ITC6000 – DATABASE MANAGEMENT SYSTEMS

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FINAL PROJECT REPORT

Introduction:

Project Idea: Smart Management in Farming

About: Food is one of the most basic requirements for all living beings. And I am very much passionate about farming and knowing about crop growing patterns and at the same time minimize the crop wastage during and after farming and yielding the crop. Smart Farming integrates technology with traditional farming to increase revenue, production and efficiency. This project is interesting because it combines IoT, data analytics, and real-time monitoring to improve agricultural practices. It also addresses global challenges such as food security, climate change, and sustainable farming. Also, it includes vendors those sell equipment for various crops so that farmers can buy those at lower prices.

Use Cases:

1. **Weather Forecast Integration:** Farmers may schedule important tasks like planting or harvesting depending on the weather by using the information and report as provided to them by analysts. This lowers the possibility of crop damage due to unfavourable weather.
2. **Market Price Tracking:** To determine when and what to crop product to sell, they can decide volume of the crop to harvest. Additionally, the system can offer perceptions into local pricing patterns, facilitating better decision-making for profit maximization.
3. **Equipment Monitoring & Maintenance:** The technology keeps track of how farming equipment is used and sends out maintenance alerts. In order to help farmers maximize use and lower running expenses, it also monitors fuel use and machine efficiency.
4. **Irrigation Management:** Based on the amount of water required by crops and the moisture content of the soil, farmers can design and oversee irrigation programs. Water waste can be minimized by the system's ability to automate irrigation schedules and modify water usage in response to weather and report by analysts.

Business Analysis:

Farmers would contact Agricultural Analysts/Analysis company for getting expert advice about which crop/s to grow in their farm according to their soil type, nutrients, weather conditions, etc. In exchange for a small percentage of total revenue generated from the respected farmers' farm, Analysis company would get their income. So, even if there is less revenue than a small part has to be given so no such major loss or fee has to be provided. But, all in all, due to scientific studies by Agricultural Analysts, chances of a crop failure is minimal and hence becomes beneficial for Farmers too.

For Equipment Vendors or Sellers, they can keep stock of required equipment and technicians for those equipment which would be in high demand in the upcoming farming season and provide them to farmers whenever they require. This makes services faster and chances of generating maximum revenue increases. Also, they can provide equipment on rent to farmers in case farmers require equipment for just one season or cannot invest capital on all equipment. For them, this data would become accessible by Analysis Company and for this they would charge them a service fee for each season.

So, overall this keeps money flowing into the market and hence drives the economy for everyone. This way, farmers can maximise their income, analysis company earns from farmers and vendors while vendors earn by selling/renting equipment to farmers.

Personas:

- **Farmers**
  The primary users of the app are farmers who want to make informed decisions about which crops to plant based on the specific conditions of their land, such as soil type, nutrient levels, and climate patterns. Farmers enter details about their farm, including land characteristics and location, and receive tailored crop recommendations aimed at optimizing yield and maximizing revenue. For them, the app serves as a decision-making tool, helping to minimize risk and make their farming practices more sustainable and profitable. Their interaction is straightforward, with a focus on receiving actionable insights without extensive technical details.

- **Analysts**

  Agricultural analysts are professionals who conduct scientific assessments of the farmers' land using data-driven techniques. They review soil and climate conditions, assess nutrient requirements, and generate customized crop recommendations for each farm. These analysts rely on the app's interface to input their findings, store past analyses, and make adjustments based on season-specific conditions. For analysts, the app is a data-centric platform that enables efficient data entry and analysis, offering a structured way to support farmers in maximizing crop output through precision recommendations.

- **Equipment Selling Dealers**

  Equipment selling dealers use the app to gain insights into which types of farming equipment will be in high demand in the coming season. By analyzing crop recommendations and anticipated farming activities, dealers can prepare inventory and adjust their stock to meet upcoming demands efficiently. Their interaction with the app involves purchasing or accessing analysis data and viewing forecast reports, enabling them to stock relevant equipment (e.g., plows, seeders) in line with the needs of farmers in specific regions. This forecasting supports their inventory management, ensuring they have the necessary equipment available for the next growing season.

Business Rules:

- A Farmer will have his/her own Farm_ID and Farmer_ID which uniquely identifies himself and the farm.
- Each Crop will be identified by a Crop_ID.
- Equipment Selling company will have relation with Analysis company which would provide data about upcoming farming season and crops in exchange for money.
- Analysis company will enrol those farmers and their farms along with their farm details so can make a study report.
- Agricultural Analysis company will have **Primary Key Analysis_ID** and **Foreign Key Equipment_ID.**
- Equipment company will have Foreign Key Farmer_ID which would connect Farmer table and Equipment Table.

Table Design and Analysis:

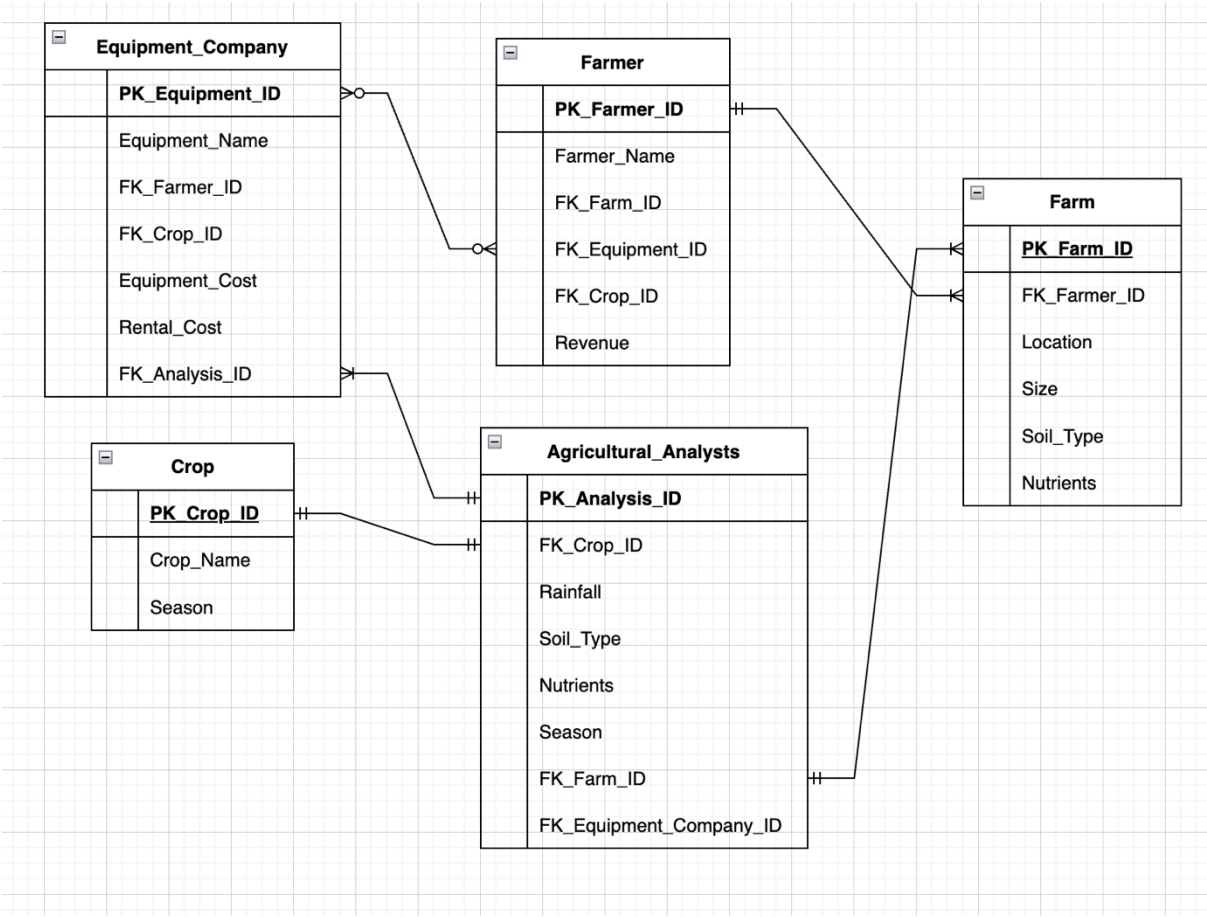
There are 5 Data Entities or Tables for this project. Those tables are:

1. Farmer
2. Farm
3. Crop
4. Agricultural_Analysts
5. Equipment_Company

Below is the **Entity-Relationship Diagram** for these above Tables showing the necessary relationships between them and the **Primary Keys** and **Foreign Keys** for the tables.

Also, the relationship like **One-to-One** or **One-to-Many** and **Many-to-Many** are depicted using **Crow-Foot Notations** to make the project yet more concise and effective.

Entity Relationship Diagram:



Database Implementation:

First, I created the tables assigned required **Primary Key** and **Foreign Key** for the tables using Create Table Query, according to the **Entity-Relationship Diagram.**

Then, as per the requirement for the project, with the use of Insert Query, I inserted the Data according to the various values it requires to have necessary data.

For example, for same farmer different farms at different locations, different soil types, different seasons, etc combinations are identified and then inserted the data into the tables for creating the dataset.

1. For Farmers to decide which crop to grow according to water requirements, this query produces results which performs **JOIN** on **Analysis** and **Crop.**

```
SELECT
  c.Crop_Name,
  AVG(a.Rainfall) AS Avg_Rainfall
FROM
  Analysis AS a
JOIN
  Crop AS c ON a.Crop_ID = c.Crop_ID
GROUP BY
  c.Crop_Name
ORDER BY
  Avg_Rainfall DESC;
```

- From the below output, crop analyses can be performed by understanding required rainfall for each crop.

	Crop_Name	Avg_Rainfall
1	Tobacco	130.0
2	Rice	120.0
3	Millet	120.0
4	Sugarcane	110.0
5	Soybean	100.0
6	Peas	100.0
7	Cotton	100.0
8	Pumpkin	95.0
9	Potatoes	95.0
10	Maize	90.0
11	Peanuts	85.0

2. The below query is performed to **JOIN Farmer** and **Farm** tables where all the information of **Farm** has been displayed.

```
SELECT
  f.Farm_ID,
  f.Location,
  f.Size,
  f.Soil_Type,
  f.Nutrients,
  f.Farmer_ID
FROM
  Farm AS f
WHERE
  f.Farmer_ID = '100';
```

- And below output contains all the **Farm** locations including its **Primary Key** to uniquely identify the farm for the **Farmer** having **ID = 100**.

	Farm_ID	Location	Size	Soil_Type	Nutrients	Farmer_ID
1	F100	Boston	50	Clay	Nitrogen	100
2	F111	Miami	70	Sandy	Potassium	100
3	F112	Atlanta	40	Loamy	Phosphorus	100

Apart from above queries, this project focuses on end results for the personas which are **Farmers, Equipment Companies/Vendors** and **Analysts.**

Below section contains detailed implementation where **Analytics, Metrics** and **Reports** are produced.

Analytics, Reports and Metrics:

1. Below is the query which **JOIN Analysis Table** and **Farm Table** and displays output of the report for that farm.

```
SELECT
  a.Analysis_ID,
  f.Farm_ID,
  f.Location,
  c.Crop_Name,
  a.Rainfall,
  a.Soil_Type,
  a.Nutrients,
  a.Season
FROM
  Analysis AS a
JOIN
  Farm AS f ON a.Farm_ID = f.Farm_ID
JOIN
  Crop AS c ON a.Crop_ID = c.Crop_ID
WHERE
  f.Farm_ID = 'F100';
```

- Below output image shows the farm id, its unique report analysis id, location of the farm, crop that can be grown, expected rainfall at that location, type of soil for that land, the nutrients in that soil and upcoming season for which this report is generated.

	Analysis_ID	Farm_ID	Location	Crop_Name	Rainfall	Soil_Type	Nutrients	Season
1	A100	F100	Boston	Cotton	100cm	Clay	Nitrogen	Summer

- Below image has query about the report that number of crops that would be grown for the **summer** season. This is done by **Join** of two tables "**Analysis" and "Crop".**

```
SELECT
  c.Crop_Name,
  COUNT(a.Crop_ID) AS Suggested_Count
FROM
  Analysis AS a
JOIN
  Crop AS c ON a.Crop_ID = c.Crop_ID
WHERE
  a.Season = 'Summer'
GROUP BY
  c.Crop_Name
ORDER BY
  Suggested_Count DESC;
```

2. The above query result is in the below generated image which shows the expected count for that crop.

- **Note:** All the count is 1 because this data is inserted by myself and not by importing any csv file or dataset. Therefore, limited but variety of data is inserted.

	Crop_Name	Suggested_Count
1	Tobacco	1
2	Soybean	1
3	Rice	1
4	Peas	1
5	Maize	1
6	Cotton	1
7	Corn	1

3. From the below query, equipment vendors can analyze for the requirement of various crops and keep necessary stock for equipment to sell or rent.

```
SELECT
  c.Crop_Name,
  a.Season,
  COUNT(a.Analysis_ID) AS Crop_Count
FROM
  Analysis AS a
JOIN
  Crop AS c ON a.Crop_ID = c.Crop_ID
GROUP BY
  c.Crop_Name, a.Season
ORDER BY
  Crop_Count DESC;
```

- The below output shows the result for above query.

271 Farmer AS f

	Crop_Name	Season	Crop_Count
1	Barley	Fall	1
2	Barley	Spring	1
3	Corn	Summer	1
4	Cotton	Summer	1
5	Maize	Summer	1
6	Millet	Fall	1
7	Oats	Spring	1
8	Peanuts	Spring	1
9	Peas	Summer	1
10	Potatoes	Fall	1
11	Pumpkin	Fall	1

4. The below query generates **Analytics and Reports** by using **JOIN** on **Farmer, Equipment, Analysis** and **Crop** tables using **Foreign Keys**.

```
SELECT
  f.Farmer_Name,
  e.Equipment_Name,
  e.Equipment_Cost,
  e.Rental_Cost,
  c.Crop_Name,
  a.Season
FROM
  Farmer AS f
JOIN
  Equipment AS e ON f.Equipment_Company_ID = e.Equipment_Company_ID
JOIN
  Analysis AS a ON e.Crop_ID = a.Crop_ID
JOIN
  Crop AS c ON a.Crop_ID = c.Crop_ID
WHERE
  a.Season = 'Summer';
```

- And below image is output where the Equipment Vendor or **Equipment_Company** gets the **Report** and **Metrics** for the Equipment that would be needed by Farmer and information like Equipment Cost, Name, its Rental Cost, required for which Crop and is **Filtered** for **Summer** season.
- This **Analytics** would help Equipment Company analyze about the Equipment quantity and cost understanding about the demand for the upcoming season.

	Farmer_Name	Equipment_Name	Equipment_Cost	Rental_Cost	Crop_Name	Season
1	Jainam	Tractor	5000	10	Cotton	Summer
2	Bob	Harvester	15000	200	Rice	Summer
3	Diana	Seeder	2000	5	Soybean	Summer
4	Fiona	Cultivator	2500	20	Corn	Summer
5	Hannah	Tiller	3500	25	Tobacco	Summer
6	Laura	Sprayer	5000	30	Maize	Summer
7	Nina	Harrow	1200	5	Peas	Summer

5. The below image contains query where **Equipment** and **Analysis** tables are operated by **JOIN.**

```
SELECT
  e.Equipment_Name,
  COUNT(a.Crop_ID) AS Demand_Count
FROM
  Equipment AS e
JOIN
  Analysis AS a ON e.Crop_ID = a.Crop_ID
WHERE
  a.Season = 'Summer'
GROUP BY
  e.Equipment_Name
ORDER BY
  Demand_Count DESC;
```

- And the below image output shows the expected demand to be in **summer** season for that equipment.
- **Note:** The demand count is 1 because the data is limited as it has been inserted by myself and not imported from any csv file.

	Equipment_Name	Demand_Count
1	Tractor	1
2	Tiller	1
3	Sprayer	1
4	Seeder	1
5	Harvester	1
6	Harrow	1
7	Cultivator	1

Security Concerns:

The sensitive commercial and agricultural data that each user group enters and retrieves is the main source of security and privacy issues in this project. We gather comprehensive data on crop preferences, land attributes, and personal information for farmers. This information is important since it may provide confidential details about the farmer's business practices and tactics, which could jeopardize their ability to compete if they were made public. It is crucial to make sure that farmer data is safe and restricted in access so that only farmers and analysts with permission can read or alter it.

The information that analysts enter, such as crop recommendations, environmental considerations, and land assessments, is extremely valuable to them and should be shielded from unwanted access. Maintaining the accuracy and security of this data is essential since it influences decisions that may affect crop output and equipment requirements.

Analysis data that forecasts equipment demand is considered sensitive information for dealers that sell equipment since it is useful for planning and stocking. Such information could impact competitors' business operations by giving them insight into expected market demands if it were made public.

From security point of view, I would implement multi-layered security measures, including data encryption both at rest and in transit to protect sensitive information from unauthorized access. User authentication and role-based access controls will ensure that only authorized personnel can access specific data, safeguarding the integrity of farmer and equipment company information. Regular security audits and compliance checks will further enhance our security posture.

Architecture:

1. **Client/Server Architecture -** I will implement a client/server architecture to facilitate communication between farmers, analysis companies, and equipment companies. The client side will include user interfaces for farmers to input their data and receive crop recommendations. On the server side, a robust database management system (DBMS) will handle data storage, retrieval, and analysis, ensuring that all interactions are efficient and secure.
2. **Hosting Model -** I will adopt a cloud hosting model for our solution. Utilizing cloud infrastructure provides scalability, flexibility, and cost-effectiveness. This model allows for dynamic allocation of resources based on demand, enabling us to handle varying workloads, especially during peak seasons when farmers may seek analysis and equipment recommendations. Cloud services also offer robust security measures and high availability, ensuring that our data is protected and accessible.
3. **Storage -** In terms of storage requirements, I estimate needing approximately 100 GB initially, considering the expected number of users and the volume of data generated by various interactions. This includes data from farmer profiles, farm information, equipment details, crop analyses, and seasonal recommendations. As the project scales, we can easily increase storage capacity to accommodate growing datasets.

Project Wrap-Up and Future Considerations:

This project has offered thorough insights into the entire process of developing, putting into practice, and refining a system that solves practical problems for a variety of user groups. I've discovered how crucial it is to match system capabilities with user requirements throughout the whole planning and implementation process, particularly when working with a variety of stakeholders like farmers, analysts, and equipment dealers. These users all have different demands, so creating a database structure that can accommodate these diverse interactions was a fulfilling challenge that helped me better understand user-centered design.

Potential improvements and the changing needs of its users are the main topics of **future inquiries and considerations for this project:**

1. How can the accuracy of crop predictions be increased?
   Using predictive models could yield more accurate suggestions as machine learning advances and datasets rise. This would entail looking into joint ventures with agronomists or specialists in machine learning to improve the analysis of agricultural performance, soil data, and climatic trends.

2. What other sources of information would be useful?
   External datasets, including current weather data, market trends, or local agricultural reports, could enhance research as the initiative expands. To provide farmers with timely insights, it would be crucial to evaluate the viability and applicability of such connections.

3. How may the recommendations for equipment stocking be made more efficient?
   Greater understanding of regional demands and demand trends may help equipment dealers manage their inventories more effectively. Future research could look into data sharing arrangements that let the app track seasonal demand surges or sales trends.

4. What effects would scaling have on privacy?
   It will be essential to reevaluate privacy policies and data protection measures as the user base expands. If the app is used in multiple locations, this involves making sure that local and international data protection rules are followed.

5. How can the experience be tailored to the various kinds of users?
   Every user group, including analysts, traders, and farmers, has different requirements. Usability and pleasure may be increased by looking for ways to further tailor the app's design and suggestions for each persona.

References:

- Coronel C., Morris S. - Database Systems Design, Implementation, & Management, 13th edition – 2019
- Draw IO - https://app.diagrams.net/
- Canvas Study Lesson and Materials