



# IoT-Enabled Risk Monitoring System for Cold Supply Chain Management in Logistics Applications

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**ABSTRACT:** A cold supply chain is a very crucial link in the chain of delivering heat-sensitive produce like fruits vegetables medicines, and other perishables. A cold supply chain ensures the quality of the produce and that it is safe for consumption by the end user. If the cold supply chain is broken during the transportation or storage of the produce, it can lead to the spoilage of the produce, financial losses for the companies involved, and safety risks for the consumers. This [paper] addresses this problem by proposing an An IoT-enabled risk monitoring system for cold supply chain logistics, which provides real-time environmental and security monitoring, is proposed in this paper. The system proposed in this paper is based on an ESP32 microcontroller working with multiple sensors that have been integrated for the main environmental factors, i.e. temperature humidity gas concentration, light, and door status. Temperature and humidity are measured using the DHT11 sensor, while gas contamination and spoilage are indicated by the MQ135 gas sensor. The system also uses door and light sensors to detect unauthorized door opening and exposure to a non-allowed light level, respectively. Besides this, the system has a GPS module providing real-time container positioning information. The ESP32 processes the sensor data it collects all the time and sends it to a cloud-based monitoring platform over Wi-Fi. The system uses ThingSpeak for remote monitoring and data visualization. This lets you store data in real time and look at it in graphs. When any parameter goes above a certain threshold, the system sends an SMS alert with a live location link so that the person can respond right away. This is done using a GSM module. Testing of the prototype in real-world situations shows that it can reliably monitor the environment, send alerts on time, and accurately display data in the cloud. The suggested system is a cost-effective and scalable way to make cold supply chain logistics safer, reduce the risk of spoilage, and make operations more open.

**KEYWORDS:** IoT, Cold Supply Chain Monitoring, ESP32, Environmental Monitoring, Logistics Safety, GSM Alert System, GPS Tracking, Cloud Monitoring.

## I. INTRODUCTION

Keeping things cold while moving or storing matters because it protects how long food and medicine stay safe to use. From apples to milk, plus shots at the doctor, these items need steady conditions so they do not go bad too soon. When heat shifts, moisture builds up, or air turns poor, what's inside can change fast - sometimes dangerously. Watching temperatures closely happens all through transit, not just once but constantly, across every step. That kind of watchful care isn't extra. It sits at the center of today's transport networks. With older systems, people check temperature by hand inside refrigerated spaces or shipping boxes, relying on simple tools like thermometers or recording devices. When checks happen just now and then, quick shifts in climate often go unnoticed - so does someone opening the



container when they should not. Since humans must do most of the work, gaps appear easily, slowing down how fast problems get fixed. Without constant watch, items can sit too long in risky environments before anyone steps in.

Out here, fresh progress in Internet-linked devices now lets smart monitors gather live details straight from different sensors. Because of that, folks handling cargo movements get updates the moment surroundings shift outside normal ranges. With these tools watching closely, shipments stay clearer to track while fewer goods go bad along the way. One thing leads to another - better oversight often means smoother operations across delivery networks. These days, more people in shipping and tracking operations choose small computers that talk wirelessly. The ESP32 is one example - it comes with built-in internet access through Wi-Fi, so information can move straight into online storage spots without extra parts. Instead of just one measurement at a time, various detectors work together using smart network methods, watching different dangers all at once. When numbers go too high or drop too low, warnings start up by themselves - no waiting needed. A new kind of tracker built for cold shipping routes uses live data from internet-connected devices. Built into one small unit, it watches conditions, checks safety, keeps tabs on where things are at any moment. A DHT11 device measures how warm or damp the space gets. Instead of waiting, changes show up right away thanks to constant updates sent by sensors like the MQ135, spotting bad air that hints something inside might be going off. Doors opened when they should not be? Sudden brightness in dark containers? These signs pop up through extra detectors added just for such events. Each clue helps confirm whether goods stayed sealed and safe along the way.

Out here, raw numbers from sensors flow into an ESP32 chip before hopping onto a live dashboard through the web. Instead of storing locally, everything feeds straight into ThingSpeak - where charts form on their own, viewable from anywhere. When air quality drops or someone tampers with the setup, a built-in GSM part fires off texts tagged with exact map spots. These warnings travel fast, showing up right where help can find them. Details arrive pinpointed, thanks to satellite-linked positioning baked into each alert. That way, nobody misses what happens when things go sideways. A fresh approach to watching shipments keeps things running smoother when cold transport is involved. Instead of guessing, sensors give live updates on conditions inside containers. When something shifts outside safe ranges, warnings appear without delay. Technology links devices directly to online platforms where data lives and moves. Location details update constantly, so nothing gets lost in transit. Using widely available tools cuts down expense while boosting control. Risks drop when every step stays visible and checked. This setup handles fragile cargo demands without complex machinery. Each piece connects simply, yet works hard behind the scenes.

## II. RELATED WORK

Out here, gadgets talk to each other now - thanks to faster-growing IoT tricks - and that shift powers smarter checks in farms, hospitals, clinics, delivery routes. These watchful setups? They stitch together detectors, tiny computers, signal senders, online hubs so updates flow live, eyes stay distant yet close. Starting with observations from multiple research efforts, IoT setups now track surroundings where heat matters most. Instead of relying on guesswork, devices grab real-time numbers - like how hot or damp the air feels, even chemical traces floating nearby. Once information surfaces, tiny computers - think Arduino, Raspberry Pi, or ESP chips - step in to make sense of it all. From there, details travel outward, landing safely on internet-connected spaces ready for inspection later. Watching changes over time becomes possible, thanks to screens tucked inside phones or browsers showing what's happening far away.

Keeping things fresh while moving them relies on steady cold tracking across shipping networks. Most current tools watch fridge temps and dampness levels, sending warnings if numbers drift too far off track. Yet quite a few miss extra layers like checking air purity, spotting light leaks, or noticing tampering risks along the way. Lately, studies have linked cloud services with GSM networks to send instant warnings and show data clearly. While certain setups include GPS for pinpointing positions, combining surroundings sensing, safety checks, and whereabouts into one IoT system still happens rarely. A setup like this pulls together different detectors - ones for heat, moisture, air quality, brightness, plus whether a door is open or shut - not to mention position checks through satellite signals and warnings sent via mobile networks. Built this way, it handles live updates and potential threats across chilled shipping routes without falling apart.

## III. SYSTEM ARCHITECTURE

### 3.1 OVERALL SYSTEM ARCHITECTURE

A network of sensors watches temperature and safety during transport of items that need cooling. This setup relies on an ESP32 chip to gather readings from each sensor. Information travels through Wi-Fi instead of cables, moving straight to online storage. The whole process runs without constant human checks, staying active across long distances.

A small DHT11 gadget checks how hot or damp the air feels, whereas an MQ135 sniffing tool keeps watch on fumes that might mean food going bad. On another note, safety tracking leans on a heat-seeing eye spotting movement, along with a hinge monitor noting when entry points open unexpectedly.

Now here comes a GPS unit, giving live position updates while a GSM part fires off texts if sensors go beyond set limits. From there, info travels up to ThingSpeak - seen from anywhere, watched as it changes. Each piece moves on its own rhythm, yet fits without force.

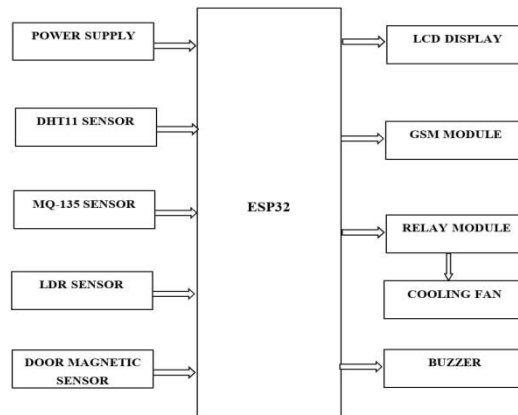


Fig.1: Block Diagram of the Proposed IoT-Enabled Risk Monitoring System

### 3.2 DATA ACQUISITION AND MONITORING PROCESS

Every few moments, fresh details flow in from linked sensors watching the surroundings. Temperature, moisture levels, air freshness, whether doors are shut, or signs of someone breaking in - these show up regularly. Running the numbers, the ESP32 chip checks each value against limits already saved inside. When results drift too far, the device knows something has shifted. A signal climbs toward the server every few minutes, provided numbers stay where they should. Should one slip past its boundary, alarms wake without delay. A signal fires off through the GSM module, delivering an SMS warning to assigned staff when danger shows up. Instead of just text, a pinpoint location tag pops into view using live GPS data - shows exactly where the unit sits. From there, everything gets stamped into the cloud system, saved for later review or tracking shifts over time.

### 3.3 CIRCUIT DIAGRAM

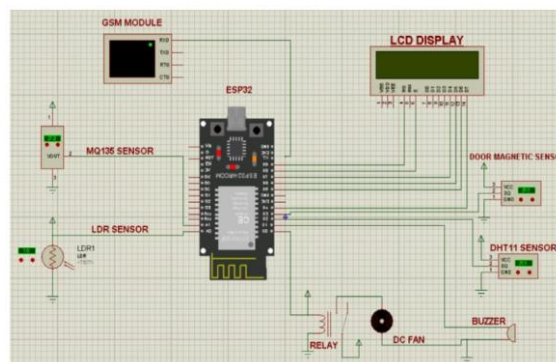


Fig.2: Circuit Diagram of the Proposed IoT-Enabled Risk Monitoring System

## IV. HARDWARE COMPONENTS

Out in the field, sensors team up with communication gear and compact computers to keep watch over temperature and safety during refrigerated transport. A different piece handles its own job, fitting into the bigger picture like parts of a



puzzle. Inside these next sections sits a look at each key physical part built into the test version. One after another, they form how the whole setup comes alive when switched on.

#### 4.1 ESP32 MICROCONTROLLER

Right in the middle sits the ESP32 chip, running the whole show. Built right into this tiny device - Wi-Fi comes standard, no extras needed. Performance stays strong even though the price tag barely registers. From nearby sensors, live info flows nonstop into its memory. Processing happens quickly, almost like second nature to the unit. Threshold checks run quietly behind the scenes every few milliseconds. When numbers cross certain lines, warnings pop up without delay. Offsite platforms receive updates through constant wireless streams. IoT setups love this little board simply because it just works.

#### 4.2 TEMPERATURE AND HUMIDITY SENSOR

Keeping track of heat and moisture levels matters when moving or storing items that spoil easily. Inside the container, a DHT11 device checks how warm it is along with air dampness. Data moves in digital form from the sensor to an ESP32 chip for handling. Once warmth climbs past a set limit, cooling begins without delay through a small fan powered by the setup.

#### 4.3 GAS DETECTION SENSOR

Cold storage transport needs clean air checks since bad gases can mean food damage or unsafe conditions. Inside the container, an MQ135 sensor watches how air changes over time. It tracks levels of carbon dioxide and ammonia by turning them into electrical signals. These readings go straight to an ESP32 chip using a continuous voltage flow. Whenever one gas rises past its set limit, alarms start without delay. Workers then get immediate notice through warning signs on site. Not every spike shows danger but each gets reviewed anyway. Signals stay active only when thresholds are crossed like that. Equipment runs nonstop yet uses little power doing it. Alerts help teams act fast before issues grow larger.

#### 4.4 INFRARED SENSOR(IR)

Flickering light? That triggers the infrared sensor inside the storage unit. When things are sealed right, hardly any light gets through. If something changes, the sensor notices it fast - right away, data moves to the ESP32 chip. Sudden detection means noise: the buzzer kicks on without delay. At that moment, a message travels out - an alert reaches the person watching over it.

#### 4.5 DOOR STATUS SENSOR

Open doors reveal what should stay hidden. A small sensor watches if the container door moves while moving or sitting still. If someone lifts the latch without permission, goods might face harm. Connected straight to one of the ESP32's digital ports, the device wakes when gaps appear. Movement breaks silence - signal flies instantly. That pulse hits the brain chip, setting off alarms without delay. Alerts rise fast, people learn fast, protection grows stronger. Security tightens each time the system speaks up.

#### 4.6 GPS MODULE

Knowing where things are matters most when moving goods. Inside this setup sits a GPS unit that grabs signals from space to pin down position on Earth as it happens. If something goes wrong - like a breach or odd movement - a message fires off containing a clickable map tied to the current spot. That link shows exactly where the cargo rests, cutting guesswork when time counts. The whole process runs without delay once trouble appears.

#### 4.7 GSM COMMUNICATION MODULE

A signal fires off by way of the GSM unit whenever emergencies arise. When set limits get crossed, communication travels via mobile networks using SMS. Alerts activate if heat rises too much, gas shows up, doors open unexpectedly, or beams break inside. Transmission carries details about what happened along with a pinpoint spot on earth through satellite tagging. Location clues arrive linked directly within each notice sent out instantly.

#### 4.8 LCD DISPLAY

On the device, a 16 by 2 line LCD screen shows live data from sensors. Temperature appears first, followed by humidity - then air quality values pop up right after. Because of this setup, people can check surroundings just by looking at the hardware itself. Skipping the need to log into any online system makes troubleshooting faster, especially when adjusting settings or running checks.



## 4.9 COOLING FAN AND BUZZER

When heat climbs past safe levels, the cooling fan kicks in to lower the container's inner temperature. A warning sound comes from the buzzer if gas is sensed, someone breaks in, or the door opens unexpectedly. Local reactions to shifting surroundings are handled by both the fan and the buzzer together. Operators notice problems fast because noise draws attention before checking any online interface becomes necessary.

## V. SOFTWARE DESCRIPTION AND PROGRAM IMPLEMENTATION

Running inside the ESP32 chip, custom code keeps watch over potential risks linked to IoT devices. Built with C and C++ within Arduino's editor, it forms the core logic without relying on outside tools. Gathering info from attached sensors happens alongside continuous checks of surrounding conditions like temperature or motion. Instead of one big block, pieces split into separate parts - each focused only on jobs like scanning inputs or deciding when something needs attention. Communication flows upward to online servers once readings are processed locally. Alerts pop up automatically if thresholds get crossed during analysis cycles. Position details tag along with every report sent outward. Each segment works alone but fits into a larger pattern meant to stay stable even under stress.

### 5.1 SENSOR DATA ACQUISITION

Every few seconds, the ESP32 grabs fresh numbers from gadgets like the DHT11 that checks heat and dampness. Because it runs on a loop, readings from the air quality module show up just after moisture updates. When the infrared unit spots motion, its signal slips into the stream alongside door switch reports. Instead of waiting, the chip lines up each value against preset limits to spot odd shifts. If something stands out - like smoke levels creeping high - the system flags trouble before it spreads. Through constant checking, hidden changes in surroundings come to light without delay. Since every part talks directly to the processor, responses happen almost instantly.

### 5.2 DECISION LOGIC AND ALERT SYSTEM

A signal kicks in when heat crosses a set point, turning on a fan to pull it down. Cooling begins the moment the system spots overheating. Should gas levels rise, a door shift happen, or someone enter without clearance, noise sounds nearby. That alarm tone alerts people close by. At the same time, a message travels through the GSM unit straight to key contacts. Alerts reach them by text without delay. The setup watches quietly until something changes.

### 5.3 GPS LOCATION TRACKING

Out here, the setup uses a GPS piece to keep tabs on where the container is at any moment. Hooked to the ESP32, the GPS swaps data bit by bit, locking onto latitude and longitude. If something odd pops up, those numbers turn into a map link - sits inside the text message that goes out. That way, anyone getting the alert can peek at exactly where the box landed online.

### 5.4 CLOUD COMMUNICATION AND DATA MONITORING

Every now and then, sensor readings get sent up to a cloud-based dashboard, just sitting there waiting to be checked from anywhere. Thanks to its onboard wireless connection, the ESP32 pushes details about surroundings straight into ThingSpeak. That online space holds on to numbers while sketching out visuals - temperature here, dampness there, traces of gases too. Watching these live feeds helps people keep track, spot shifts over time, see how things changed mile by mile.

### 5.5 SYSTEM OPERATION ALGORITHM

Out of silence, the ESP32 wakes up first, setting every sensor and communicator into motion. Midway through each cycle, light, heat, and movement feed fresh numbers to the brain chip. Only after checking past limits does it decide what counts as usual. Every few minutes, if nothing stands out, those quiet updates drift upward into online storage. But should heat spike, fumes appear, or a doorway shift open - sound erupts, fans spin awake, and a message leaps outward tagged with exact ground position.

## VI. ALGORITHM AND FLOWCHART DESCRIPTION

### 6.1 OPERATIONAL ALGORITHM

Right when power hits, the ESP32 wakes up each part - DHT11 for humidity, MQ135 sniffing air quality, infrared watching motion, plus switches tracking doors, while GPS pins location, GSM stands ready to message, and the LCD lights up. From there, streams of live data pour in nonstop, checked at once against set safety lines. Only if everything sits within safe bounds do numbers show on screen, then float into ThingSpeak's online space where supervisors can

peek anytime. But should heat spike, fumes rise, or an unauthorized hinge creak open, that quiet shifts fast - the buzzer screams, fans kick on without waiting, and a pinpointed alert shoots out by SMS through cellular reach. Instead of stacking warnings later, every hiccup triggers actions now: noise, response, traceable signal - all wired tight under one logic flow. After each loop ends, it restarts clean, no backlog, just fresh checks pulsing in rhythm with real-time surroundings.

6.2 FLOWCHART STEPS

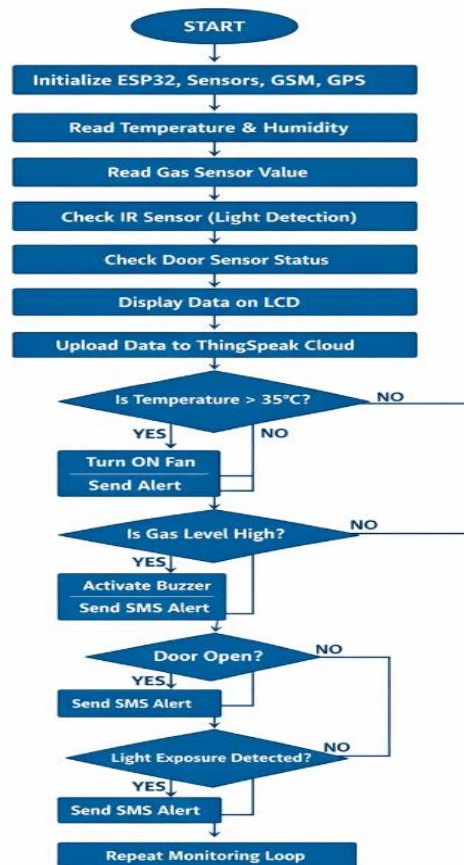


Fig.3: Flowchart of the IoT-Enabled Risk Monitoring System

VII. EXPERIMENTAL SETUP AND RESULTS

7.1 EXPERIMENTAL SETUP

Out in the open, a test version of the IoT risk monitor took shape to mirror how cold supply chains work, checking how well it performs. At its core sits an ESP32 chip, wired up to several sensing devices. Temperature and moisture levels get logged by a DHT11 gadget hooked into the network. Air freshness comes under watch through an MQ135 tool doing constant scans. Breaking the beam of an infrared watcher or opening the compartment flips signals thanks to linked detectors. Wherever it moves, a GPS piece keeps tabs on position minute by minute. When something odd shows up, a GSM radio fires off alert texts without delay. On a small screen, sixteen characters wide and two lines high, live numbers show up from sensors nearby. Written in C or C++, the code runs through Arduino's editor environment instead of some other way. From there, information travels over wireless signals toward online storage spaces where people can check it later.

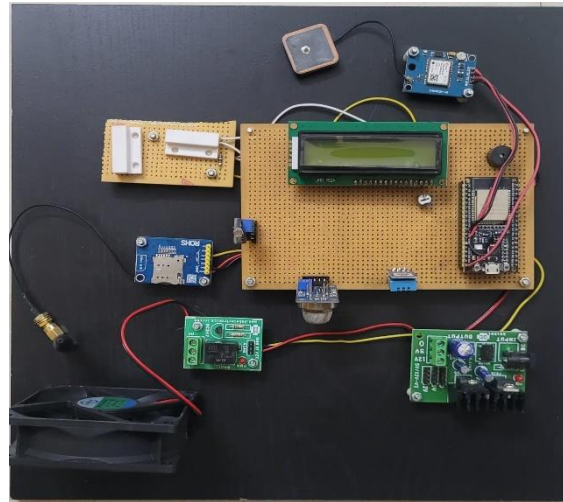


Fig.4: Hardware Prototype of the Proposed IoT Enabled Risk Monitoring System

### 7.2 CLOUD MONITORING AND DATA VISUALIZATION

From the device, sensor information travels wirelessly to ThingSpeak's online service. Over Wi-Fi, temperature, moisture, air quality, and triggered events get sent by the ESP32 chip. Visual charts show live updates while past values are saved automatically. Trends in surroundings appear clearly, helping track how conditions shift across days. Performance patterns emerge when reviewing stored logs later.



Fig.5: Cloud Monitoring Dashboard Displaying Sensor Data

### 7.3 ALERT NOTIFICATION SYSTEM

During tests with fake emergencies - like too much heat, gas presence, broken entry, or doors opened without permission - the warning setup responded each time. Once readings passed set thresholds, it turned on the alarm sound while shooting off a text through the GSM unit. That note carried specifics about what happened plus a pinpoint spot from GPS. Opening that address let people see precisely where the box stood using online maps, making reactions faster. Each trial confirmed signals moved correctly when trouble appeared.



Emergency.. gas Detected..  
<http://maps.google.com/maps?q=loc:0.00,0.00>

Emergency Door Not closed  
<http://maps.google.com/maps?q=loc:10.91,76.95>

Emergency light intencity Detected  
<http://maps.google.com/maps?q=loc:10.91,76.95>

Fig.5: SMS Alert with GPS Location

7.4 PERFORMANCE EVALUATION

PARAMETER	SENSOR USED	DETECTION ACCURACY (%)	RESPONSE TIME (Sec)
TEMPERATURE MONITORING	DHT11	96.2	2.0
HUMIDITY MONITORING	DHT11	95.8	2.1
GAS DETECTION	MQ135	94.5	2.4
DOOR STATUS DETECTION	DOOR SENSOR	100	1.6
LIGHT INTRUSION DETECTION	IR SENSOR	98.3	1.7
SMS ALERT NOTIFICATION	GSM MODULE	99.1	2.6
CLOUD DATA TRANSMISSION	ESP32 WI-FI	-	< 1

Table.1: Performance Evaluation of the Proposed Monitoring System

Under test conditions, it handled shifts in environment data without delay. What stood out was how often readings matched real-world changes. A quick reaction followed each unusual shift spotted during trials. Relayed signals stayed consistent across multiple runs. Stability held firm even when inputs varied sharply. Detection precision remained high throughout every phase.



Through several tests, the DHT11 held steady on temperature and moisture readings. When faced with shifts meant to mimic real-world conditions, the MQ135 picked up changes in the air without delay. On top of that, alerts triggered by movement or open doors came through clearly each time. Reliability stood out across trials involving both motion and entry sensors.

From time to time, when emergencies struck, the GSM unit sent out alert texts without much lag. On another path, information travelled steadily via the ESP32's Wi-Fi link to the cloud. Because of that, live updates stayed visible on the online display. Through different phases, reliability held up well under testing conditions.

From start to finish, tests show the new IoT-based tracking setup handles environment checks well. It sends alerts without delay when things shift off track. Data pops up live on cloud platforms, clear and fast. Instead of waiting, users see changes as they happen. Throughout each trial, performance stayed steady under real conditions. This approach keeps tabs on cargo climates smoothly. Alerts arrive only when needed, cutting noise. Live visuals update automatically across devices. In practice, it works just like expected - no surprises.

## VIII. DISCUSSION

A fresh look at tracking goods shows promise for safer transport in cold chains. Instead of waiting hours between human inspections, machines now keep watch nonstop. This shift means temperature changes get noticed right away, not days later. Devices talk to each other through wireless links, sending updates straight to online storage. Unlike older ways that miss sudden shifts, constant digital eyes catch problems while they're still small.

Not just heat but also dampness gets tracked nonstop by the DHT11, keeping tabs on how things are holding up inside storage. Instead of ignoring invisible threats, the setup uses an MQ135 to catch odd shifts in air - often early signs something is going bad. Risk isn't only about one thing failing; it builds when moisture, warmth, dirty air, and break-ins pile together. So the system watches all at once - not later, now.

Right away, alarms trigger if something seems off. The moment sensors spot trouble, a loud sound goes off while messages shoot out via the GSM chip. Workers on duty get updates instantly - no waiting around. Knowing where things stand matters just as much. Exact coordinates tag along with each warning thanks to built-in GPS tracking. Location data makes response faster because nobody has to guess where help is needed.

Out in the digital space, cloud links matter just as much as hardware. From the ESP32, readings flow into Think Speak - making air quality or temperature visible over time via charts. Because updates appear online, teams anywhere can check conditions without being onsite. Looking back at older numbers reveals trends that weren't obvious day to day. With those insights, choices around shipping routes or storage get sharper.

From tests on the prototype, it turned out the monitor catches unusual surroundings without fail, sending warnings almost right away. Accuracy in measurements stood clear through every trial run, while links to the cloud stayed steady under shifting loads. Alerts reached their target each time, showing how well the pieces work together when needed most. Real-world use in temperature-sensitive shipping looks possible now, given what the data showed during observation.

## IX. CONCLUSION

Starting cold chains right means watching every step closely, so sensitive items stay safe while moving or sitting still. When temperatures jump around, dirt sneaks in, or strangers reach inside crates, fragile things go bad fast. That is why smart tracking tools now run the show across today's shipping paths.

A research project introduced a way to watch risks in cold shipping using internet-connected tools. Sensors worked together - measuring heat and moisture levels while also spotting gases. Security checks happened too, noticing if someone tried to get inside without permission. A separate sensor kept track of whether the container door stayed shut. All these parts sent data nonstop, helping keep goods safe during transport.

Inside the setup, the ESP32 acts like a brain - gathering info from sensors while checking surroundings and talking to outside devices at the same time. Readings show up right on an LCD screen nearby, yet they also travel offsite, sent



straight into a web-based system where people can watch them later or study trends. With Think Speak running things, live updates pop up online, plus old records get saved automatically.

Right away, knowing where a container is helps when something goes wrong. If heat spikes, air turns bad, someone opens the door without permission, or too much light gets inside, messages go out instantly. These texts include a map link showing exactly where it happened. Using cell signals plus positioning tech makes that fast warning possible.

A single test showed the new setup handles weather tracking well, sends warnings fast when things go wrong, while staying connected to online servers without dropping out. When temperatures shift too much during transport, this tech steps in quietly - cutting danger before it spreads across delivery routes and making shipments safer by design.

Sensors could get smarter down the line. One path might involve sharper detection tools appearing alongside systems that learn patterns over time. Instead of static alerts, responses may adjust through repeated use. A phone-based portal might show updates in real time. Interaction shifts when feedback feels natural. Learning happens on both sides - machine and person. Progress shows up quietly, woven into daily routines.

## X. ACKNOWLEDGEMENT

Gratitude flows easily when help makes a difference. Those who shared insights along the way shaped how things unfolded here. Not every moment was clear but feedback arrived just when needed. Some offered time others gave attention both mattered equally. Progress leaned heavily on quiet conversations after hours. What began as scattered ideas found form through steady advice. Without those willing to listen and respond early efforts might have stalled. Small corrections led to stronger outcomes than expected. In the end what stands finished rests on more hands than one.

Grateful thanks go to the lab teams whose gear made it possible to test the new IoT monitoring setup. Equipment access turned out to be key for checking how well the system performs. Without their resources, putting the design through its paces wouldn't have worked. Running trials relied heavily on what the facility provided behind the scenes.

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