AS N
FROM       tmp
GROUP BY   city;
```

3. (a) **Requirements specification and the conceptual design of a data mart for hotel room type utilization**. See lecture notes solution to Exercise A.5: Hotels.

   (b) **Logical design of the data mart and the SQL queries**. See lecture notes solution to Exercise A.5: Hotels.

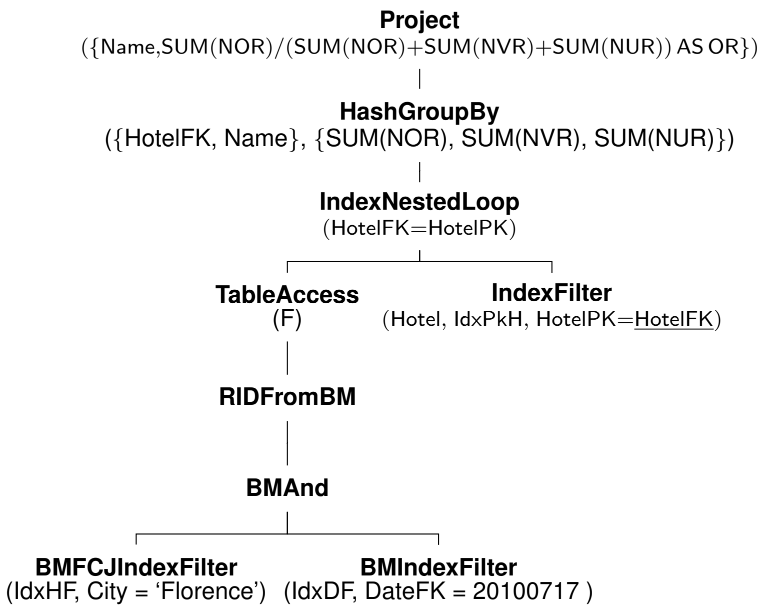
   (c) **Physical query plan** for the query

```
SELECT     H.Name
           , SUM(F.NOccupiedRooms) / ( SUM(F.NOccupiedRooms) +
                                       SUM(F.NVacantRooms) +
                                       SUM(F.NUnavailableRooms) )
                AS OccupancyRate
FROM       RoomTypeUtilization F, Hotel H
WHERE      F.HotelFK = H.HotelPK AND F.DateFK = 20100717
           AND H.City = 'Florence'
GROUP BY   F.HotelFK, H.Name;
```

   Let us assume that there is (a) a bitmap index on the fact table attribute DateFK, (b) a bitmapped foreign column join index on the Hotel dimensional attribute City, and (c) an index on the primary key of the dimensional tables.
   Let us use the following abbreviations:

   – F for RoomTypeUtilization.
   – NOR for NOccupiedRooms.
   – NVR for NVacantRooms.
   – NUR for NUnavailableRooms.
   – OR for OccupancyRate.

   The physical query plan for the first data analysis is



Project
({Name,SUM(NOR)/(SUM(NOR)+SUM(NVR)+SUM(NUR)) AS OR})
HashGroupBy
({HotelFK, Name}, {SUM(NOR), SUM(NVR), SUM(NUR)})
IndexNestedLoop
(HotelFK=HotelPK)
TableAccess
(F)
IndexFilter
(Hotel, IdxPkH, HotelPK=HotelFK)
RIDFromBM
BMAnd
BMFCJIndexFilter
(IdxHF, City = 'Florence')
BMIndexFilter
(IdxDF, DateFK = 20100717)

4. First, we observe that $10 \leq X \leq 75$. The application of the HRU algorithm yields:

	First Choice	**Second Choice**	**Third Choice** $(X \leq 55)$	**Third Choice** $(X > 55)$
$\mathbf{N_2}$	$\mathbf{50 \times 4 = 200}$			
$\mathbf{N_3}$	$25 \times 4 = 100$	$25 \times 3 = 75$	$25 \times 1 = 25$	$25 \times 2 = 50$
$\mathbf{N_4}$	$80 \times 2 = 160$	$30 \times 2 = 60$	$\mathbf{30 \times 2 = 60}$	$\mathbf{30 \times 2 = 60}$
$\mathbf{N_5}$	$70 \times 1 = 70$	$20 \times 1 = 20$	$20 \times 1 = 20$	$20 \times 1 = 20$
$\mathbf{N_6}$	$(100 - X) \times 2$	$(100 - X) \times 2$		$(100 - X) \times 1$
$\mathbf{N_7}$	$99 \times 1 = 99$	$49 \times 1 = 49$	$49 \times 1 = 49$	$49 \times 1 = 49$
$\mathbf{N_8}$	$90 \times 1 = 90$	$90 \times 1 = 90$	$X - 10$	

Observe that:

– At the first choice, since $10 \leq X$ then $(100 - X) \times 2 \leq 180$. Hence $\mathbf{N_2}$ is better than $\mathbf{N_6}$.

– At the second choice, $\mathbf{N_6}$ is selected if $(100 - X) \times 2 \geq 90$, which holds if $X \leq 55$. Otherwise $\mathbf{N_8}$ is selected.

– At the third choice with $X \leq 55$, $\mathbf{N_4}$ is selected because $X - 10 \leq 45$.

– At the third choice with $X > 55$, $\mathbf{N_4}$ is selected because $(100 - X) < 45$.

5. (a - first part) Show if and how the **GROUP BY** can be pushed on the join (OrderLine $\underset{\text{FKOrder = PKOrder}}{\bowtie}$ Order).

The group-by can be pushed on the join (OrderLine $\underset{\text{FKOrder = PKOrder}}{\bowtie}$ Order) because the *invariant grouping* property holds: the aggregate functions use an attribute from the join result, and (CCity, FKCustomer $\rightarrow$ FKCustomer).

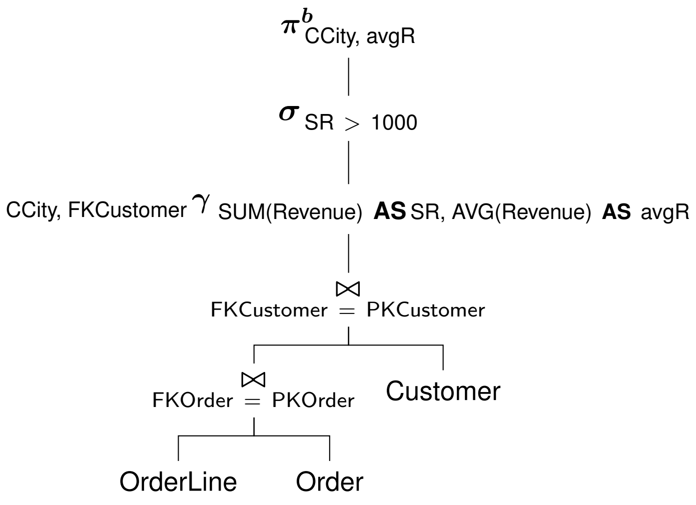

$\pi^b_{\text{CCity, avgR}}$
$\sigma_{\text{SR} > 1000}$
CCity, FKCustomer γ SUM(Revenue) **AS** SR, AVG(Revenue) **AS** avgR
$\bowtie$ FKCustomer = PKCustomer
$\bowtie$ FKOrder = PKOrder
Customer
OrderLine
Order

Figure 6: Logical query plan

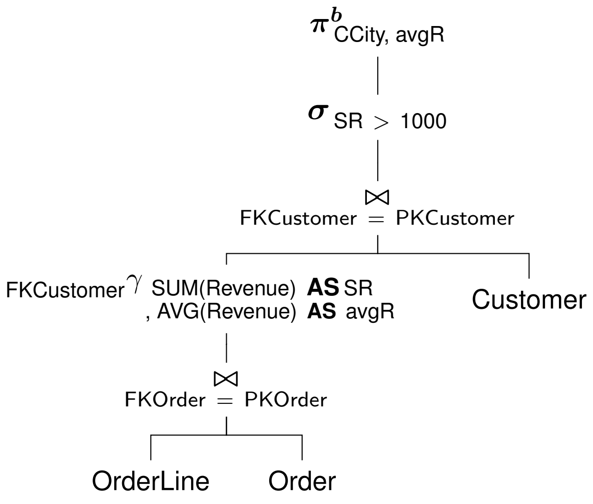
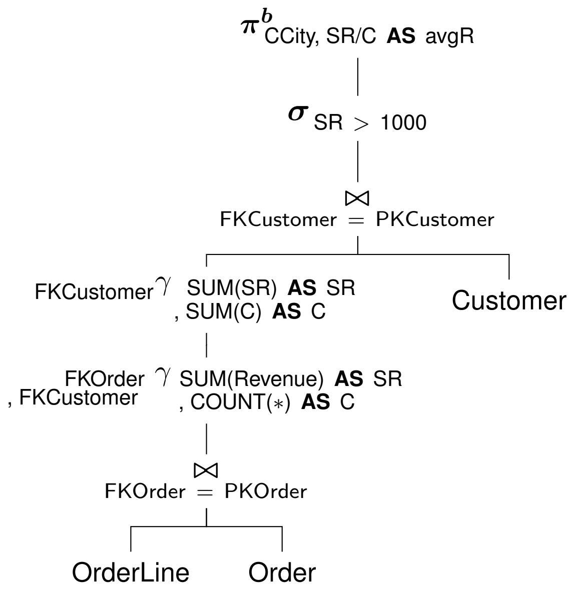

$\pi^b_{\text{CCity, avgR}}$
$\sigma_{\text{SR} > 1000}$
$\bowtie$ FKCustomer = PKCustomer
FKCustomer γ SUM(Revenue) **AS** SR , AVG(Revenue) **AS** avgR
Customer
$\bowtie$ FKOrder = PKOrder
OrderLine
Order

Figure 7: Logical query plan: the **GROUP BY** is pushed below the first join with the invariant grouping

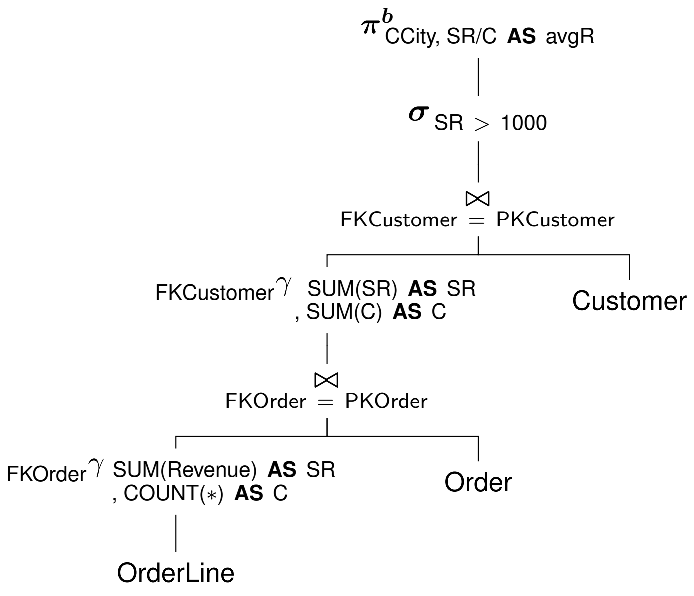
(a - second part) Show if and how the **GROUP BY** can be pushed on the relation OrderLine.

OrderLine does not have the invariant grouping property because Condition 1 does not hold: FK-Customer $\not\to$ FKOrder. The double grouping can be applied, with the rewriting of the not decomposable aggregation function AVG(Revenue) as SUM(Revenue) / COUNT(Revenue), equivalent to SUM(Revenue) / COUNT($*$) because the data mart is without null values.



$\pi^b_{\text{CCity, SR/C AS avgR}}$
$\sigma_{\text{SR} > 1000}$
$\bowtie_{\text{FKCustomer} = \text{PKCustomer}}$
FKCustomer γ SUM(SR) AS SR, SUM(C) AS C
Customer
FKOrder, FKCustomer γ SUM(Revenue) AS SR, COUNT(*) AS C
$\bowtie_{\text{FKOrder} = \text{PKOrder}}$
OrderLine
Order

Figure 8: Logical query plan: the **GROUP BY** is rewritten with the double grouping and the rewriting of AVG



$\pi^b_{\text{CCity, SR/C AS avgR}}$
$\sigma_{\text{SR} > 1000}$
$\bowtie_{\text{FKCustomer} = \text{PKCustomer}}$
FKCustomer γ SUM(SR) AS SR, SUM(C) AS C
Customer
$\bowtie_{\text{FKOrder} = \text{PKOrder}}$
FKOrder γ SUM(Revenue) AS SR, COUNT(*) AS C
Order
OrderLine

Figure 9: Logical query plan: the second **GROUP BY** is pushed below the second join with the invariant grouping

(b) Show if and how the query Q can be rewritten using the materialized view V

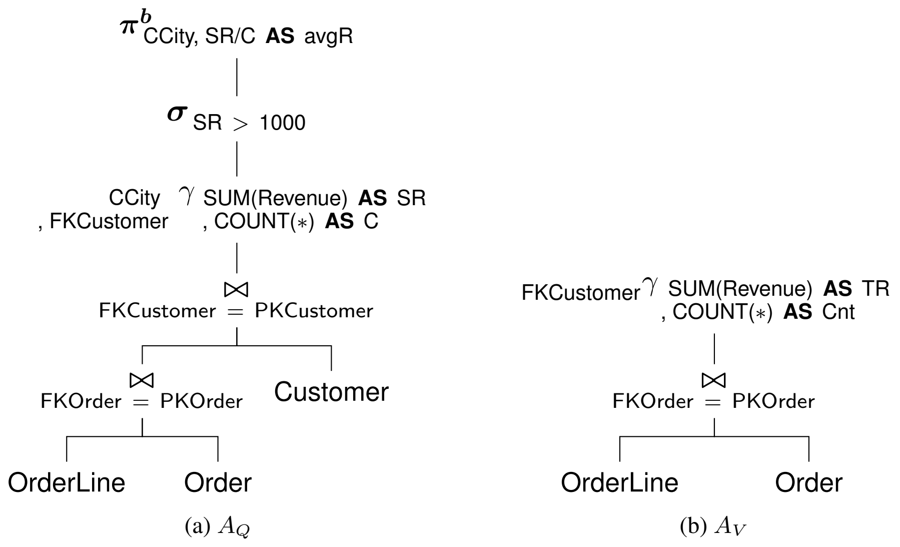
```
Q:  SELECT      CCity, AVG(Revenue) AS avgR
    FROM        OrderLine, Order, Customer
    WHERE       FKOrder = PKOrder AND FKCustomer = PKCustomer
    GROUP BY    CCity, FKCustomer
    HAVING      SUM(Revenue) > 1000;

V:  SELECT      FKCustomer, SUM(Revenue) AS TR, COUNT(*) AS Cnt
```

```
FROM        OrderLine, Order
WHERE       FKOrder = PKOrder
GROUP BY    FKCustomer;
```

Let us use the approach with a *compensation on the view*.

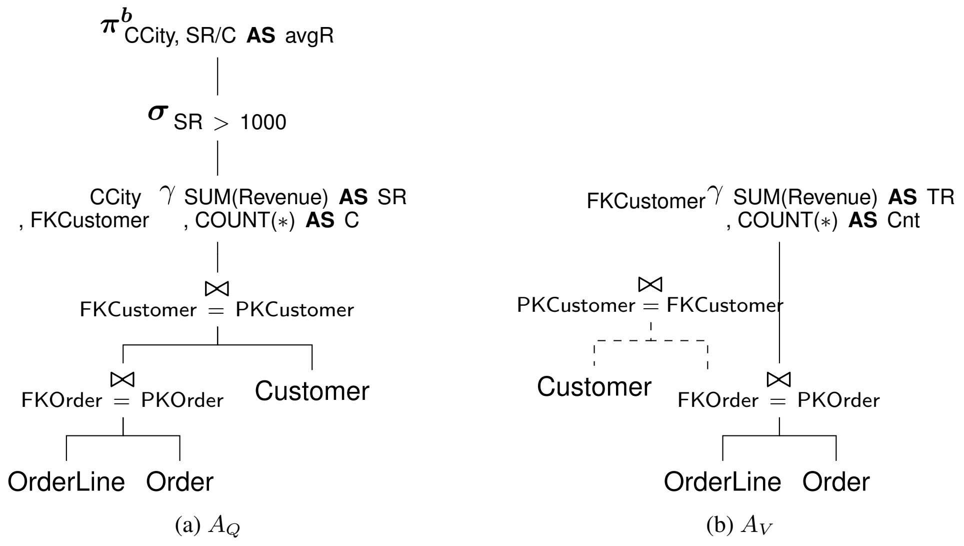
Since the approach requires that the **SELECT** and **HAVING** clauses may contain only the aggregate functions MIN, MAX, SUM and COUNT, the AVG function in Q is rewritten to compute it from given values for SUM and COUNT.



$\pi^b_{\text{CCity, SR/C AS avgR}}$
$\sigma_{\text{SR} > 1000}$
CCity, FKCustomer γ SUM(Revenue) AS SR, COUNT(∗) AS C
$\bowtie_{\text{FKCustomer} = \text{PKCustomer}}$
$\bowtie_{\text{FKOrder} = \text{PKOrder}}$
Customer
OrderLine
Order
(a) A_Q
FKCustomer γ SUM(Revenue) AS TR, COUNT(∗) AS Cnt
$\bowtie_{\text{FKOrder} = \text{PKOrder}}$
OrderLine
Order
(b) A_V

Figure 10: Query and view logical query plans

The join operations do not match. Therefore, a compensation is added as shown in the figure:



$\pi^b_{\text{CCity, SR/C AS avgR}}$
$\sigma_{\text{SR} > 1000}$
CCity, FKCustomer γ SUM(Revenue) AS SR, COUNT(∗) AS C
$\bowtie_{\text{FKCustomer} = \text{PKCustomer}}$
$\bowtie_{\text{FKOrder} = \text{PKOrder}}$
Customer
OrderLine
Order
(a) A_Q
FKCustomer γ SUM(Revenue) AS TR, COUNT(∗) AS Cnt
$\bowtie_{\text{PKCustomer} = \text{FKCustomer}}$
Customer
$\bowtie_{\text{FKOrder} = \text{PKOrder}}$
OrderLine
Order
(b) A_V

Figure 11: Join compensation

To match the groupings, the compensation on the operand of γ_V floats, and since $g(Q) \to g(V) \wedge g(V) \to g(Q)$, the rewriting does not require a grouping compensation, but an aggregate compensation only with a project, as shown in the figure:

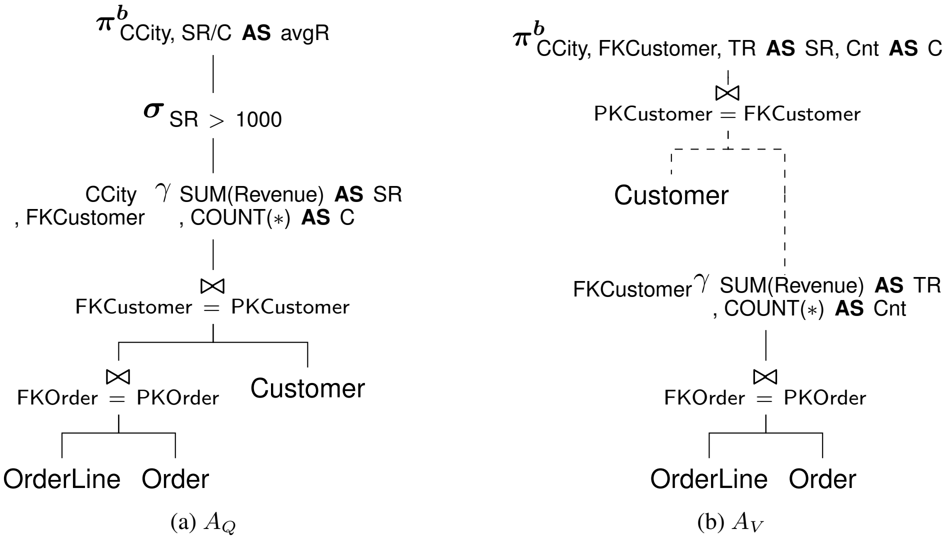

$\pi^b_{\text{CCity, SR/C AS avgR}}$
$\sigma_{\text{SR} > 1000}$
CCity, FKCustomer γ SUM(Revenue) AS SR, COUNT(*) AS C
$\bowtie$ FKCustomer = PKCustomer
$\bowtie$ FKOrder = PKOrder
Customer
OrderLine
Order
(a) A_Q
$\pi^b_{\text{CCity, FKCustomer, TR AS SR, Cnt AS C}}$
$\bowtie$ PKCustomer = FKCustomer
Customer
FKCustomer γ SUM(Revenue) AS TR, COUNT(*) AS Cnt
$\bowtie$ FKOrder = PKOrder
OrderLine
Order
(b) A_V

Figure 12: The float of the join compensation and the groupings compensation

The other compensations required for the σ and π^b in Q are shown in the figure:

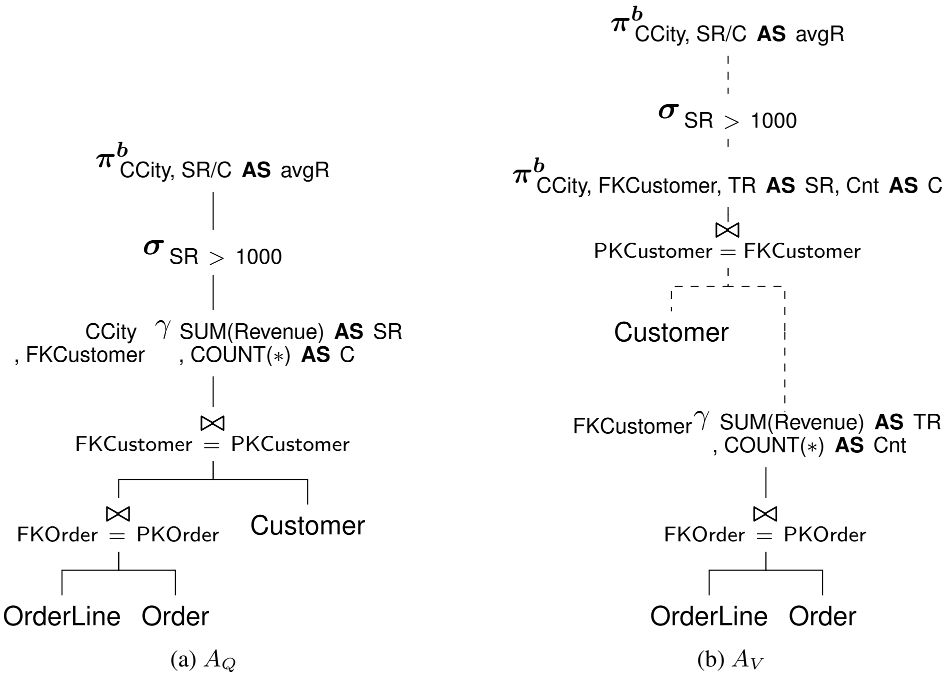
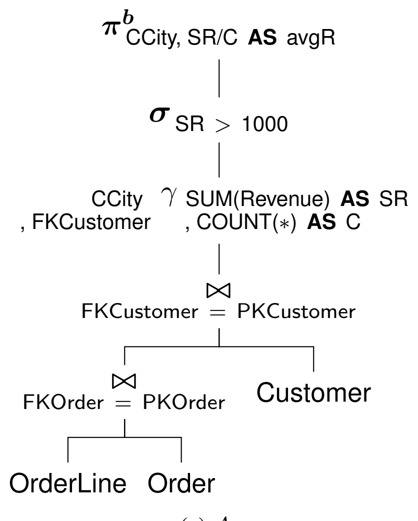
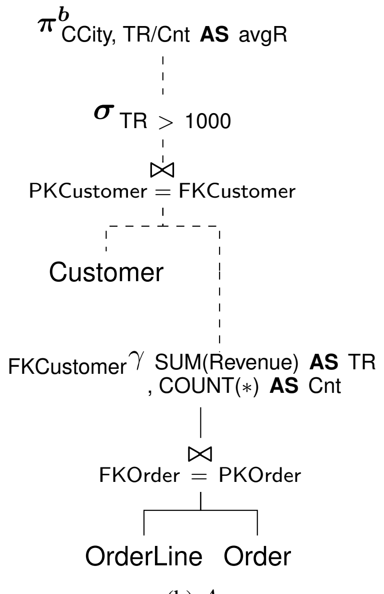

$\pi^b_{\text{CCity, SR/C AS avgR}}$
$\sigma_{\text{SR} > 1000}$
CCity, FKCustomer γ SUM(Revenue) AS SR, COUNT(*) AS C
$\bowtie$ FKCustomer = PKCustomer
$\bowtie$ FKOrder = PKOrder
Customer
OrderLine
Order
(a) A_Q
$\pi^b_{\text{CCity, SR/C AS avgR}}$
$\sigma_{\text{SR} > 1000}$
$\pi^b_{\text{CCity, FKCustomer, TR AS SR, Cnt AS C}}$
$\bowtie$ PKCustomer = FKCustomer
Customer
FKCustomer γ SUM(Revenue) AS TR, COUNT(*) AS Cnt
$\bowtie$ FKOrder = PKOrder
OrderLine
Order
(b) A_V

Figure 13: Other compensations

Since the internal π^b of the compensation is useless, the final solution is the following:


$\pi^b_{\text{CCity, SR/C AS avgR}}$
$\sigma_{\text{SR} > 1000}$
CCity, FKCustomer γ SUM(Revenue) AS SR, COUNT(*) AS C
$\bowtie_{\text{FKCustomer} = \text{PKCustomer}}$
$\bowtie_{\text{FKOrder} = \text{PKOrder}}$
Customer
OrderLine
Order

(a) A_Q


$\pi^b_{\text{CCity, TR/Cnt AS avgR}}$
$\sigma_{\text{TR} > 1000}$
$\bowtie_{\text{PKCustomer} = \text{FKCustomer}}$
Customer
FKCustomer γ SUM(Revenue) AS TR, COUNT(*) AS Cnt
$\bowtie_{\text{FKOrder} = \text{PKOrder}}$
OrderLine
Order

(b) A_V

Figure 14: Final solution

Rewriting of Q:

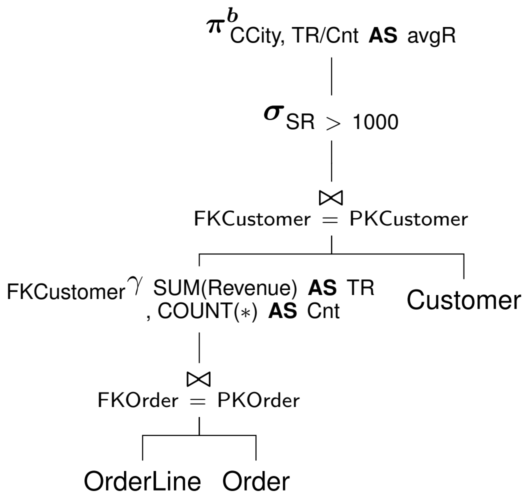
```
QR: SELECT   CCity, TR/Cnt AS avgR
    FROM     V, Customer
    WHERE    FKCustomer = PKCustomer AND TR > 1000;
```

Let us use the approach with a *transformation of the logical query plan*.

The rewriting of Q with the γ pushed below the first join

$$(\text{OrderLine} \underset{\text{FKOrder = PKOrder}}{\bowtie} \text{Order})$$

produces a logical tree that, with the rewriting of AVG and the changing of SR and C in the γ with TR and Cnt, has as subtree the tree of the view.



$\pi^b_{\text{CCity, TR/Cnt AS avgR}}$
$\sigma_{\text{SR} > 1000}$
$\bowtie_{\text{FKCustomer} = \text{PKCustomer}}$
$_{\text{FKCustomer}}\gamma_{\text{SUM(Revenue) AS TR, COUNT}(*)\text{ AS Cnt}}$
Customer
$\bowtie_{\text{FKOrder} = \text{PKOrder}}$
OrderLine
Order

Figure 15: The rewriting of Q to have V as a subtree

Rewriting of Q:

```
QR: SELECT    CCity, TR/Cnt AS avgR
    FROM      V, Customer
    WHERE     FKCustomer = PKCustomer AND TR > 1000;
```