<u>Smart Building Automation</u>

Group- Quantile

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The following team members for Group #, certify that the following document is our work and that all material drawn from other sources has been fully acknowledged. Each team member certifies that he/she possesses a copy of the attached work and has contributed to its content.

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TEAM EVALUATION FOR GROUP PROJECT ASSIGNMENT – PT#

Each team member identifies the overall rating of this assignment based on the Group Contract signed at the beginning of the semester. The rating scale is 5 (Highest) to 0 (Lowest). Please add actions required to improve group teamwork.

NAME	OVERALL GROUP CONTRACT COMPLIANCE (0 – 5 SCALE)	ACTIONS REQUIRED TO IMPROVE PERFORMANCE OF GROUP
Aryan Bisht	5	
Shubham Bharat Raut	5	
Ankush Sanjay Harishchandre	5	
Apurva Annasaheb Dange	5	
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1. **Project Overview**

1.1. Purpose, Scope, and Objectives and Business Case

1.1.1. Scope

1.1.1.a. Background

Arizona State University (ASU) has a four-story building that currently relies on an old building management system (BMS), where major tasks are performed manually. This results in high energy consumption, high electricity bills, poor security, and poor climate control. Ultimately, this leads to downtime, errors, security concerns, and less-than-optimal performance.

In response to all the challenges, team Quantile got the project to transform this building into a smart, sustainable, and automation-based building. Our objective is to develop and install a new and advanced Building Management System (BMS), which includes lighting, HVAC, security, and energy control, into a fully integrated and automated platform.

1.1.1.b. Problems

The current operation of the building has some major challenges,

1. **Overconsumption of Energy:** The building does not have a system to monitor and control energy usage, resulting in more unnecessary electricity consumption and high energy bills.
2. **Inefficient Climate Control:** The HVAC system is old and lacks automation features. It causes discomfort to the students and occupants in the building and consumes more and sometimes unnecessary energy.
3. **Poor Security Management:** The building relies heavily on old and manual security systems, which creates security concerns within and around the building. Major upgrades are required in security systems like access control systems, high-resolution CCTV cameras covering blind spots, and smart fire alarm systems to improve security and response time.
4. **Lack of Automation and Bad Data Tracking:** Basic controls within the building are highly dependent on manual operations, which take too long and always have the risk of errors. The lack of a centralized data collection and management system makes it difficult to manage the overall building operations efficiently and it is hard to make smart decisions.

1.1.1.c. Current Operation

The building depends on manual intervention to monitor and control energy, security, and maintenance.

1. **Lighting and HVAC Control:** Staff turn lights on and off manually and adjust the thermostats on every level manually. Individuals do not have designated schedules, and lights and HVAC remain on even in vacant rooms. It is slow and wasteful and results in high electrical costs and operational costs for ASU. Without automation, there is no system in place to maximize resources at the moment, resulting in inconvenience to people in the building and added pressure on the HVAC. Placing a smart building automation system in position will address these issues by utilizing power efficiently based on how many are in the building and the weather.

2. **Building Security Operations:** The building's system is not automated and operates on old technology based on manual approaches. It operates on regular keys and not smart keycards or fingerprints, and monitoring and restricting access without approval is difficult. The cameras are not monitored automatically since there are no alarm signals for suspicious movement, so that security issues could go unchecked. The alarm system is not activated automatically in the presence of fires and smoke, and employees have to locate and handle fires manually, resulting in responses with a time loss. The break-in is not sensed because there are no motion sensors and no alarm on illegal access post-work hours. All these issues in security cause slow responses, increased chances of break-ins, and increased possibilities of human error, endangering people and belongings. An automated system in the area would secure the area, hasten responses, and enable monitoring and alarm in real-time.

3. **Tracking Building Performance:** Real-time data tracking is unavailable for energy consumption, occupancy, system performance, temperature, and other parameters. Everything relies on manual inspections, which ultimately slow down the response time, maintenance, and decision-making capabilities. It also adds additional operational costs.

Fig. Various components of Building Automation

1.1.1.d. Overview of the project

To upgrade the current system with a fully integrated Building Management System (BMS), ASU and team Quantile decided to upgrade the systems below.

1. **Smart lighting system:** Automatic light adjustment based on daylight level and occupancy.
2. **Advanced HVAC System:** Intelligent HVAC system to control heating and cooling based on usage and temperature needs, helping to save energy and maintain a temperature to keep a comfortable work environment.
3. **Enhanced security system:** Installation of high resolution cctv cameras, access control system, smart fire detection and alarm system to make the building more secure.
4. **Centralized Control System:** Installation of a brand new control system for monitor, control, analytics and alerts of overall building processes from one location.

Implementation Plan

- **Phase 1 -** Current system analysis, Requirement analysis, discussion with stakeholders
- **Phase 2 -** Procurement planning of necessary sensors, materials.
- **Phase 3 -** Installation and integration of systems.
- **Phase 4 -** Testing the system in the actual work environment, training the staff and final system deployment.

1.1.1.e. Objectives

The aim of this intelligent change is to make the building more functional, secure, and economical. We aim to save maximum energy using machines, guard it with intelligent cameras and access controls, and maintain pleasant temperatures with effective heating and cooling control. Machines will also minimize manual labor, so everyday tasks will be faster and more dependable. Single-screen monitoring will provide real-time monitoring, alarms, and reports to inform decision-making. The system will enhance fire protection, equipment maintenance, and environmentally friendly operations. These advancements align with ASU's commitment to sustainability, safety, and innovation.

1.1.1.f. General Approach

To ensure this intelligent shift takes place, we will plan and execute both technical and management plans with careful consideration.

The first thing to do is select the appropriate technology, such as smart sensors, automated controls, and cloud-based management systems. Then, install IoT-enabled devices, including smart lights, HVAC controllers, and advanced security systems. Once the devices are installed, software integration is required to connect all systems with a central Building Management System (BMS) that is remotely accessible and provides real-time information. Once the devices are installed, the team will thoroughly test everything and make adjustments to optimize how the system functions and to make everything run smoothly.

There will be a well-defined project plan with key steps, how to handle risks, and a schedule. Communication with stakeholders and having open communication and feedback with ASU's facilities management team is crucial. Budgeting will be a top priority, as will making intelligent buys and being cost-conscious. Throughout the project, we will monitor and report performance through data monitoring and periodic checks to ensure everything remains on track and within budget.

Team Quantile's disciplined method of working and effective project management will ensure that the transition is smooth, well-planned, and extremely successful. This will lead to a more sustainable, secure, and affordable building for ASU.

1.1.2.a. Statement of Work (SOW)

Date to Finish	Task By Milestone
1-Feb-25	Project initiation, requirements gathering, and stakeholder approval
21-Feb-25	Procurement of smart devices, sensors, and automation software
8-Mar-25	Installation of smart lighting and HVAC automation systems
23-Mar-25	Installation of advanced security systems (smart access control, real-time surveillance
2-Apr-25	Integration of energy optimization and centralized BMS control
1-May-25	System testing, debugging, and performance optimization
15-May-25	Staff training and stakeholder demonstration
30-May-25	Final review, handover, and project closeout

Fig. 1.1.2.A Key Milestones

Resource	Requirements
Smart Devices & IoT Sensors	Motion sensors, occupancy detectors, temperature sensors, automated lighting controllers
Building Management Software (BMS)	Cloud-based system for remote monitoring and control
Smart Access Control	Biometric readers, RFID keycards, and automated door locks
Security Surveillance	AI-powered CCTV cameras, motion detection alarms
Energy Management System	Smart meters and energy optimization software
Project Team	Engineers, IT specialists, energy consultants, security experts
Training & Support	On-site and remote training sessions for ASU staff

Fig. 1.1.2.B Resource Requirements

1.1.2.b. Acceptance Criteria

The project would be considered a success in the following ways:

1. All smart home networks are configured, networked, and functioning properly.
2. Energy use is reduced at least by 20%.
3. Security systems are able to rapidly notify and secure access.
4. HVAC automation ensures optimal climate control based on occupancy.
5. The building automation system is operated and monitored remotely.
6. All ASU employees are trained on how to properly use the system.

Each acceptance criterion is related to the aims of the project and will be verified on completion and hand over.

1.1.3. Business Case

To ensure that this smart switch functions effectively, comprehensive technical and management plans would be developed and implemented.

First, we will decide the suitable technology to use after analyzing the current system, such as smart sensors, automated controllers, and cloud management systems. Then, the team installed IoT devices such as smart lights, heating and air conditioning controllers, and smart security systems. Once the hardware is installed, the integration phase will begin where all the softwares will be interlinked with the primary Building Management System (BMS) which will be accessible remotely and receive real-time information. Once everything is in place, the team will thoroughly test and fine-tune such that the system functions properly and every device functions properly.

A good project plan should be well-defined with goals, risk management, and a timeline. Communication with the stakeholders is crucial, with frequent reports and updates to the facility management of ASU. The budget should be well managed with intelligent purchasing and cost-cutting strategies. We will also monitor our progress continuously and provide updates on how we are progressing, using the data and frequent audits to keep on course and within budget.

Team Quantile has a definite process and sound project management that will keep the transition simple, orderly, and highly efficient. The outcome will be a better, greener, and safer structure for ASU.

1.2 Project Deliverables

1.2.1 Major Deliverables

1.2.1.a Final Version of Project Plan

This document will provide detailed documentation about the Building Automation project, including the objectives, project timeline, strategy, and budget.

1.2.1.b Signed Project/Timeline Plan

In this section, approval from key stakeholders such as ASU facility management, sponsors of the project, and contractors needs to sign the project details and timeline plan before the execution.

1.2.1.c Signed Budget Plan

This deliverable will finalize the budget allocation and approval by the ASU management which includes procurement, installation and other costs such as software/hardware costs.

1.2.1.d Selection of Building Automation System Components

This deliverable will contain the final selected quotations of the equipment which are needed in building automation project such as HVAC, lighting control, security system (CCTV, biometric) approved by stakeholders.

1.2.1.e Procurement and Licensing of Software & Hardware
All of the licensing of software and hardware ie. Automation control systems, dashboards, analytics for a seamless projection without any issue.

1.2.1.f Prototype Testing & Approval of System Modules
Before proper installation of the automation system in ASU building, testing will be done in accordance with smooth installation and commissioning. FAT (Factory Acceptance Test) will be carried out for making sure that the cold run is properly executed without any defects.

1.2.1.g Final Implementation and System Integration
After successful execution of the FAT(Factory Acceptance Test), final deployment of building automation will start which will integrate all of the subsystems(HVAC, security, energy monitoring).

1.2.1.h Final Performance Metrics Report
This report will contain a summary of the system performance post implementation, which will evaluate the energy savings, security improvement, temperature control and operational efficiency.

1.2.1.i Final Contract of Completion and Payment
After this project is successfully completed, a formal contract will be signed between the client which will confirm the completion of the ASU Building Automation project and after this final sign-off payment will be released which will ensure that every department is paid their due payments.

1.3 Project Organization

1.3.1 Organizational Table

1.3.1a. Table Overview

The organizational table shows the different teams, employees, and stakeholders that will be involved in the planning and execution of the project. The table highlights the name, title, and the Department the team member will be working in. (See Figure 1.3.1.a)

1.3.1.b Position Breakdown

Project Leadership

I. Project Sponsor: A senior executive from ASU will be responsible for making sure the project outcomes align with the goals that ASU has set for the project.

II. Project Manager: The project manager will be responsible for monitoring the progress, budget, and timeline of the project. Project Manager is also the primary point of contact between the contracting company and the project sponsor.
III. Technical Program Manager: The Technical Program Manager will be responsible for coordinating with the Project Manager and the technical team to make sure the engineering efforts are aligning with the business requirements.

Business and Finance Team

I. Procurement and vendor manager: The procurement and vendor manager is responsible for selecting hardware, software, and vendors and negotiating the terms of the contracts.
II. Finance Manager: The finance manager approves the expenses/bills and makes sure that the project is within budget.
III. Regulatory Compliance Officer: The Regulatory Compliance Officer ensures that compliances like energy efficiency, cybersecurity, and building codes are being met by the engineering team.

Project Execution Team

I. Hardware Engineer: Hardware engineers work on sensor integration, ensuring all the sensors work cohesively with the network.
II. On-site Technician: On-site Technician installs the sensors with the help of the hardware engineer.
III. Customer Success: Helps ASU's team with any questions about the overall system and provides them with end-to-end support.

Name	**Title**
James Carter	Project Sponsor
Aryan Bisht	Project Manager
Shubham Bharat Raut	Technical Program Manager
Ankush Sanjay Harishchandre	Procurement and vendor manager
Apurva Annasaheb Dange	Finance Manager
Yarasi Bhuvaneswar Reddy	Regulatory Compliance Officer

Robert Wilson	Hardware Engineer
Ashley Davis	On-site Technician
William Brown	Customer Success

Table 1.3.1. a Name and Title of all the stakeholders involved

1.4 Work Breakdown Structure (WBS)

The Work breakdown Structure provides a detailed timeline for Setting up a Building Automation system in a Four-Floor building. The system includes HVAC, lighting, security and access control automation. This systematic Technique guarantees effective project management which reduces expense and optimizes energy use. (See Fig. 1.4.1.a)

Task Name	Duration
Building Automation: Four-Floor Building	60 days
Deliverable 1: System Design & Planning	20 days
- Sub-Task 1: Conduct Site Survey & Assessment	5 days
- Sub-Task 2: Identify Automation Requirements	5 days
- Sub-Task 3: Develop System Architecture & Integration Plan	10 days
Deliverable 2: Procurement of Equipment & Components	15 days
- Sub-Task 1: Purchase HVAC Control Equipment	5 days
- Sub-Task 2: Purchase Smart Lighting Controllers	3 days
- Sub-Task 3: Purchase Security & Access Control Devices	3 days
- Sub-Task 4: Purchase Networking Infrastructure	4 days
Deliverable 3: Installation & Setup	25 days
- Sub-Task 1: Install HVAC Automation System	10 days
- Sub-Task 2: Install Smart Lighting Controls	5 days
- Sub-Task 3: Install Security & Access Control System	5 days
- Sub-Task 4: Configure Network & System Integration	5 days
Deliverable 4: System Testing & Optimization	10 days
- Sub-Task 1: Perform Initial System Testing	3 days
- Sub-Task 2: Troubleshoot & Optimize System Performance	4 days
- Sub-Task 3: Finalize System Calibration	3 days
Deliverable 5: User Training & Handover	10 days
- Sub-Task 1: Train Building Management & Staff	5 days
- Sub-Task 2: Conduct Final Walkthrough & Approval	3 days
- Sub-Task 3: Deliver Final Documentation & Support Plan	2 days

Fig. 1.4.1.a - Work Breakdown Structure

1.5 Responsibility matrix:

1.5.1 a Matrix Overview

The RAM is one of the key instruments for stipulating each individual's role and responsibility in relation to our contracting company. It avows clear definitions of accountability for each task, who renders expertise, and who is to be kept informed about progress. The matrix's quite graphic form allows quick reference by employees and, if necessary, clients. Of course, planning and final approval are reserved for management inasmuch as a task is undertaken by skilled professionals such as engineers and technicians. Most often, this expertise would be sought when a task is to be substantiated efficiently and at excellent standards.

	Aryan Bisht	Shubham Bharat Raut	Ankush Sanjay Harishchande	Apurva Annasaheb Dange	Yarasi Bhuvaneswar Reddy
Conference planning	➕	➕	🔵🟥	➕	🔵➕
Budget and Sponsorship		🔵🟥	🔵		➕
Venue booking and logistics		🔶	🔶	🔵🟥	
Registration and attendee Management Marketing Initiation	➕🔶			🔵🟥	
Marketing Initiation	🔵🟥				➕🔶
Event operations (Venue setup and handling)	🔵🟥	➕	➕	➕🔶	🔶

🔵= Responsible: The staff members in charge of executing this task
🟥= Accountable / Approval: The employees who bear responsibility for the output and verifying its completion
➕= Consulted / Supported: The staff members who should be consulted as experts when necessary
🔶= Informed/ Notified: The staff members who will get updates on the status of the deliverables.

2. **Project Risk Assessment**

2.1 Risk Analysis

2.1.1 Identifying Likely Risk Factors

2.1.1.a Failure of a Hardware Component:

Important automation parts like sensors, controllers, and HVAC systems can fail during setup or use as a result of poor connectivity or manufacturing flaws. System problems, higher maintenance expenses, and project delays can happen from this.

2.1.1.b Problems with Software Connectivity:

The smooth communication of several software components is important to the automation system. Project delays may result from system failures caused by problems across several platforms (BMS, HVAC control, security systems), which require detailed debugging and replacement.

2.1.1.c Cybersecurity threats:

Due to its central network connection, the smart building system is at risk of hacking and unauthorized access. Cyberattacks have a chance to disable security systems, reveal private information, and interfere with building operations. There could be serious financial and social consequences if strong security measures are not put in place.

2.1.1.d Budget Overrun:

Unexpected costs which include extra hardware specifications, licensing fees, software updates, and labor charges could cause costs to go above the expected budget. This can affect the project's feasibility from a financial standpoint and cause delays in its completion.

2.1.1.e Shipping and installation delays:

It can take longer than expected to get the required parts (IoT sensors, HVAC controllers, security cameras) because of supply chain problems, vendor delays, or import restrictions. This may cause delays in installation schedules and affect the project's overall progress.

2.1.1.f Problems with System Performance:

Due to incorrect measurement, improper testing, or real-world changes, the installed automation system might not provide the desired energy savings, security improvements, or efficiency improvements. Stakeholder trust in the project might drop as a result.

2.1.1.g Problems with rules and Regulation:

Local building standards, energy efficiency rules, and cybersecurity requirements must all be met by the system. Legal issues, fines, or the requirement for expensive changes and permits could result from failure with legal guidelines.

2.1.1.h Disruptions in the Power Supply:

Automation of smart buildings requires a steady power source. Automation controls may become useless due to power failures, voltage fluctuations, or electrical system failures, which could result in operational errors, security threats, and temperature control failures.

2.2 Qualitative Risk Assessment Matrix

By analyzing the overall project idea and initial documentation, below the possible risks and their probability, as well as consequences, are explained.

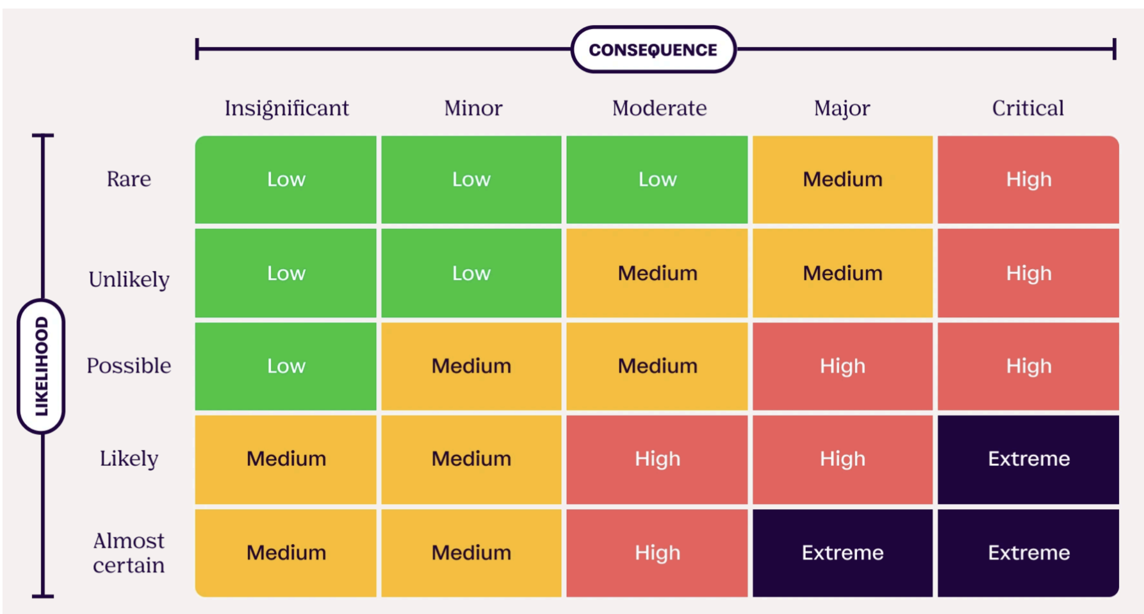


Fig. Risk Assessment Matrix

A Risk Matrix is a tool to find and rank risks in relation to their probability of occurrence (likelihood) and the consequence of the effect (impact). It is presented as a matrix where one axis represents likelihood, ranging from Rare to Almost Certain, and the other axis represents impact, ranging from Insignificant to Severe.

The risks are typically divided into three levels based on the colors as follows:

1. Low Risk: Green color
2. Medium Risk: Yellow color
3. High Risk: Pink color
4. Critical Risk: Violet color

Here, low risk indicates small issues, medium risk are the risks that should be analyzed and remaining pink indicates that the risk should be addressed in order to solve the issue and violet risk which needs to be solve immediately.
With the help of risk matrix analysis, it is simplified for the team to prioritize the issue resolution process. Leading a better decision-making strategy to reduce the risk in the project. This will help the Building Automation system to be secure, more efficient, and reliable. This will also protect the project from bursting with major issues earlier.

2.3 Quantitative Assessment of Probability & Consequences

Possible Risks	Likelihood	Risk Level	Consequences
Overconsumption of Energy	Possible	Medium	Moderate
HVAC Breakdown	Possible	High	Major
Security Failure	Unlikely	High	Critical
Fire alarm system Failure	Unlikely	High	Critical
Data Monitoring Tracking Failure	Likely	High	Moderate
Access Control System Failure	Possible	High	Major
Network Outage	Unlikely	Medium	Major

1. Energy overuse is when HVAC, lighting, or appliances run unnecessarily, therefore increasing the electricity bills and their environmental impact. However, automation can mitigate it, but inefficiency could be a result of poor configuration or malfunctioning of sensors. Measures that may help in mitigation are: Real-time monitoring, AI-driven energy optimization, and automated power control to prevent overconsumption.

2. An HVAC system failure will result in an uncomfortable temperature condition, inefficient energy usage, and equipment damages. In the case of HVAC automation failing, users would be at the mercy of extreme heat or cold that would impede productivity and shorten the longevity of the system. Preventive maintenance, predictive analytics, and backup systems help avert the risk.

3. Security system failure could mean unauthorized access, theft, or worse safety issues. The impact is dramatic since personnel and information security will be at risk. The risk is still low, however, good security measures, access control upgrades, and real-time monitoring of surveillance should always be in place to mitigate it.

4. A failure of the fire alarm system could mean serious consequences: emergency responses are delayed, lives and assets get at risk. In theory, a fire alarm is a highly reliable mechanism, but malfunctions of the sensor, lack of power, or faulty programming are some of the factors that may negatively affect its reliability. Testing the system regularly, using redundant fire detection, and an automated alert can minimize the impact of this risk.

5. A failure in data monitoring would mean a lack of insight into the status of energy consumption, security, and system health. Without appropriate monitoring, issues could be missed, which may cause delay in maintenance and increase operational cost. Implement cloud-based backups, AI-driven analytics, and automated failure detection to ensure that the tracking of data is ongoing.

6. An access control failure could result in unauthorized entry or block access to authorized personnel, leading to security breaches, and operational disruption, To solve this issue smart locks, biometric identification, and dual-factor authentication can be used to enhance the overall safety operation

7. Network outages affect the automated functions, control systems, and real-time monitoring. With systems like HVAC or fire alarm systems relying heavily on connectivity, failures could disrupt the whole building function. This one can be treated by enabling redundancy, wherein additional internet channels would allow load-sharing, while backup power supplies and even hybrid cloud-local storage systems ensure continuity when outages come.

2.4 Risk Mitigation Strategies

Figure 2.4.1.A - Risk Management Strategies	
Risk	Mitigation Strategies
Failure of a hardware component	- Source hardware material from trusted vendors that provide a minimum of 3 years warranty - Conduct regular tests and maintenance on the hardware components - Keep a backup of components vital for the functioning of the overall system
Problems with software connectivity	- Have technical documents that can be used to troubleshoot the software - Using a standardized communication protocol - Before deployment, test the system with integration testing
Cybersecurity threats	- Have a firewall in place for the overall system - Provide cybersecurity training to the building staff - Conduct periodic cybersecurity audits for possible vulnerabilities
Cost overrun	- User project management tool to manage expenses - Continue researching cost-effective alternatives for reducing the cost
Shipping and installation delays	- Using multiple vendors for ordering supplies to reduce dependency on one - Placing orders in advance to allow time for any possible delays - Create a backup plan for key possible delays
Problems with System performance	- Install performance monitoring systems to monitor system performance regularly - Create a SOP for fixing common errors in the system
Problems with Rules and Regulations	- Hire a legal consultant to help with the project planning
Disruption in power supply	- Install power generators on site for backup power supply - Install voltage regulators to avoid damage due of sudden influx of voltage

3 Project Schedule Development

3.1 Activity Duration Estimates

3.1.1 Activity Duration Table Description

In the planning and scheduling scenarios of our Smart Building Automation project for the Arizona State University system, we developed an activity duration table to help provide better estimates of how long each major project task would take to complete. This has the significant advantage of applying realistic time frames to each of the components according to relevant prior experiences, team input, and dependability on technology.

Importantly, however, this specifies predecessor relationships between pairs of preceding and succeeding activities. It is possible to identify dependencies and possible parallel work modalities, which then lead into minimization of downtimes, maximization of efficiency, and optimization of the entire project timeline. Tasks that do not rely on other tasks can be scheduled to have overlapping durations thereby compressing the whole schedule but maintaining the quality of product provided.

Such planning serves the project team in identifying the bottlenecks well in advance, making an arrangement of resources accordingly. The end result is an effectively managed schedule since it is created to ensure timely completion while retaining each phase's integrity.

3.1.2 PERT Probability Estimates

The Program Evaluation and Review Technique (PERT) was used to estimate the durations of an activity with accuracy these days. The probabilistic avenue works best with a task that has uncertain or limited hindsight history. Integration of technology is one such project.

The time each activity is estimated for by the three estimates:

Optimistic (O): The least time the activity could possibly take.

Most Likely (M): The time most expected, under normal conditions.

Pessimistic (P): The most time it could possibly take under the longest anticipated prolonged periods of inactivity.

We then calculate the expected duration using PERT formula:

$$\text{Expected duration(D)}=\frac{0+4M+P}{6}$$

Activity Duration Estimates table

ID	Activity	Predecessor(s)	Optimistic (O)	Most Likely (M)	Pessimistic (P)	Expected Duration (D)
A	Requirement Analysis	—	3	5	7	5.00 days

B	Procurement Planning	A	2	4	6	4.00 days
C	System Installation	B	5	7	11	7.33 days
D	Software Integration	C	3	6	9	6.00 days
E	Staff Training	D	1	2	4	2.17 days
F	System Testing	D	2	4	6	4.00 days
G	Final Deployment	F	1	2	3	2.00 days

For example let us take PERT calculation for C: system installation

$$D = \frac{5+4(7)+11}{6} = 7.33 = Approx\ 8\ days$$

3.2 Gantt Chart with Critical Path

3.2.1 Gantt Chart and Critical Path Explanation

3.2.1.a Gantt Chart Explanation

The activity duration, responsible teams, and deadlines are tracked by this visual scheduling tool. In addition, this tool monitors progress in real-time, which restricts the team's time in meeting deadline requirements.

The Gantt Chart, through an explicit mapping of each task's location within the project timeline, allows team members and stakeholders to make informed decisions regarding proper sequencing, resource planning, and rescheduling in case of slippages.

Under the current schedule, the estimated completion date:

Estimated completion Date:

3.2.1.b Critical Path Explanation

The critical path is the longest sequence of dependent activities that determines the shortest time the project can be finished. Any delay affecting this critical path will directly affect the completion of the project.

The critical path, in our Gantt Chart, includes the following activities:

Requirement Analysis → Procurement Planning → System Installation → Software Integration → System Testing → Final Deployment

The path traverses significant phases within the project, which makes the hardware and software components derived from this path so critical to being managed on a timely basis.

Activities such as Staff Training are occurring in parallel and thus are not on the critical path, which means this particular activity can be delayed a bit without impacting the overall project delivery date.

Estimated time to completion:

		Name	Duration	Start	Finish	Predecessors
1		Requirements Analysis	5 days	8/4/25 8:00 AM	8/8/25 5:00 PM	
2		Procurement Planning	4 days	8/11/25 8:00 AM	8/14/25 5:00 PM	1
3		System Installation	7.33 days	8/15/25 8:00 AM	8/26/25 10:38 AM	2
4		Software Integration	6 days	8/26/25 10:38 AM	9/3/25 10:38 AM	3
5		Staff Training	2.17 days	9/3/25 10:38 AM	9/5/25 1:00 PM	4
6		System Testing	4 days	9/3/25 10:38 AM	9/9/25 10:38 AM	4
7		Final Deployment	2 days?	9/9/25 10:38 AM	9/11/25 10:38 AM	6

Figure 3.2.1.a - Gantt Chart schedule

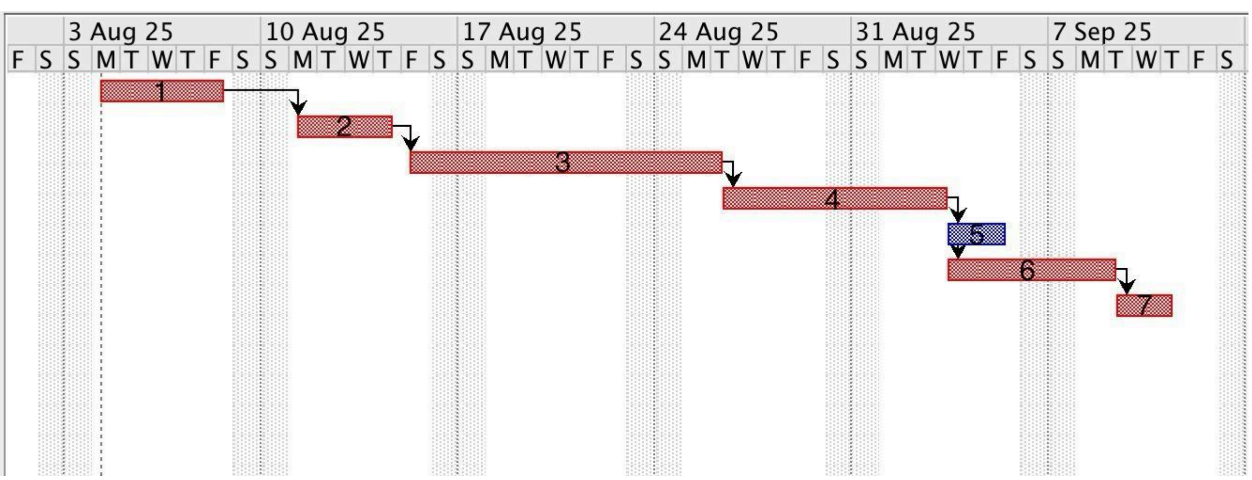
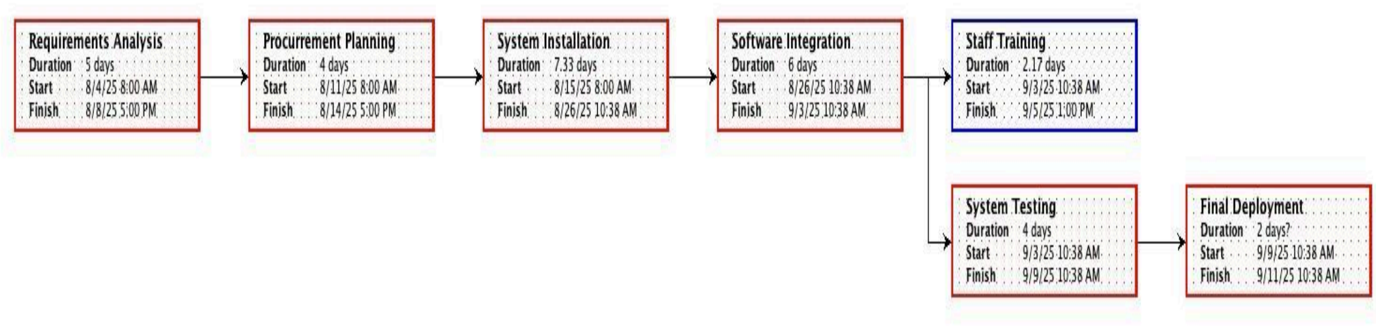


Figure 3.2.1.b - Gantt chart and the critical path of the project



3.3 Resource Allocation

3.3.1 Resource Allocation View and Gantt Chart

Effectively allocating the resources is a critical process in order for project success. We have used ProjectLibre for the allocation and creation of the Gantt chart. By this process, we are ensuring that every resource is allocated to the building of this process applying their skills to 100%. Our resource allocation was documented in detail, with resource names displayed on our Gantt chart for real time monitoring.

3.3.1.a Resource Allocation

In our project, the resources which are required for technical procedures for installing smart sensors, configuring HVAC controllers, setting up high resolution security cameras, and integrating these systems into the Centralised Building Management System (BMS). We started by entering details of our team into the software in Resource Usage view in Project Libre. By this step we were able to allocate our team to the steps of this project which helped us plan the assignments based on everyone's unique specialities.

3.3.1.b Assigning Resources

Once our resource pool was established, we systematically assigned team members to tasks aligned with their roles. For example, hardware engineers managed the installation of various sensors and equipment, software engineers mostly Instrumentation engineers were responsible for all the programming of the resources of the smart building. We have used the feature of Project Libre, "Assign Resources" to link the task to the personnel, which ensures that every aspect of the installation process is overseen by a qualified individual.

3.3.1.c Display Resource Names on Tasks

To prevent the overallocation of the resources, we customize the Gantt Chart in ProjectLibre to display the allocated resource over the task on the task bar of the project from being in the Gantt Chart. This visibility will increase the data-ink ratio of the Gantt chart and make the understanding of the schedule easier among the team.

3.3.1.d Final Gantt Chart Presentation

This final Gantt Chart provides a zoomed-out view of the timeline of the project including the responsibilities, resource per day costing, deadlines, etc, which is very important in project planning. This chart will be very useful in communicating with the ASU stakeholders and out team to manage the project as a tool for tracking the progress.

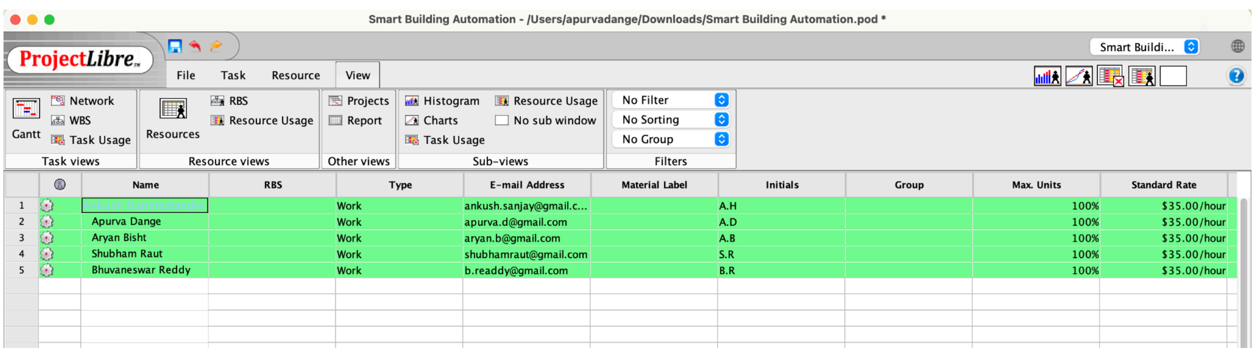


Figure 3.3.1.a Assigning Resources

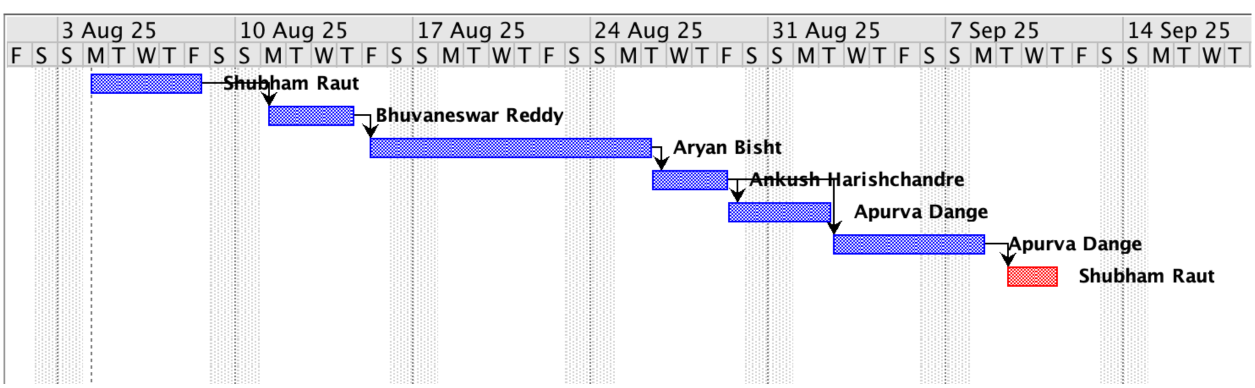


Figure 3.3.1.b Display Resource Names on Tasks

4. Project Budget

4.1 Project Resources

To implement the Smart Building Automation project in ASU, we have estimated the total resource cost which will be required to complete this project. The budgeting takes into account hourly rates, estimated hours per week, and total duration for each team member. Overhead costs are taken into account in fully loaded rates which will cover the overall expense that includes training, equipment and support.

Name	Title	Department	Hourly Rate	Time (hrs/week)	Duration (weeks)	Fully Loaded Rate*	Cost
Aryan Bisht	Project Manager	Management	$22	40	20	$33	$26,400
Shubham Bharat Raut	Technical Program Manager	Engineering	$20	35	18	$30	$18,900
Ankush Harishchandre	Procurement Manager	Finance	$18	30	12	$27	$9,720
Apurva Dange	Finance Manager	Finance	$20	30	12	$30	$10,800
Yarasi Bhuvaneswar Reddy	Regulatory Officer	Compliance	$19	20	10	$28.5	$5,700
Robert Wilson	Hardware Engineer	Engineering	$22	35	15	$33	$17,325
Ashley Davis	On-site Technician	Technical Support	$18	30	12	$27	$9,720
William Brown	Customer Success Lead	Client Relations	$17	25	10	$25.5	$6,375

The total estimated resource cost for this project is **$104,940.** (including overhead cost)

4.2 Other costs

4.2.1 Hardware costs

This is a list of key hardware devices that will keep the building operating efficiently on a daily basis. The devices have been categorized under HVAC, Smart Lighting, and Security & Access Control.

Smart controllers, zone boxes, and sensors automatically regulate the climate for heating and cooling the space with the aim of conserving energy while maintaining a comfortable environment. The CO_2 sensors, humidity sensors, and temperature sensors continuously monitor the rooms' environment, whereas dampers and actuators directly control the airflow themselves.

The Smart Lighting System features power-saving LED lighting, sensors for movement detection, sensors for daylight detection, dimmers, and control units. The components ensure that the lighting comes on only when required and adjusts their brightness according to the available daylight. The system makes users feel more convenient while reducing electricity bills.

At Security & Access Control, we employ CCTV cameras, fingerprint access systems, motion sensors, fire alarms, and exit devices for emergencies. These protect the building at all times, manage who can access it, and enable rapid response in the event of an emergency.

All of the parts that were selected were selected because they are robust, reliable, and simple to interface. The majority of them form the foundation of the smart building system.

Device	Details	Quantity	Cost (Individual)	Cost (Total)
HVAC				
Smart HVAC Controllers	Control heating/cooling via automation	4	$600.00	$2,400.00
VAV (Variable Air Volume) Boxes	Adjust airflow in individual zones	8	$400.00	$3,200.00
Temperature Sensors	Monitor and regulate room temperature	20	$80.00	$1,600.00
Humidity Sensors	Optimize air quality and comfort	10	$70.00	$700.00
CO_2 Sensors	Monitor air quality in occupied spaces	10	$90.00	$900.00
Actuators and Dampers	Control duct airflow based on sensor feedback	10	$150.00	$1,500.00
Smart Lighting System				
LED Smart Lighting Fixtures	Energy-efficient and automated lighting	60	$120.00	$7,200.00
Occupancy/Motion Sensors	Detect presence to turn lights on/off automatically	60	$45.00	$2,700.00

Daylight Sensors	Adjust brightness based on ambient sunlight	20	$60.00	$1,200.00
Smart Switches and Dimmers	Enable programmable/manual lighting control	40	$55.00	$2,200.00
Lighting Control Hub/Panel	Centralized control for entire building lighting	4	$500.00	$2,000.00
Security & Access Control				
High-Resolution CCTV Cameras	Monitor all areas of the building (360°, night vision)	25	$200.00	$5,000.00
Biometric Access Control Terminals	Fingerprint/smart card for entry authentication	10	$250.00	$2,500.00
Magnetic Door Sensors	Detect door opening/closing	20	$40.00	$800.00
Motion Sensors	Intrusion detection after hours	15	$75.00	$1,125.00
Smart Fire Alarms with Smoke Detectors	Automated alerts for fire/smoke	10	$150.00	$1,500.00
Panic Buttons and Emergency Exit Devices	Emergency response tools for occupants	6	$100.00	$600.00
				Total = $37,125

4.2.2 Networking and Control Room Setup Costs

This is the overall price for everything required to establish the network for the building, including the control room hardware.

In the area of Networking, we've got servers, desktops, routers, switches, cables, and a firewall. These are the key components of the smart building system. The servers will store and execute the Building Management System (BMS), while the desktops will serve as operators' workstations for the control room. The switches and the cables will enable devices to easily hook up with one another, while the firewall will guard the network against external threats.

The Control Room contains all of the key equipment required to operate and monitor all systems. The BMS Controller interfaces with the lighting, heating, cooling, and security systems. Touchscreen HMIs are simple to use to access systems, and data loggers permit later checking of sensor data. Monitors will display a clear picture of how the system is operating, and UPS units will keep everything operating if there is a power outage.

This configuration will enable building managers to manage all systems from a single secure and user-friendly location.

Device	Details	Quantity	Cost (Individual)	Cost (Total)
Networking				
Dell PowerEdge Servers	Host BMS software, handle data storage	3	$ 1,600.00	$ 4,800.00
Dell T30 Mini Desktops	Control room, client-side system interfaces	250	$ 100.00	$ 25,000.00
Cat-6 Cable Reels	Data and power connections for all systems	5	$ 130.00	$ 650.00
Cisco SG110 Switches	Distribute network connections	11	$ 230.00	$ 2,530.00
Cisco RV345 Router	Manage internet and external connectivity	1	$ 260.00	$ 260.00
Fortigate Firewall	Cybersecurity and network protection	1	$ 740.00	$ 740.00
Control Room Setup				
BMS Controller/Main Panel	Central system to integrate HVAC, lighting, security	1	$ 2,500.00	$ 2,500.00
Touchscreen HMI	Real-time control and system overview	2	$ 800.00	$ 1,600.00
Data Logger/Edge Device	Collect sensor data for cloud/BMS processing	2	$ 300.00	$ 600.00
Control Room Monitors	Visualization for building performance, alerts	4	$ 250.00	$ 1,000.00
UPS	Backup for servers and core systems	2	$ 450.00	$ 900.00
				Total = $40,580

4.3 Cost Estimates

The cost estimate shown in the figure below shows the estimate of the overall cost of the project. The Smart Building Automation Project at ASU involves a variety of costs like labor, hardware, software, integration, training, and support. The goal of the cost estimate is to answer the question, “Where is the money going?”

Type of Cost	Total Value
Labor	$104,940
Hardware & Sensors	$37,125
Software	$40,580
Installation & Testing	$12,500
Training & Support	$6,000
Travel & Accommodations	$4,000
Contingency (10%)	$20,514
Total Cost Estimate	$225,659

4.4 Time Phased Budget

The Smart Building Automation project is divided into seven distinct phases as defined by the WBS and durations of the activities based on PERT. It will then allocate each of these cost components according to the relevant phase for its realization. The project officially kicks off in August of 2025 and the table summarizes key resources, estimated costs, and how those costs are spread out throughout the project timeline.

By allocating monthly costs the project team would be able to foresee possible cash flow needs, identify early imbalances in the budget and thus be able to align spending to milestone achievements. This is all achieved through time-phased budgeting which tracked timing of expenditures, matched costs with activity schedules and thus ensured effective financial control across the project. This proactive approach makes the budget more visible and supports timely decision-making.

Activity	August	September	October	November	December	Totals
Requirement Analysis	5000					5000
Procurement Planning		25000	25000			50000

Sensor & HVAC Installation		20000	20000	20000		60000
BMS & Dashboard Integration			20000	10000		30000
System Testing				7500		7500
Staff Training					5000	5000
Final Deployment					20000	20000
Contingency Reserve	3000	3000	3000	3000	3000	15000
Total	8000	48000	73000	40500	28000	192500

5. Communication management

5.1 Communication management chart

5.1.1 Communication Management Chart Description

The project of Smart Building Automation necessitates very effective communication. A communication plan maintains all stakeholders informed and aligned throughout the lifecycle of a project. It describes what information is to be shared, to whom, with what frequency, and by what means.

This ensures collaboration across project team members in decision-making processes, reducing misunderstanding and ensuring accountability. The open lines of communication help the project team to quickly respond to issues, update stakeholders, and keep implementation on schedule.

Communication Type	Audience	Frequency	Method	Purpose

Team Meetings	Project Team (Quantile)	Weekly	In-person / Zoom	Review progress, address issues, assign new tasks
Progress Reports	Facilities Management & Project Sponsor	Bi-weekly	Email (PDF format)	Provide status updates, summarize milestones, highlight risks
Stakeholder Briefings	Project Sponsor and Senior Stakeholders	Monthly	Presentation / Dashboard Reports	Discuss major achievements, upcoming work, and seek approvals
Installation Notifications	Building Occupants / Security	As Needed (Pre-installation)	Email / On-site Notices	Alert stakeholders about installation timelines to minimize disruption
Testing & Handover Summary	Facilities Management	At System Testing Phase	Email + Demonstration	Show system readiness, confirm training, and transition responsibilities
Emergency Communications	All Key Personnel	Immediate (If required)	Phone / Text / Email	Escalate critical system failures, security breaches, or schedule impacts
Final Project Report	Stakeholders	End of Project	PDF Report + Presentation	Provide full documentation, performance metrics, and project closeout data

6. Tracking and Status Updates

6.1 <u>Tracking Method</u>

This section outlines the methodology followed by the Smart building automation project team to track the progress of the project. This method would be used to maintain control throughout the project. The team has divided the project into a few major milestones and will be using them as goal posts to track the progress of the project. **See Figure 6.1.A** table below for the project milestones

Event	Milestone	Milestone Meeting Date
Milestone 1	Requirement Analysis	8/8/25
Milestone 2	Procurement	8/14/25
Milestone 3	Installation	8/26/25
Milestone 4	Software Integration	9/3/25
Milestone 5	System Testing	9/5/25
Milestone 6	Final Deployment	9/9/25

6.2 <u>Notification Record</u>

6.2.1 Status Update Communication:

- Recipients:
    - Project Sponsor
    - Facility Manager
    - Senior Stakeholders
    - Project Team
- Methods:
    - Email
    - In-person/zoom meeting
    - On-site notification
    - Emergency alert via text as needed

All the project updates would be communicated to the above-mentioned recipients via one of the communication methods mentioned above depending on the nature of the update.

6.2.2 Recipients of Project Updates and Signing-off

The project manager will need to sign off the project to move forward with any changes. All the updates will be logged in the project communication register.

All the key stakeholders are required to acknowledge project updates via email or sign to maintain the accountability of the project.

6.3 Control Systems

Project Control Mechanism used in the Building Automation Project are:

- Configuration control will be maintained by the very structure of our team hierarchy. Any changes are reviewed by the appropriate level
- Design Control is achieved through detailed documentation and visualization of project milestones.
- Quality Control is managed through standardized processes and checks.
- Document Control is managed through google docs ensuring there is a single centralized source of truth and all the changes are tracked by google docs.
- Specification Control is maintained by having a specialized domain area expert for very domain.

7.0 Project Close-out

7.1 Close Cost-Accounts

For our Smart Building Automation project, for Team Quantile we made sure every cost was tracked, verified and closed properly, all in line with our approved project budget of $225,659.

We followed a time-phased budgeting strategy, which really helped us spread out costs across different project phases like requirement gathering, procurement, system installation, integration, and deployment. This made it easier for us to control our cash flow better.

- Labor costs came to $104,940. These were verified using ProjectLibre, where we tracked hours worked by team members and matched them to specific tasks and deliverables. Weekly updates made it easy to stay on top of everything.
- Procurement of hardware and sensors cost us $37,125, and software/network infrastructure added another $40,580. We double-checked all purchases against supplier invoices and made sure everything ordered was delivered and in use.
- Installation, testing, training, and support costs were linked directly to project milestones and team member assignments. Payments for these tasks were only approved after confirming that the related work had been successfully completed.
- We also included a 10% contingency reserve of about $20,514. It came in handy a few times and helped us handle small budget swings without affecting the quality or scope of the project.

Once all expenses were reviewed and closed out, We prepared a final financial summary that compared actual costs with what we had originally estimated. It included notes explaining any differences, proof of all vendor payments, and confirmation that there were no pending dues.

7.2 Lessons Learned

During this project we faced a number of challenges, learned valuable lessons and identified improvements which can be applied to implement in future smart building systems. We made sure to track our progress and meet our goals as any real world project.

- **Exceptions/Other problems:**
  One of the initial problems we faced was understanding the technical requirements of a building automation system. Since we come from different technical backgrounds we had to spend time researching things like HVAC integration, smart sensors, and security systems. We also faced coordination issues as a group in the start but learned splitting and combining tasks to work on different sections smoothly.
- **Mitigation strategies employed:**
  To stay on track, we started the work early on time so that everyone could do their part smoothly without issues. We held regular meetings to discuss progress and clear up confusion. We took the initiative as leaders each week so no one has to take the load alone and to understand each other better as a team and work as one.
- **Success of the strategies:**
  By the end of our project, we learned to divide the workload evenly which improved a lot from the start. Dividing the work early and reviewing each other's parts helped improve quality and consistency. We were also able to apply project management concepts like WBS, cost estimation, risk assessment, and scheduling in our project.
- **Suggestion for future:**
  We'd start building our WBS and schedule early as they affect a lot of parts of our report. For future projects like this, we recommend preparing a standard integration checklist for smart buildings. That would help speed up the software configuration process. Another idea is to prepare reusable templates for documentation and reports. It would save time and keep everything consistent.

7.3 Integrated Project Plan Lessons Learned:

Working on this group project taught us a lot about how to plan, organize, and document a real engineering project from start to finish. Going through the full planning process gave us a better understanding of the coordination and thinking involved in a project like this. Here are some of our experience:

- **Clear task division is essential:**
  In the beginning we were not sure about who would do what which caused some confusion. Once we created a proper Work Breakdown Structure (WBS) and assigned

tasks based on each member’s strengths, things became much smoother. This showed us how helpful it is to set clear roles early on in a project.

- **Communication is necessary during a project:**
  At first we struggled a little with staying updated with everyone’s progress, but eventually we started using shared documents and held short team meetings or check-ins to stay on track. This helped us reduce repetition and catch missing parts before the final deadline.
- **Planning is more important:**
  While creating the activity durations, Gantt chart, and cost estimates, we realized that planning involves more assumptions and estimation logic than we initially thought. Tools like ProjectLibre were very useful in helping us visualize timelines for the project which gave us an idea about professional project planning.
- **Teamwork and accountability:**
  Everyone contributed to the project in different ways, and we learned how to depend on each other while also staying responsible for our own parts. It was a good lesson in managing groups and deadlines which are really important skills in a workplace.

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