Normalization

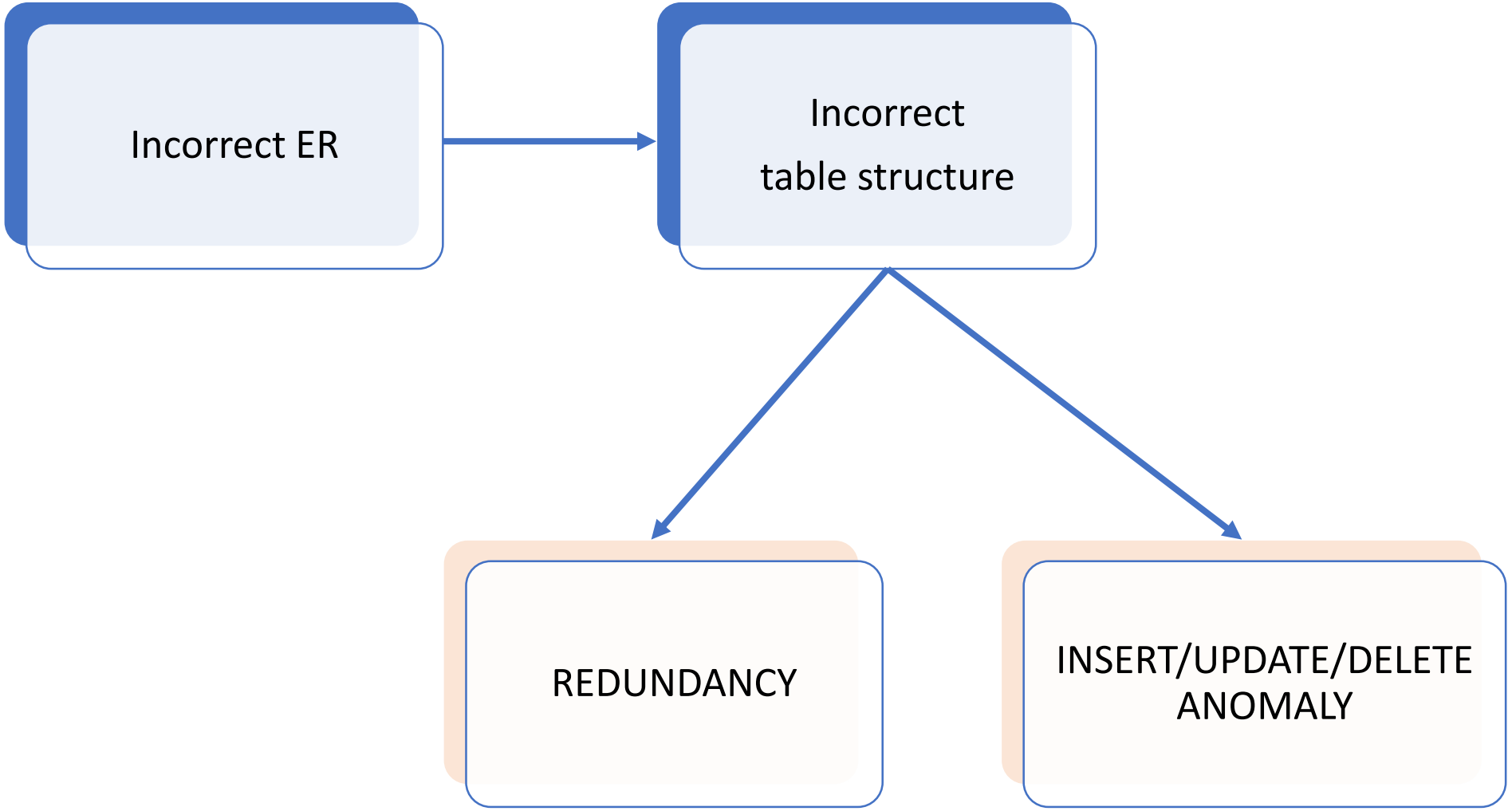
COURSE 4: Databases

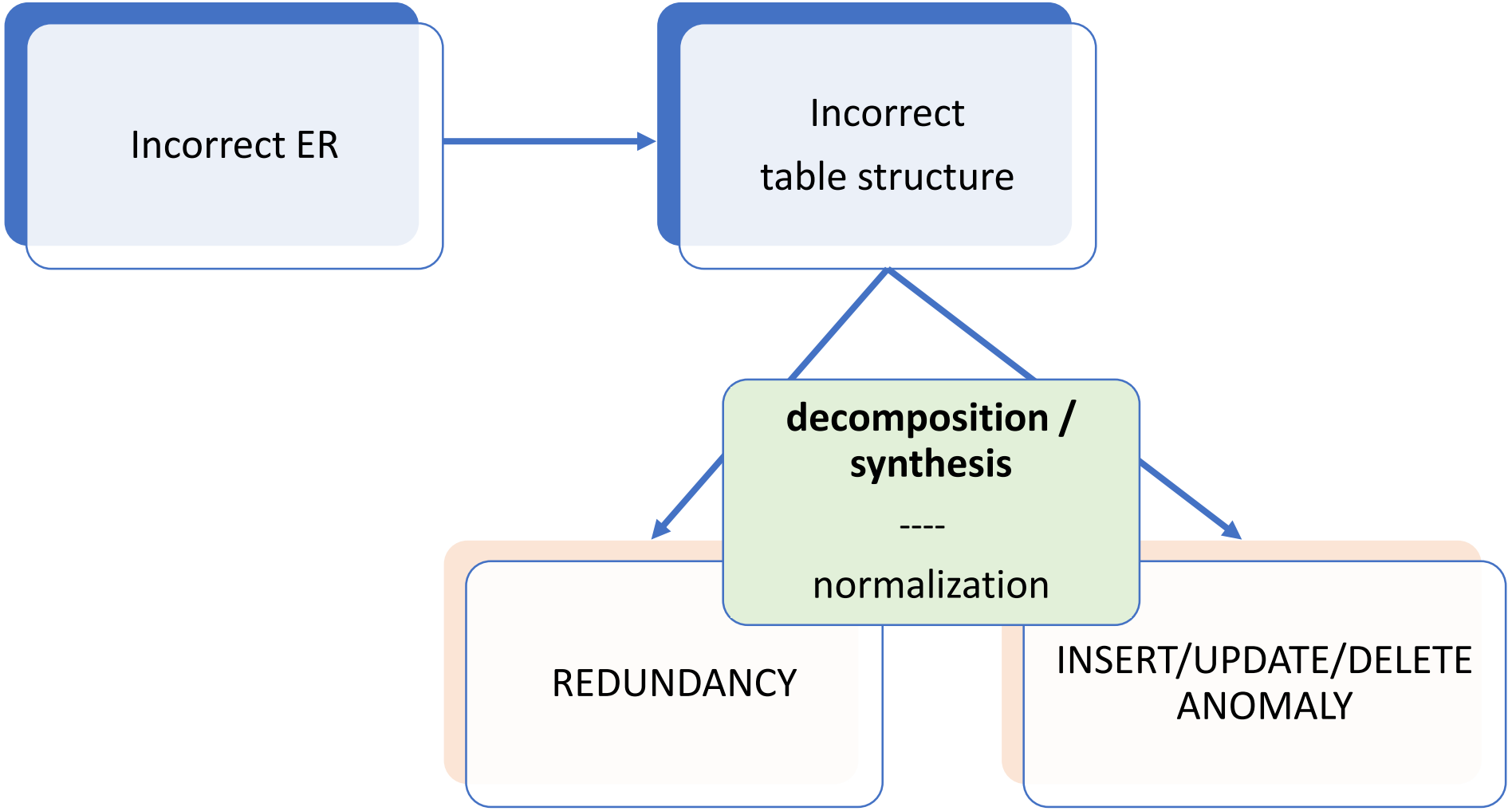
Normalization

when and why

Normalization

- Informal:
  - Organize data in a relational database in order to avoid redundancy and data manipulation anomalies.
  - Decompose a relation (table) without loosing information.


Incorrect ER
Incorrect
table structure
REDUNDANCY
INSERT/UPDATE/DELETE
ANOMALY


Incorrect ER
Incorrect
table structure
decomposition /
synthesis
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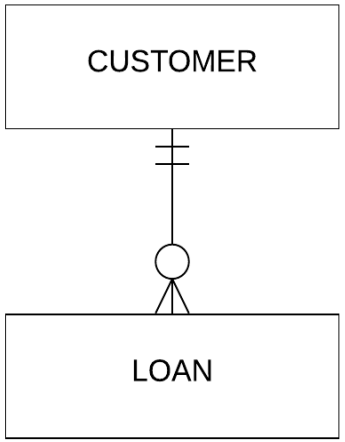
normalization
REDUNDANCY
INSERT/UPDATE/DELETE
ANOMALY

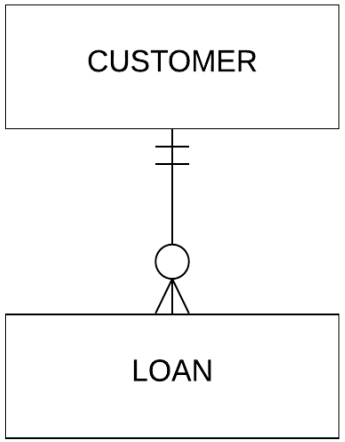
Normalization

- Avoid redundancy



Normalization

- Avoid redundancy

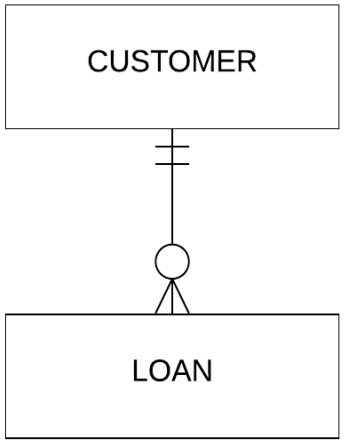


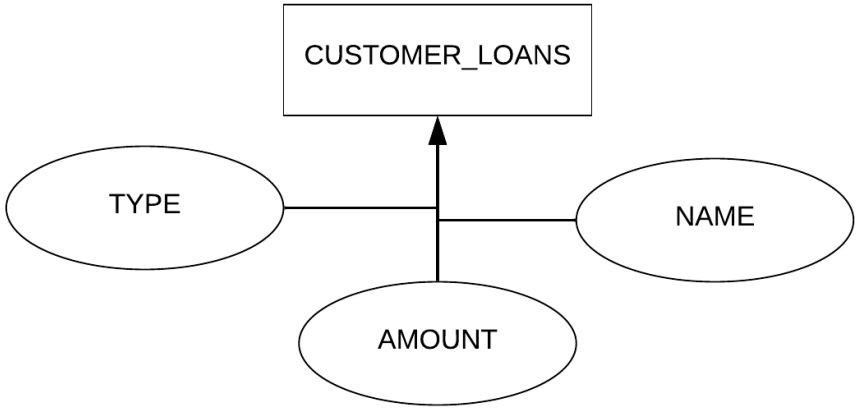
CUSTOMER			
CUSTOMER_ID	**LAST_NAME**	**…**	**….**
1	Smith	...	….
2	Green	…	….
3	Avery	...	….

LOAN			
LOAN_ID	**CUSTOMER_ID**	**AMOUNT**	**DATE**
101	1	125000	18/04/21
102	1	25000	14/04/22
103	2	12500	03/05/21
127	2	20000	…
389	3	75000	…

Normalization

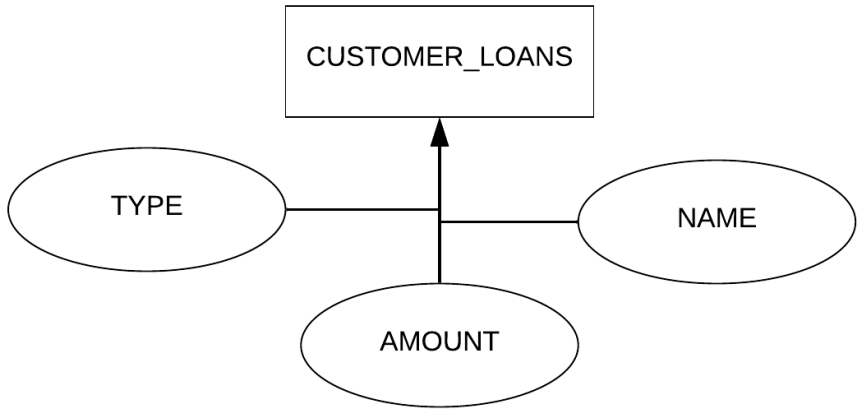
- Avoid redundancy





Normalization

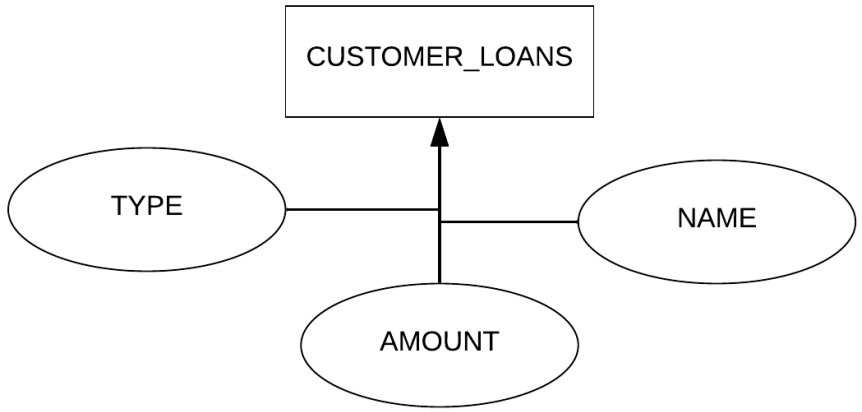
- Avoid redundancy



CUSTOMER_ID	NAME	LOAN_ID	TYPE	AMOUNT
1	Smith	101	mortgage	125000
1	Smith	102	credit card	25000
2	Green	103	credit card	12500
2	Green	127	mortgage	20000
3	Avery	389	mortgage	75000
3	Avery	486	credit card	5000
3	Avery	769	mortgage	45000

Normalization

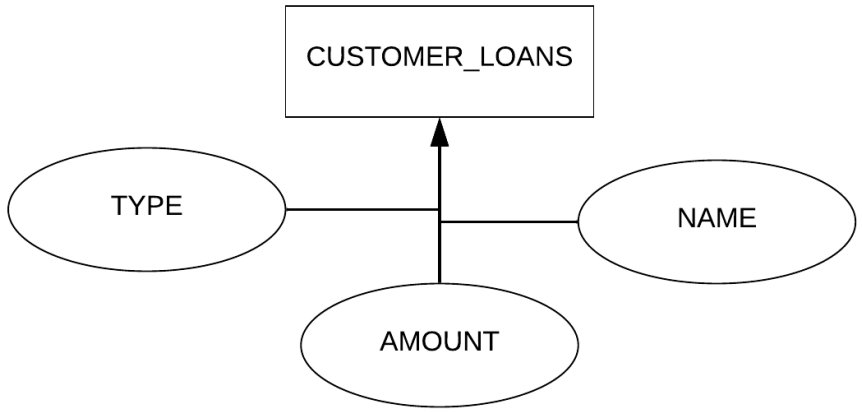
- INSERT anomaly



CUSTOMER_ID	NAME	LOAN_ID	TYPE	AMOUNT
1	Smith	101	mortgage	125000
1	Smith	102	credit card	25000
2	Green	103	credit card	12500
2	Green	127	mortgage	20000
3	Avery	389	mortgage	75000
3	Avery	486	credit card	5000
4	Stark	???	null	null

Normalization

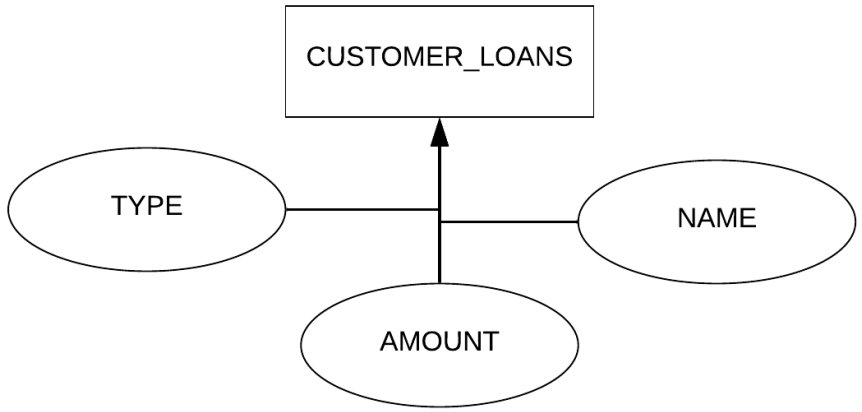
- UPDATE anomaly



CUSTOMER_ID	NAME	LOAN_ID	TYPE	AMOUNT
1	Smith	101	mortgage	125000
1	Smith	102	credit card	25000
2	Green	103	credit card	12500
2	Green	127	mortgage	20000
3	Avery	389	mortgage	75000
3	Avery	486	credit card	5000
3	Avery	769	mortgage	45000

Normalization

- DELETE anomaly



CUSTOMER_ID	NAME	LOAN_ID	TYPE	AMOUNT
1	Smith	101	mortgage	125000
1	Smith	102	credit card	25000
2	Green	103	credit card	12500
2	Green	127	mortgage	20000
3	Avery	389	mortgage	75000
3	Avery	486	credit card	5000
4	Stark	700	mortgage	45000

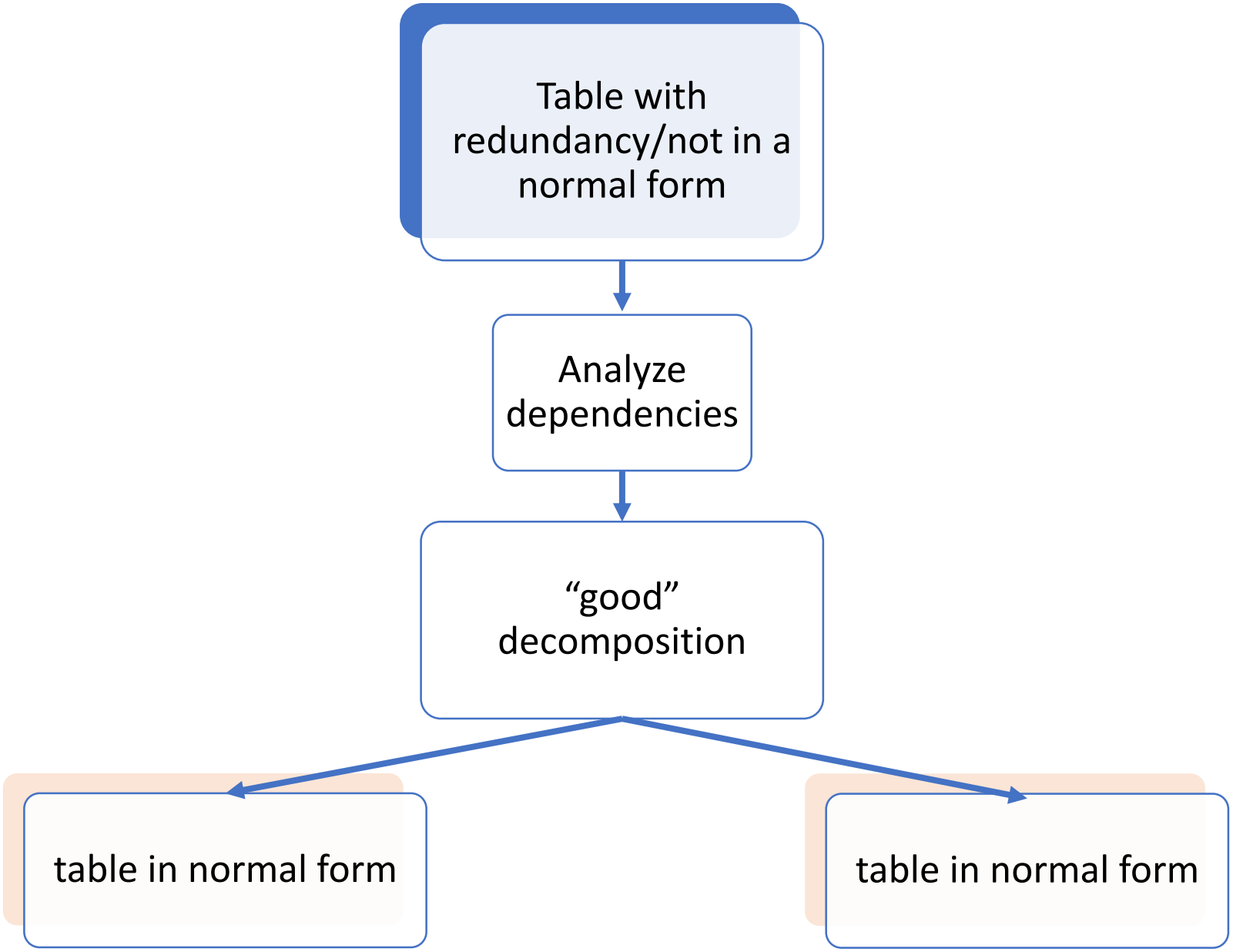


Table with redundancy/not in a normal form
Analyze dependencies
“good” decomposition
table in normal form
table in normal form

Decomposition

Decomposition Step 1: Projection

- $S_1 = \prod_{(NAME, LOANID, TYPE, AMOUNT)} R$

CUSTOMER_ID	NAME	LOAN_ID	TYPE	AMOUNT
1	Smith	101	mortgage	125000
1	Smith	102	credit card	25000
2	Green	103	credit card	12500
3	Smith	389	mortgage	75000

NAME	LOAN_ID	TYPE	AMOUNT
Smith	101	mortgage	125000
Smith	102	credit card	25000
Green	103	credit card	12500
Smith	389	mortgage	75000

- $S_2 = \prod_{(CUSTOMERID, NAME)} R$

CUSTOMER_ID	NAME
1	Smith
1	Smith
2	Green
3	Smith

Decomposition Step 2: Join

CUSTOMER_ID	NAME
1	Smith
1	Smith
2	Green
3	Smith

NAME	LOAN_ID	TYPE	AMOUNT
Smith	101	mortgage	125000
Smith	102	credit card	25000
Green	103	credit card	12500
Smith	389	mortgage	75000

- Lossy decomposition
  $S_1 \bowtie S_2 \supseteq R$

CUSTOMER_ID	NAME	LOAN_ID	TYPE	AMOUNT
1	Smith	101	mortgage	125000
1	Smith	102	credit card	25000
1	Smith	389	mortgage	75000
3	Smith	101	mortgage	125000
3	Smith	102	credit card	25000
3	Smith	389	mortgage	75000
2	Green	103	credit card	12500

Decomposition Step 1: Projection

- $S_1 = \prod_{(CUSTOMERID, LOANID, TYPE, AMOUNT)}$

CUSTOMER_ID	NAME	LOAN_ID	TYPE	AMOUNT
1	Smith	101	mortgage	125000
1	Smith	102	credit card	25000
2	Green	103	credit card	12500
3	Smith	389	mortgage	75000

CUSTOMER_ID	LOAN_ID	TYPE	AMOUNT
1	101	mortgage	125000
1	102	credit card	25000
2	103	credit card	12500
3	389	mortgage	75000

- $S_2 = \prod_{(CUSTOMERID, NAME)} R$

CUSTOMER_ID	NAME
1	Smith
1	Smith
2	Green
3	Smith

Decomposition Step 2: Join

CUSTOMER_ID	NAME
1	Smith
1	Smith
2	Green
3	Smith

CUSTOMER_ID	LOAN_ID	TYPE	AMOUNT
1	101	mortgage	125000
1	102	credit card	25000
2	103	credit card	12500
3	389	mortgage	75000

- Lossless decomposition
  $S_1 \bowtie S_2 = R$

CUSTOMER_ID	NAME	LOAN_ID	TYPE	AMOUNT
1	Smith	101	mortgage	125000
1	Smith	102	credit card	25000
3	Smith	389	mortgage	75000
2	Green	103	credit card	12500

Decomposition

- lossy decompositions and lossless decompositions.

- Lossy: R → decompose(R): S1, S2 → recompose(S1,S2) ⊇ R

  lossy =/= less data, (less is more!)

  lossy = lost information

- Lossless R → decompose(R): S1, S2 → recompose(S1,S2) = R

Decomposition

- Lossy

$$\prod_{R1} R \bowtie \prod_{R2} R \supseteq \mathrm{R}$$

- Lossless

$$\prod_{R1} R \bowtie \prod_{R2} R = \mathrm{R}$$

Functional dependencies

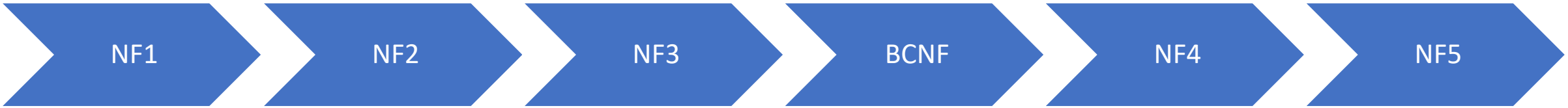
Functional dependencies

CUSTOMER_ID	NAME
1	Smith
1	Smith
2	Green
3	Smith

X	Y	Z	T
X1	Y1	Z1	T1
X1	Y2	Z1	T2
X2	Y2	Z2	T2
X2	Y3	Z2	T3
X3	Y3	Z2	T4

- CUSTOMER_ID -> NAME
- X -> Z
- Z --/--> X
- X -> X

Normal Forms


NF1
NF2
NF3
BCNF
NF4
NF5

NF1

ATOMIC ATTRIBUTES

NF1

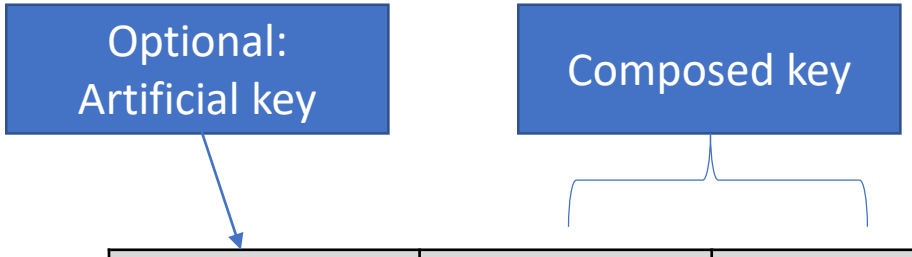
- Atomic attributes
- No multi-valued attributes

- The domain of each attribute contains only atomic values and each attribute contains only a value of its domain.

- A relational database is **at least in NF1**

NF1

EMP_ID	NAME	EMAIL
1	Williams	williams@gmail.com williams@yahoo.com
2	Davis	davis@gmail.com davis@academy.com
3	Miller	miller@gmail.com
4	Stewart	stewart@gmail.com office@academy.com



EMAIL_ID	EMP_ID	EMAIL
1	1	williams@gmail.com
2	1	williams@yahoo.com
3	2	davis@gmail.com
4	2	davis@academy.com
5	3	miller@gmail.com
6	4	stewart@gmail.com
7	4	office@academy.com

NF2

NO PARTIAL DEPENDENCIES

NF2

- Tables in NF1
- No non-key attributes (not part of the key) that depend on a subset of the attributes forming the key.

- There are no partial dependencies.

Functional dependencies

X	Y	Z	T
X1	Y1	Z1	T1
X2	Y1	Z1	T2
X2	Y2	Z2	T3
X2	Y3	Z2	T3
X2	Y3	Z2	T3

X	Y	Z	T
X1	**Y1**	Z1	…
X2	**Y1**	Z1	…
X2	**Y2**	Z2	…
X2	**Y3**	Z2	…
X2	**Y3**	Z2	…

- partial (X,Y) → Z
  - Y →Z

Functional dependencies

X	Y	Z	T
X1	Y1	…	T1
X2	Y1	…	T2
X2	Y2	…	T3
X2	Y3	…	T3
X2	Y3	…	T3

- total (X,Y) → T
  - X -/-> T
  - Y -/-> T

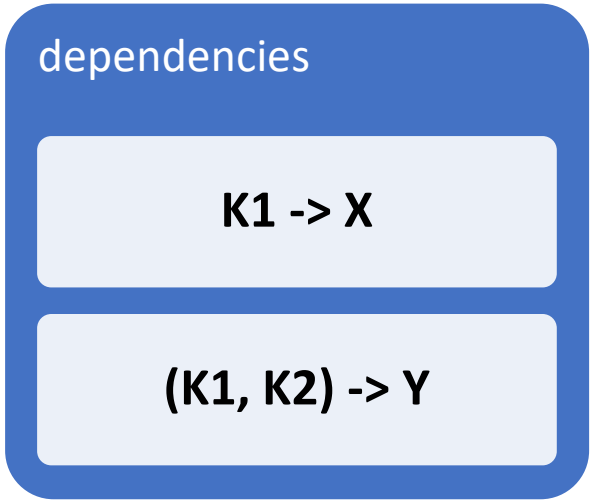
X	Y	Z	T
…	Y1	…	T1
…	Y1	…	T2
…	…	…	…
…	…	…	…
…	…	…	…

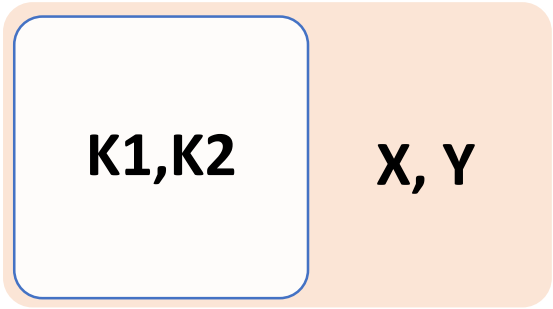
X	Y	Z	T
…	…	…	…
X2	…	…	T2
X2	…	…	T3
…	…	…	…
…	…	…	…

Functional dependencies

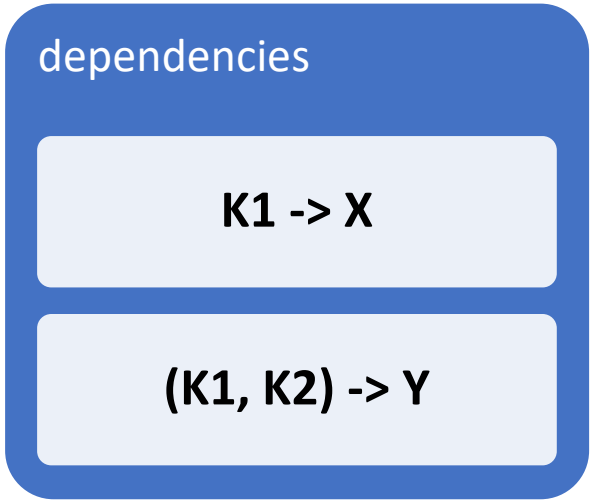
AIRPORT_ID	AIRPLANE_ID	DEPARTURE	AIRPLANE_MODEL	BOARDING_GATE
1	101	30/03/20 17:00	Boeing 777	42
1	102	02/05/20 09:30	Airbus A320	50
2	201	06/08/20 10:45	Boeing 757	35
2	202	10/10/20 06:20	Airbus A320	10
1	101	06/04/20 16:35	Boeing 777	23

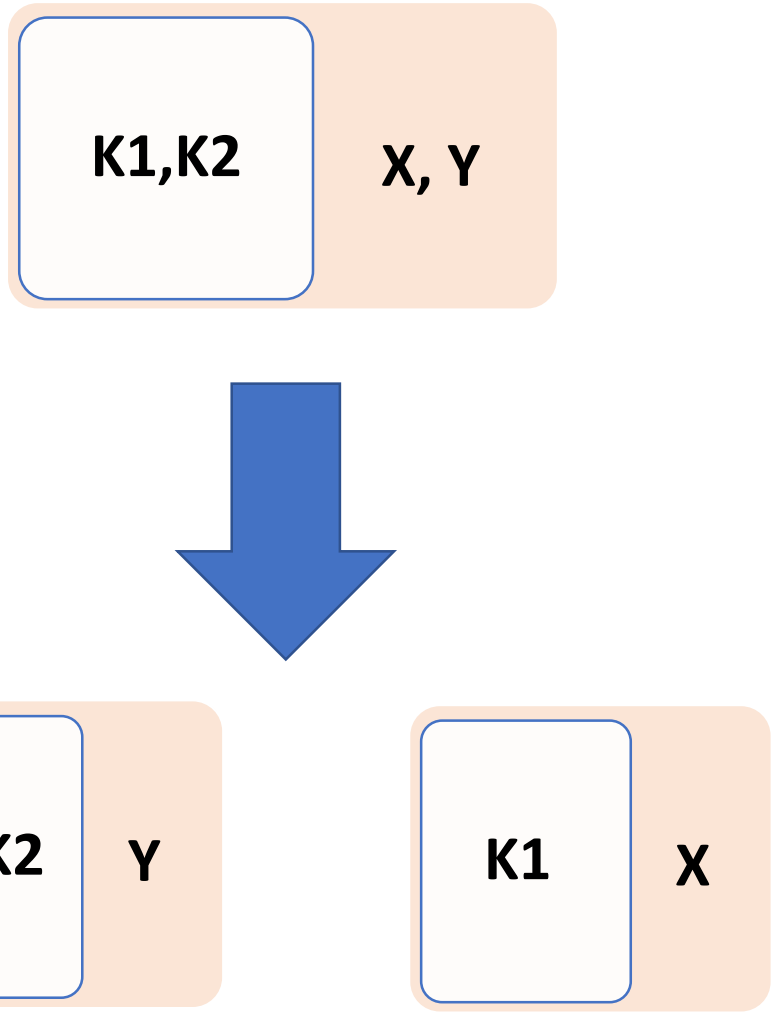
NF2



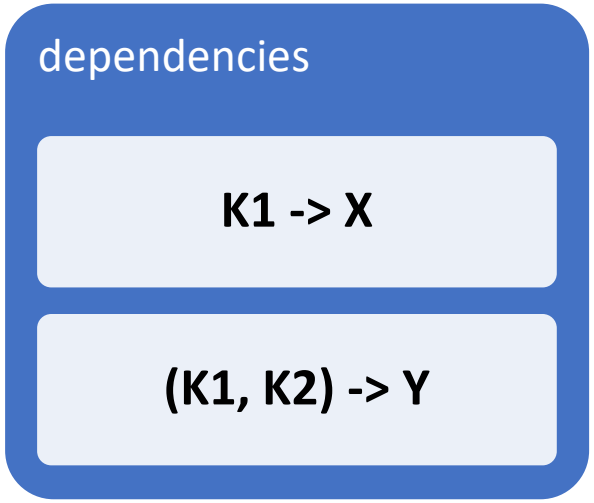


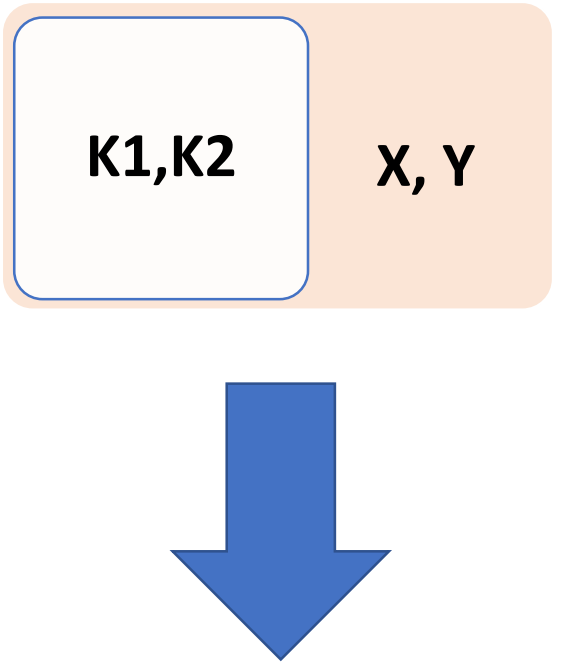
NF2





NF2





K1 = AIRPLANE_ID
K2 = AIRPORT_ID, DEPARTURE
Y = BOARDING_GATE
X = AIRPLANE_MODEL

AIRPORT_ID	AIRPLANE_ID	DEPARTURE	AIRPLANE_MODEL	BOARDING_GATE
1	101	30/03/20 17:00	Boeing 777	42
1	102	02/05/20 09:30	Airbus A320	50
2	201	06/08/20 10:45	Boeing 757	35
2	202	10/10/20 06:20	Airbus A320	10
1	101	06/04/20 16:35	Boeing 777	23

AIRPORT_ID	AIRPLANE_ID	DEPARTURE	BOARDING_GATE
1	101	30/03/20 17:00	42
1	102	02/05/20 09:30	50
2	201	06/08/20 10:45	35
2	202	10/10/20 06:20	10
1	101	06/04/20 16:35	23

AIRPLANE_ID	AIRPLANE_MODEL
101	Boeing 777
102	Airbus A320
201	Boeing 757
202	Airbus A320

NF3

NO TRANSITIVE DEPENDENCIES

NF3

- Tables in NF2
- Non-key attributes (not part of the key) depend on the entire key and only on the key.

- There are no transitive dependencies.

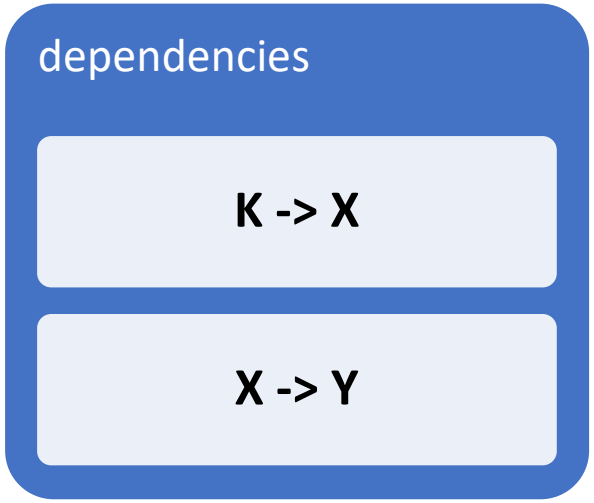
AIRPORT_ID	AIRPLANE_ID	DEPARTURE	MODEL	CAPACITY	REVISION_DATE	BOARDING_GATE
1	101	30/03/20 17:00	Boeing 777	451	01/01/2021	42
1	102	02/05/20 09:30	Airbus A320	150	01/03/2020	50
2	201	06/08/20 10:45	Boeing 757	295	03/05/2020	35
2	202	10/10/20 06:20	Airbus A320	150	04/06/2021	10
1	101	06/04/20 16:35	Boeing 777	451	08/09/2020	23

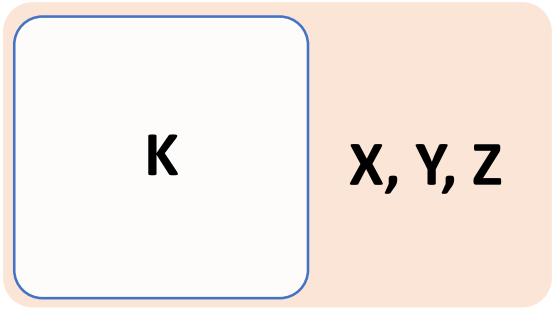
AIRPORT_ID	AIRPLANE_ID	DEPARTURE	BOARDING_GATE
1	101	30/03/20 17:00	42
1	102	02/05/20 09:30	50
2	201	06/08/20 10:45	35
2	202	10/10/20 06:20	10
1	101	06/04/20 16:35	23

AIRPLANE_ID	MODEL	CAPACITY	REVISION_DATE
101	Boeing 777	451	01/01/2021
102	Airbus A320	150	01/03/2020
201	Boeing 757	259	03/05/2020
202	Airbus A320	150	04/06/2021

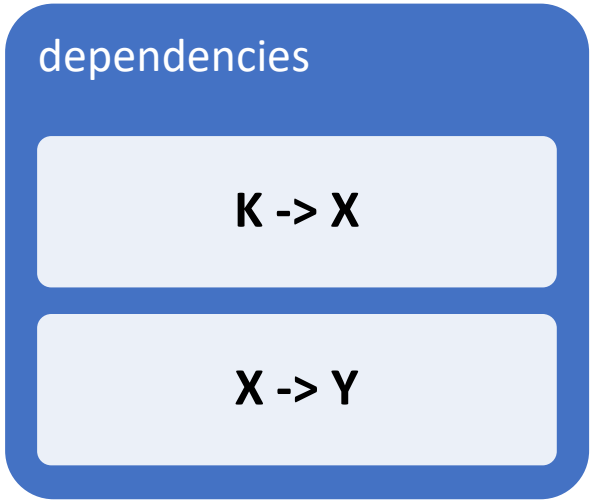
AIRPLANE_ID	MODEL	CAPACITY	REVISION_DATE
101	Boeing 777	451	01/01/2021
102	Airbus A320	150	01/03/2020
201	Boeing 757	259	03/05/2020
202	Airbus A320	150	04/06/2021

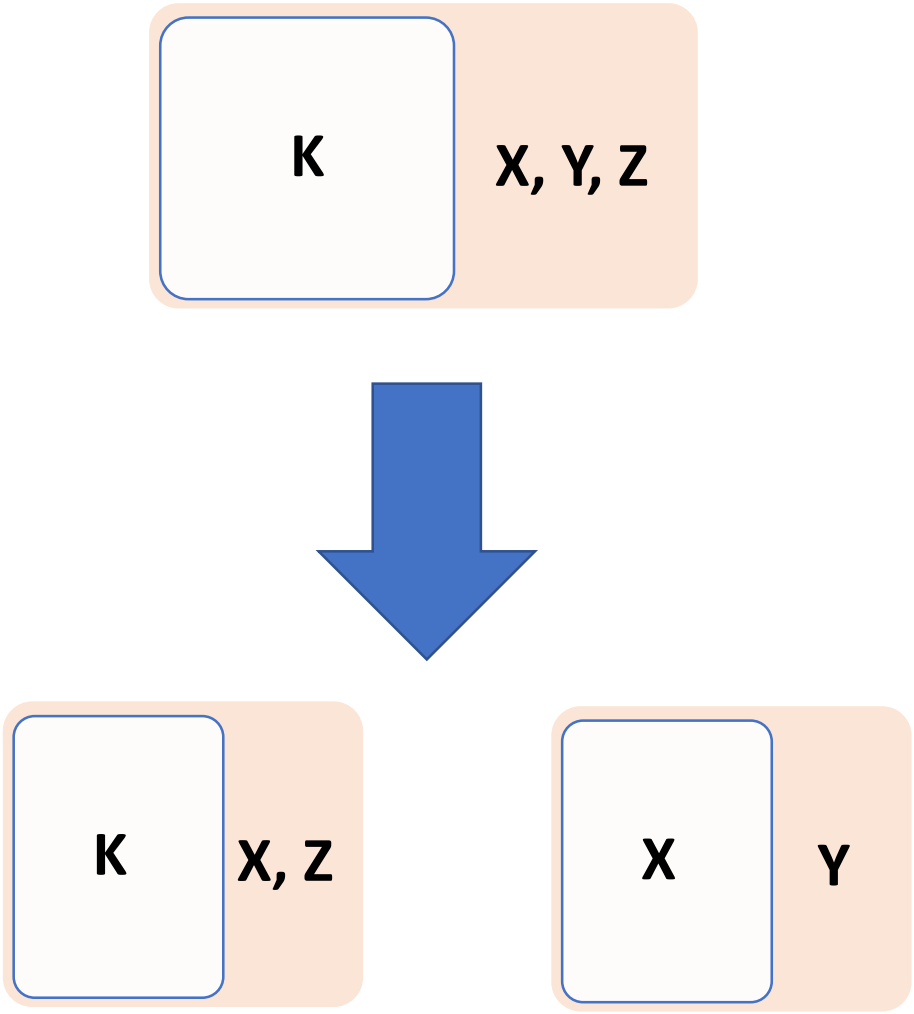
NF3



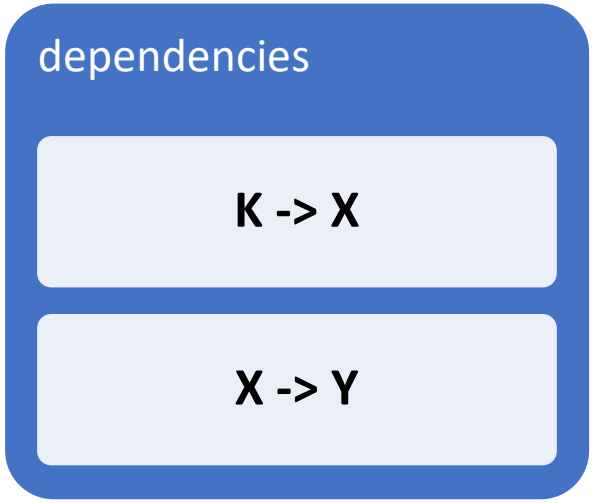


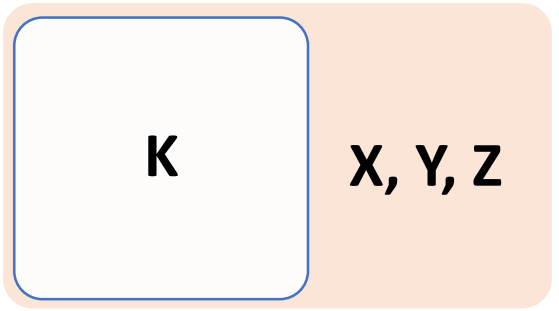
NF3

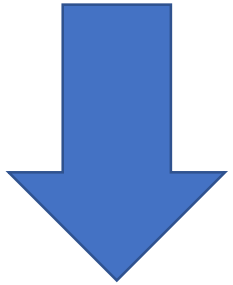


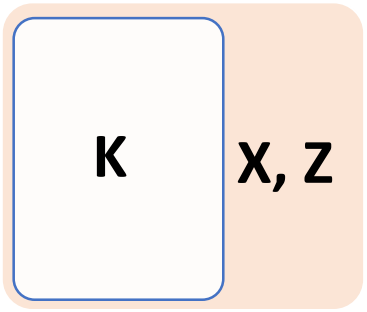


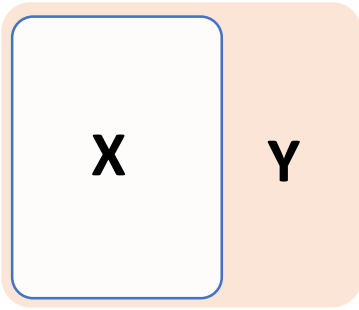
NF3











K = AIRPLANE_ID
X = AIRPLANE_MODEL
Y = CAPACITY
Z= REVISION_DATE

AIRPLANE_ID	MODEL	CAPACITY	REVISION_DATE
101	Boeing 777	451	01/01/2021
102	Airbus A320	150	01/03/2020
201	Boeing 757	259	03/05/2020
202	Airbus A320	150	04/06/2021

AIRPLANE_ID	MODEL	REVISION_DATE
101	Boeing 777	01/01/2021
102	Airbus A320	01/03/2020
201	Boeing 757	03/05/2020
202	Airbus A320	04/06/2021

MODEL	CAPACITY
Boeing 777	451
Airbus A320	150
Boeing 757	259