UNIVERSITÀ DEGLI STUDI DI PADOVA

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Foundations of Databases A.Y. 2023-2024

Homework 2 – Conceptual and Logical Design

Master Degree in Computer Engineering
Master Degree in Cybersecurity
Master Degree in ICT for Internet and Multimedia

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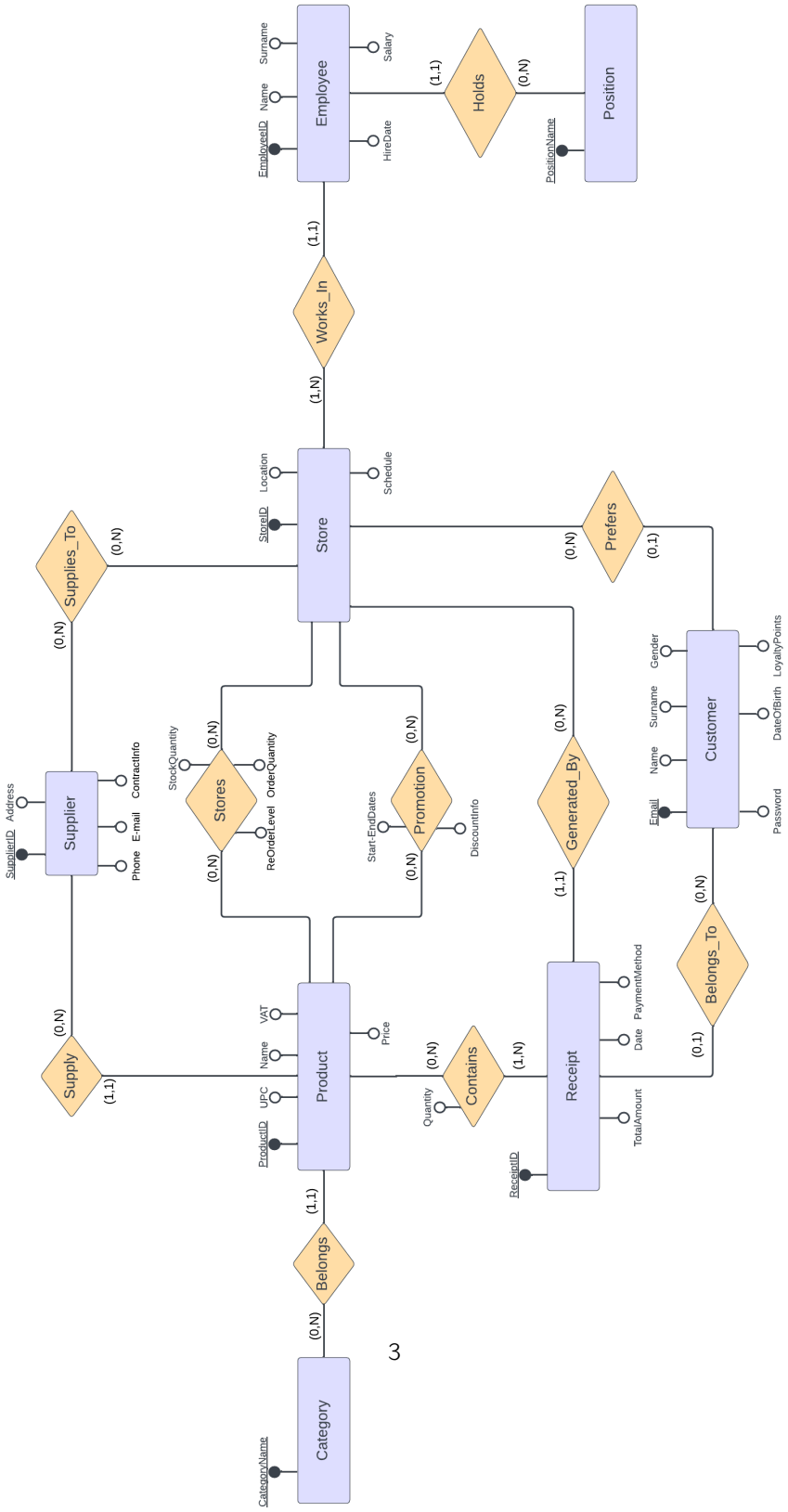
Conceptual Design

Variations to the Requirement Analysis

Several modifications are made to the functional requirements and explained in details. It also divided into semantically related headings for better understanding. The new list of functional requirements is included in the final section regarding the functional requirements satisfaction check.

Entity-Relationship Schema



Data Dictionary

Entities Table

Entity	Description	Attributes	Identifier
Product	Items sold in the supermarkets	• ProductID: unique identifier (serial) • Name: brief description of the product (text) • UPC: Universal Product Code (serial) • VAT: Value-Added Tax (float) • Price: the amount customer has to pay (float)	ProductID
Store	Where customers buy products	• StoreID: unique identifier (serial) • Location: the place where store is (text) • Schedule: the store timetable (datetime)	StoreID
Receipt	Contains information about each purchase	• ReceiptID: unique identifier (serial) • Date: the time when the payment is done (datetime) • TotalPrice: the amount customer paid for all products (float) • PaymentMethod: a way of how a customer made the payment (text)	ReceiptID
Supplier	A company that supplies the product	• SupplierID: unique identifier (serial) • Address: the place where supplier is (text) • Phone: the telephone number of the supplier (text) • E-mail: Electronic mail address of the supplier (text) • ContractInfo: details of the contract between supplier and store (text)	SupplierID

Customer	A client registered in the loyalty program	• E-mail: unique identifier (text) • Name: name of the customer (text) • Surname: surmane of the customer (text) • DateOfBirth: birth date of the customer (datetime) • Gender: Gender of the customer (text) • Password: the code required to enter the loyalty program (text) • LoyaltyPoints: represent the points of customer registered in the loyalty program (integer)	E-mail
Category	Categories to which products belong	• CategoryName: unique identifier (text)	CategoryName
Employee	A person who works in a store	• EmployeeID: unique identifier (serial) • Name (text) • Surname (text) • HireDate: a time when an employee hired (datetime) • Salary: amount to be paid an employee monthly (float)	EmployeeID
Position	A title of an employee	• PositionName: unique identifier (text)	PositionName

Relationships Table

Relationship	Description	Component Entities	Attributes
Stores	Number of a specific product stored in a store, its re-order level and the order quantity	• Product (0,N) • Store (0,N)	StockQuantity ReOrderLevel OrderQuantity

Contains	Products bought that are printed in the receipt	• Product (0,N) • Receipt (1,N)	Quantity
Promotion	Discounts for the products in a store	• Product (0,N) • Store (0,N)	Start-EndDates DiscountInfo
Supply	Associates a product with its supplier	• Product (1,1) • Supplier (0,N)	—
Belongs	Associates a product with its category	• Product (1,1) • Category (0,N)	—
Generated_By	In which store was a receipt generated	• Receipt (1,1) • Store (0,N)	—
Works_In	Associates a worker with the store they work in	• Employee (1,1) • Store (1,N)	—
Supplies_To	Associates a supplier with the stores they are currently supplying	• Supplier (0,N) • Store (0,N)	—
Belongs_To	Associates the customer with the receipt (if customer used the loyalty program while purchasing)	• Customer (0,N) • Receipt (0,1)	—
Prefers	Which store does customer prefer	• Customer (0,1) • Store (0,N)	—
Holds	Associates an employee with a position	• Employee (1,1) • Position (0,N)	—

External Constraints

- A product can only belong to one category and can only be supplied by one supplier.
- An employee can work at only one store and also can hold only one position at a time.
- A receipt can only be generated by one store and can be associated with at most one customer (if they are registered in the loyalty program and used the app during the purchase)

Functional Requirements Satisfaction Check

The database must store:

- The details of the **Customer**, including the following attributes: name and surname, e-mail, password
- The details of the **Product**, including the following attributes: Price, Product ID, UPC, VAT, name
- The details of the **Employee**, such as employee id, name, date, surname, hire date, salary, etc.
- The details of the **Receipt**, including the date, payment method, total amount and product name/names.
- The details of the **Supplier** including the SupplierID, Address, Phone, E-mail, contract details, etc.

The system must allow:

- **Customers** to login and signup.
- **Stock Management**
  - Store managers to input stock quantities for products, to track reorder levels for products and to transfer stock from one store to another
  - Stock clerks to track product stock levels within their store
- **Purchase and Payment Management**
  - Customers to purchase products at stores
  - Store managers to input purchase prices for products
  - Customers to use their loyalty points while making a purchase
  - Customers to view and download their receipts
  - Store managers to track the payment methods used by customers
- **Receipt and Transaction Management**
  - Store managers to keep track and record unique receipt numbers for each purchase
  - Customers to see transaction details, such as purchase quantity, date, and store location
- **Product Information Management**

  - Stock clerks and Store Managers to input detailed product information, such as product ID, name, UPC, VAT, and price
  - Inventory Control Specialists to manage product availability, including in-stock and out-of-stock statuses

- **Store Information Management**
  - Store managers to input detailed store information, such as store ID, name, location, schedule, and manager details
  - Store managers to manage product supply chains, including supplier information and transfer schedules

- **Category and Supplier Management**
  - Store managers to input detailed category information, such as category name
  - Store managers to input detailed supplier information, such as supplier ID, e-mail, address, phone and contract information

- **Promotion and Discount Management**
  - Store managers to input detailed promotion and discount information, such as discount type, percentage or amount, start and end dates
  - Store managers to associate specific promotions and discounts with individual products

- **Reporting and Analysis**
  - Store managers to generate various types of reports, such as sales reports, inventory reports, and employee performance reports and also to analyze data from these reports to identify trends and make informed business decisions.
  - Data Analysts to view the database and reports, such as sales reports, inventory reports and employee performance reports, in order to make statistics and to study the performance of supermarkets

- **Security and User Management**
  - Store managers to create and manage user accounts for employees, suppliers, and customers
  - Store managers to assign appropriate user roles and permissions to each user account individual products
  - Store managers to monitor and control user access to sensitive data and functions within the system

Logical Design

Transformation of the Entity-Relationship Schema

Redundancy Analysis

Intentional redundancy: The schema does not contain any intentional redundancy.
Extensional redundancy: The schema does not contain any cycle of entities.

Choice of Principal Identifiers

There are no circular dependencies among the weak entities and their owners in the schema, and the primary keys follow the best practices for choosing identifiers.

Analysis of Database Load

Assuming that the Customer entity had a derived attribute for the Customer Lifetime Value, we perform the load analysis on the given ER-Schema. We consider two operations that involve the redundant attribute CLV:

- O1: store the transaction data in the loyalty program;
- O2: Calculate the CLV data for a specific customer in the loyalty program;

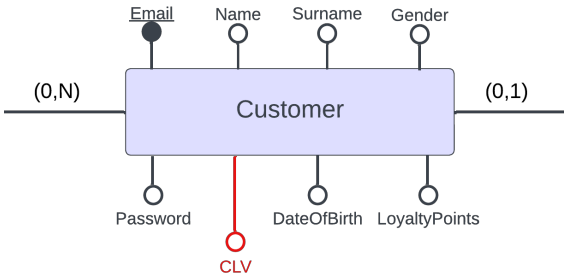


Table 4 reports the description of each operation, its frequency and type. O1 is an online operation since the customer's receipt needs to be stored right after the transaction while O2 is related to statistical analysis conducted on the data and is batch operation.

Operation	**Description**	**Frequency**	**Type**
O1: Store the transaction data	Store the transaction data of customers in the loyalty program if he/she enrolled	10000/month	Online
O2: Calculate the CLV	Calculate the Lifetime value of a specific customer	10/month	Batch

Table 4: Frequency Table

Table 5 shows how often and in what way O1 accesses the data with redundancy. The Customer entity reads the data to determine the current number of receipts or current total amount of how much the customer spends and writes the data to change this number.

Operation O1: 10000/month				
Concept	**Construct**	**Access**	**Type**	**Average Access**
Receipt	Entity	1	W	1x10000x2 = 20000
Belongs_To	Relationship	1	W	1x10000x2 = 20000
Customer	Entity	1	R	1x10000x1 = 10000
Customer	Entity	1	W	1x10000x2 = 20000
Total Access				**70000**

Table 5: Access/volume Table for O1 with redundancy

Table 6 shows how O2 uses the data that is with redundancy. Because of the redundancy, O2 only needs to access the Customer entity once to get all the information it needs.

Operation O2: 10/month				
Concept	**Construct**	**Access**	**Type**	**Average Access**
Customers	Entity	1	R	1x10x1 = 10
Total Access				**10**

Table 6: Access/volume Table for O2 with redundancy

In Table 7 we report the access/volume data related to O1 without redundancy. In this case we have to consider the insertion of a new instance in Customer, and the insertion of a new instance in Belongs_To to store the receipt the customer had.

Operation O1: 10000/month				
Concept	**Construct**	**Access**	**Type**	**Average Access**
Receipt	Entity	1	W	1x10000x2 = 20000
Belongs_To	Relationship	1	W	1x10000x2 = 20000
Total Access				**40000**

Table 7: Access/volume Table for O1 without redundancy

Table 8 shows how O2 uses the data that is not repeated. We assumed that each customer has an average of 10 receipts per month.

Operation O2: 10/month				
Concept	**Construct**	**Access**	**Type**	**Average Access**
Customers	Entity	1	R	1x10x1 = 10
Belongs_To	Relationship	10	R	10x10x1 = 100
Total Access				**110**

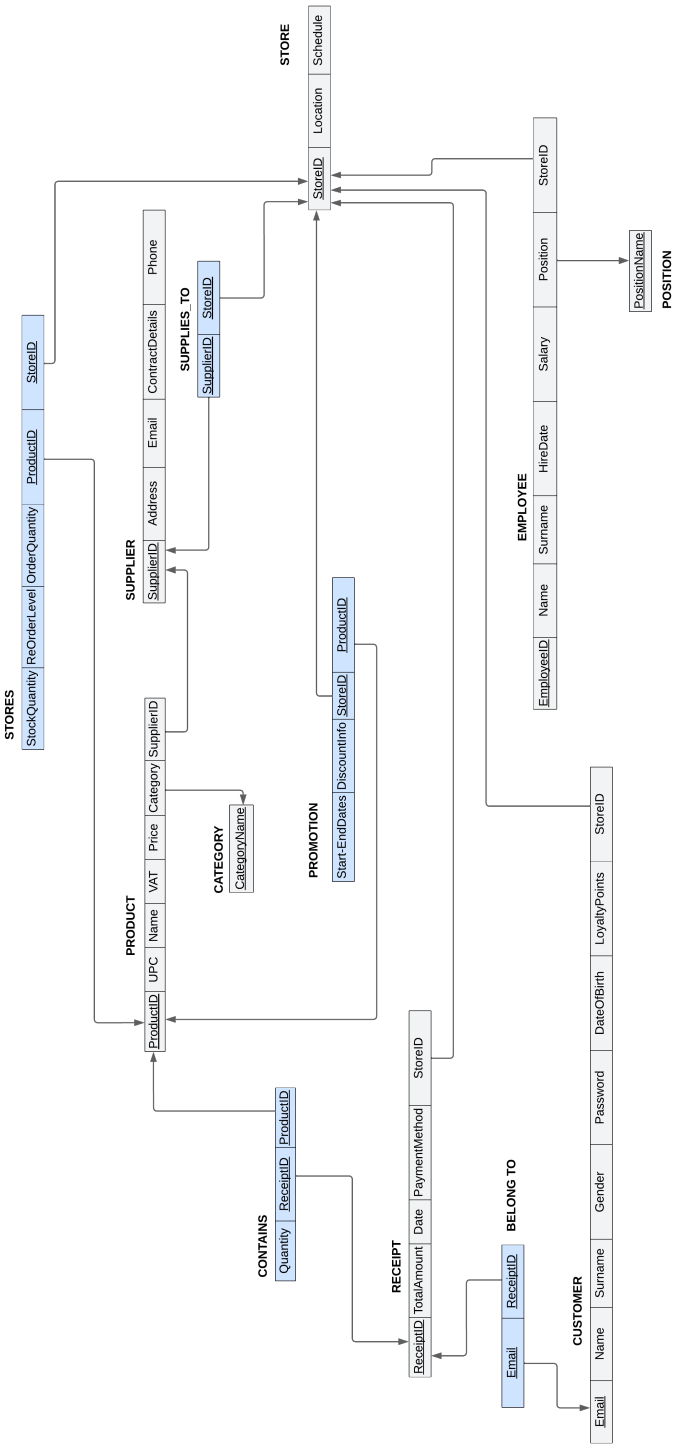
Table 8: Access/volume Table for O2 without redundancy

In Table 9, we report the final access counts with and without redundancy. According to the obtained results, we can clearly see that removing the redundant attribute from the Customer entity improves the database load.

Comparison		
Operation	**With Redundancy**	**Without Redundancy**
O1	70000	40000
O2	10	110
Total access	**70010**	**40110**

Table 9: Comparison of the number of accesses for each operation

Relational Schema



Not all of our customers are going to be part of our loyalty program, so to avoid systematic NULL values, we have decided that Belongs_To relationship should have its own relation.

Data Dictionary

Relation	Attribute	Description	Domain	Constraints
STORES	StockQuantity	Quantity available in the store	Int	Not NULL
	ReOrderLevel	Minimum quantity that must be in the store	Int	Not NULL
	OrderQuantity	Quantity of product that will be ordered	Int	Not NULL
	ProductID	Identification of the product	Serial	Foreign key to Product, not NULL, primary key with StoreID
	StoreID	Identification of the store	Serial	Foreign key to Store, not NULL, primary key with ProductID
PRODUCT	ProductID	Identification of the product	Serial	Primary Key
	UPC	Universal Product Code, standardized barcode symbology used for tracking items	Long	Not NULL
	Name	Name of the product	Text	Not NULL
	VAT	Value Added Tax	Float	Not NULL
	Price	Price of the product	Int	Not NULL
	Category	Category of the product	Text	Not NULL
	SupplierID	Identification of the supplier of the product	Serial	Not NULL
CATEGORY	CategoryName	Name of the category	Text	Primary Key, Not NULL
RECEIPT	ReceiptID	Identification of the receipt	Serial	Primary Key, Not NULL
	TotalAmount	Total price of the purchase	Int	Not NULL
	Date	Date of the purchase	Datetime	Not NULL
	PaymentMethod	Type of payment used	Text	Not NULL
	StoreID	Identification of the store	Serial	Not NULL
BELONGS TO	Email	Email of the customer	Text	Foreign Key to Customer, Primary Key with ReceiptID
	ReceiptID	Identification of the receipt	Serial	Foreign Key to Receipt, Primary Key with Email, not NULL
PROMOTION	Start-EndDates	Initial and final date of a promotion	Datetime	Not NULL

	DiscountInfo	Information or description of the promotion	Text	Not NULL
	StoreID	Identification of the store that has the promotion	Serial	Foreign key to Store, not NULL, primary key with ProductID
	ProductID	Identification of the product promoted	Serial	Foreign key to Product, not NULL, primary key with StoreID
CUSTOMER	Email	Email of the customer	Text	Primary Key, Not NULL
	Name	Name of the customer	Text	Not NULL
	Surname	Surname of the customer	Text	Not NULL
	Gender	Gender of the customer	Text	Not NULL
	Password	Password of the customer	Text	Not NULL
	DateOfBirth	Date of Birth of the customer	Datetime	Not NULL
	LoyalityPoints	Number of loyalty points acquired	Int	Not NULL
	StoreID	Identification of the preference store	Serial	Not NULL
CONTAINS	Quantity	Quantity of product bought	Int	Not NULL
	ReceiptID	Identification of the receipt	Serial	Foreign key to Receipt, not NULL, primary key with ProductID
	ProductID	Identification of the product	Serial	Foreign key to Product, not NULL, primary key with ReceiptID
SUPPLIER	SupplierID	Identification of the supplier	Serial	Primary Key, Not NULL
	Address	Address of the supplier	Text	Not NULL
	Phone	Phone number of the supplier	Text	Not NULL
	Email	Email of the supplier	Text	Not NULL
	ContractDetails	Details and description of the contract between store and supplier	Text	Not NULL
SUPPLIES TO	SupplierID	Identification of the supplier	Serial	Foreign key to Supplier, not NULL, primary key with StoreID
	StoreID	Identification of the store	Serial	Foreign key to Store, not NULL, primary key with SupplierID
STORE	StoreID	Identification of the store	Serial	Primary key, Not NULL

	Location	Address of the store	Text	Not NULL
	Schedule	Timetable of the store	Datetime	Not NULL
	ManagerID	Identification of the manager of the store	Serial	Not NULL
POSITION	PositionName	Name of the position held by the employees	Text	Primary Key, Not NULL
EMPLOYEE	EmployeeID	Identification of the worker	Serial	Primary Key, Not NULL
	Name	Name of the employee	Text	Not NULL
	Surname	Surname of the employee	Text	Not NULL
	HireDate	Date of the hire of the employee	Datetime	Not NULL
	Salary	Salary of the employee	Float	Not NULL
	Position	Name of their work position	Text	Not NULL
	WorkStore	Identification of the store they work in	Serial	Not NULL

External Constraints

- Only the employees with the position of 'Manager' can check the information about other employees in the shop. They need to login in the system with their Manager identification credentials.
- Human Resources employees can edit the information of the employees, as well as add or delete them.
- Authorized employees can check and edit the information of the products.
- Backups are meant to be done every shift change in order to avoid mistakes.
- The employees of a store can see the products' quantities of another store but cannot change them.
- If authorized employees of a store wants to view or update stock inventory into a store, login information is requested.
- Only 1 promotion can be applied to a product at the same time in a store. Two promotions cannot be applied at the same time. This means that we cannot apply other promotions to the product until the previous one reaches its ending date.
- The absence of email addresses or non-registration among customers constrains personalized communications, targeted marketing, and the full engagement potential of the loyalty program in the supermarket database system.

Group Members Contribution

- **Umut Berk CAKMAKCI:** Contributed to the development of **Entity-Relationship Schema, Entities Table, Relationships Table** and **Analysis of Database Load** sections;
- **Alara Selen OZGEN:** Responsible for the development of **Data Dictionary** and **External Constraints** sections;
- **Meltem YANOGLU:** Contributed to the development of **Functional Requirements Satisfaction Check** and **External Constraints** sections;
- **Isabel TORRES-PARDO LÓPEZ:** Responsible for developing the sections of the project pertaining to **Relational Schema, Data Dictonary** and **External Constraints**;
- **Alejandro VARELA MARTÍN:** Responsible for developing the sections of the project pertaining to **Entity-Relationship Schema, Entities Table** and **Relationships Table**;
- **Desalegn MATHEWOS MALOCHE:** Responsible for **Redundancy Analysis, Choice of Principle Identifiers** and **Analysis of Database Load**;
- **Milad Faghih Loo:** We could not make contact with him. He did not participate any work.

Each member of the group (except Milad) has diligently reviewed the text, offering insightful comments and implementing necessary corrections to enhance its quality and accuracy.