Trailer YardFinder: Yard Layout, Camera Inventory, Billing, and Verified Gate Release

Executive Summary

A trailer storage yard has three jobs. It has to let a driver find a trailer fast. It has to bill the customer accurately for every day the trailer sits there. And it has to make sure the trailer leaves only with the right carrier, the right driver, and the right authorization. Trailer YardFinder treats them as one design problem that spans civil engineering, operations, and software.

The intended experience works like a retail planogram. A driver enters a trailer number and immediately sees the trailer's slot, a current photo, and the route to reach it. Nobody walks the rows hunting for equipment, and the driver never has to scan or type inventory data just to find a trailer.

Four principles govern the design. **No driver scavenger hunt.** The yard is laid out and camera-covered so the system knows where each trailer is. **Event-based billing.** Gate arrival and departure events set the bill; hourly snapshots check it. **Verified chain of custody.** The trailer at the exit gate must be the trailer that was released, to the carrier that was authorized. **Fail closed for cargo, open for people.** Unauthorized departures are held, but lawful emergency exit and responder access are always preserved.

The design does not depend on buying an enterprise yard-management suite. It uses commodity outdoor cameras, existing infrastructure, and open-source components where they meet the requirements, with purpose-built logic only where off-the-shelf tools fall short.

1. Engineer the Yard for Access and Visibility

Camera sightlines and trailer access are design inputs at the grading and striping stage, not retrofits. Pole positions and heights, lens choices, lighting, trailer orientation, slot geometry, aisle widths, turning radii, sight obstructions, drainage, pavement loading, fencing, gate queuing, and emergency-service access are planned together. Tractor-trailer swept paths are checked against actual vehicle envelopes.

Density is measured as productive, accessible parking, not the theoretical maximum stall count.

Every trailer space receives a permanent yard coordinate, such as B-042. Camera coverage is tested for day, night, rain, glare, obscured trailer numbers, and vehicles in motion. Where fixed cameras cannot reliably identify equipment, the design adds overlapping views or imaging from the yard tractor. A pole camera's field of view is not the same as an unblocked line of sight to a trailer number. Cameras are placed where they can be maintained safely and have protected power and network connections.

2. Identification and the Live Trailer Planogram

At entry, the system captures the tractor, the trailer, the trailer's existing printed number, the license plate where appropriate, the time, the customer, and condition photos. Optical character recognition reads the numbers and reports how confident it is. A person reviews anything unreadable, mismatched, or duplicated.

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A weatherproof, removable barcode or QR label can serve as a secondary identifier, with the asset owner's approval. It is optional, never a required driver task, and the design does not assume a label can be read when it is hidden from the camera.

The system keeps three separate location fields for every trailer: **assigned position**, **last observed position**, and **confirmed position**, each with a confidence level and a last-seen time. Camera events and yard-tractor observations track moves, and blocked views are resolved explicitly. When the system is unsure, it shows the uncertainty rather than presenting an old guess as a confirmed location.

Driver view. Enter a trailer number; see the zone and slot, a current photo, the confidence and time of the last sighting, and an accessible route.

Customer view. Current inventory, history, charges, hold status, and who is authorized to pick up.

3. Billing, Evidence, and Audit

The illustrative base storage rate used in planning is **$14 per trailer per day**. The actual rate is contractual, set per customer and per yard. The billing rules support 24-hour periods or calendar days, grace periods, minimums, exemptions, dispute credits, and taxes where they apply.

Gate arrival and departure events determine whether a trailer is present. Hourly snapshots are reconciliation checkpoints. They confirm the event record; they do not replace it.

For each trailer, the system records tamper-evident entry and exit event IDs, supporting images, the customer, the rate version, the authorizations, and the invoice lines generated. Every hour it compares the physical inventory the cameras see against active billing records and builds exception queues for three cases: trailers seen with no account, trailers that departed with no release record, and records still accruing charges after a verified departure.

Evidence is retained under a written policy with access controls, backups, and legal-hold capability. The system avoids collecting driver personal data it does not need.

> **How much data is an hourly snapshot?**
>
> At 200 trailers and roughly 500 bytes per inventory row, one complete hourly snapshot is about 100 kilobytes. A full year of hourly snapshots is about 876 megabytes of raw rows. That figure excludes indexes, backups, photos, and video, which will be the larger share of storage.

4. Cargo Security: Cameras Working with Operations

The fence, controlled gate, lighting, and around-the-clock cameras are layers of protection, not a guarantee against theft. The camera system watches for people near trailers after hours, unexpected movement, fence events, door activity where it can be detected, and any attempt to leave without a release. It separates routine, authorized yard moves from high-priority intrusion events.

When an event fires, the system keeps video from before and after, notifies a monitored response party, and logs who acknowledged the alert and how it was resolved. Camera-only detection of a door opening or a broken seal is not presented as foolproof. Higher-value loads can carry supplemental seals, sensors, escorts, or customer-specific rules.

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Security response never traps people, forces unsafe vehicle stops, or blocks emergency responders. The gate stays controlled against unauthorized release of freight, while fire and life-safety access and emergency opening are engineered with the local authority having jurisdiction.

5. Chain of Custody: Matching the Full Movement

Each trailer record links the owner, the shipper or customer, the shipment reference, the broker if any, the transporting motor carrier, the driver, the tractor, the pickup appointment window, the pickup trailer, the destination, and the release authority.

The trailer number observed at the exit must match the released asset. A driver's claim of a matching USDOT or MC number is not proof of identity. Carrier authority, and the identity of the actual carrier, are verified through trusted onboarding, account, and release channels. Legitimate substitutions are handled through an explicit, signed and recorded amendment.

A common failure is not theft but an honest mistake: a legitimate driver hooks to the wrong trailer and heads for the gate. A valid appointment is not permission to remove any trailer in the yard. Camera identification at the gate, checked against the current release record, stops routine wrong-trailer pickups before the gate opens.

6. Selectable Release Security Modes

Customers choose a release policy by account, by shipment, or by trailer. When more than one policy applies, the more restrictive one governs.

Standard. The system verifies the registered shipment release, carrier, driver, trailer, tractor where required, a valid time window, and the absence of holds.

Carrier code. Standard checks, plus a one-time code issued through the authenticated office of the transporting carrier. The carrier can text the code to its own driver outside the yard system; the yard never sends a code to an unverified number. A carrier can issue a code days ahead but becomes valid only inside a defined pickup window.

Office approval. Standard checks, plus an affirmative, authenticated approval of this specific release by the customer or a designated shipper office. The gate waits for the decision.

Dual approval. Both the carrier code and office approval, for higher-value shipments. Both options are configurable together on the same release.

Each code is bound to one trailer, one pickup, one carrier, one pickup window, and one release request. It works once, can be revoked, expires on schedule, and is rate-limited against guessing. The system stores verifiers rather than plain-text codes, blocks replay, audits every issuance and failed attempt, and does not allow universal or reusable carrier codes. Trusted-driver status can relax advance scheduling but never becomes a permanent bypass. A text message is a delivery channel, not proof of identity.

The office approval screen shows the actual trailer and tractor photos or identifiers, the carrier, the driver, the time, and the pickup reference. The approver can approve, deny, or ask for more information from a secure phone or desktop. Silence or an expired timer never counts as approval. Unanswered requests escalate to a designated alternate, and a safe holding area keeps waiting trucks from blocking

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the exit. Approvers are authenticated and authorized for that customer, and the system logs the approver's identity, device or session, the time, and the exact release approved.

7. The Gate Sequence and What Happens When Something Fails

Every release follows the same sequence: request, identity checks, trailer match, carrier code if required, office approval if required, a final live identity recheck, authorized gate opening, observed departure, and closure of the inventory and billing record.

If any check fails, the release moves to a hold and the designated person is notified. A gate failure, camera outage, network loss, stale location, duplicate trailer number, changed tractor, reassigned carrier, wrong trailer, missing office response, or reused code never results in a silent release of cargo.

A supervised manual-release process requires independently verified authority and a documented reason, with two-person control where appropriate. A separate emergency and life-safety procedure follows local code. Cargo doors are not remotely locked by default, because door hardware, emergency access, and safety requirements vary.

8. System Architecture, Privacy, and Integration

The camera layer uses outdoor IP cameras that support the ONVIF and RTSP standards, with fixed identification views at the gate and pole-mounted views of each zone. Open-source video ingestion and detection software, such as Frigate, can form one component. Trailer-number reading, slot mapping, chain-of-custody rules, and release authorization require their own validated application logic. Off-the-shelf object detection is not assumed to read obscured trailer numbers or to track trailers through camera blind spots.

The data model covers yards, spaces, cameras, asset identifiers, trailers, sightings, positions, arrivals, departures, customers, storage contracts, rate rules, invoice lines, shipments, carriers, drivers, tractors, pickup orders, release policies, release requests, carrier codes, approvals, gate events, alerts, evidence, and audit events. A relational database is the source of truth, with immutable audit and event IDs, role-based access, encryption, and restricted access to evidence. Customer transportation management systems connect by API or by import and export, so staff do not re-enter data by hand.

9. Pilot and Acceptance

The first deployment is a single area of 25 to 50 slots, using existing pole infrastructure and one controlled entry and exit lane, before any hardware is bought for a full yard. A visibility survey comes first. The pilot records a baseline of time spent locating trailers, misidentifications, billing disputes, manual gate releases, and security alerts, so improvement can be measured.

Acceptance tests. A trailer is identified reliably on entry. Its exact slot is found without the driver searching. Blocked or obscured identifiers are flagged. A re-park is detected. The driver sees a reliable route. Hourly reconciliations run. Billing follows accurate arrival and departure events. A wrong-trailer pickup is denied. Forged or wrong-carrier claims are rejected. A one-time code works once and only once. Office silence fails closed. Dual approval requires both approvals. Authorized exceptions are audited. Outages and emergencies are handled safely. Pass thresholds are set after the site survey. The design does not promise centimeter accuracy or zero false alarms in advance.

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Implementation sequence. First, the civil and camera-coverage survey and the slot plan. Second, the camera identification pilot. Third, event recording and billing reconciliation. Fourth, the verified-release workflow, run in simulation. Fifth, connection to the physical gate, only after safety, security, and local-code review. Sixth, the customer portal and broader rollout.

Scope

This paper sets out the requirements and the architecture for a trailer yard that is easy to work in, accurate to bill, and hard to steal from. It is a design baseline. It does not describe an installed system, and it does not authorize changes to live gates, purchase of hardware, or deployment of security-critical behavior. Gate operation depends on safety review, security review, and approval from the local authority having jurisdiction.

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