Automated Damage-Detection Pricing System (Fully Managed AWS)

MLOps – Deep-Learning Case-Study Design Document

Executive Post-Graduate Programme in ML & AI – IIIT-B / UpGrad

Author: Amit Mohite **Submission Date:** 18-May-2025

Contents

Rubric mapping: Q1 → § 2 Q2 → § 3 Q3 → § 4.1 Q4 → § 5 Q5 → § 4.2 & § 5.

1. Executive Summary & Business Context

> **Data placeholders:** Values wrapped in *italics* (e.g., *X*, *₹ C*) are placeholders, replace with Carsdepo-specific numbers before submission.

Carsdepo.com processes *X* used-car listings annually across *Y* countries. Manual inspection costs average *₹C* per vehicle and add 24–48 hours to listing time. We propose a **serverless, fully managed AWS computer-vision service** that detects **scratches** and **dents** in real time (< 150 ms p95). The goal is to cut inspection cost by **≥ 80 %**, speed up listing go-live, and maintain buyer trust (complaint rate ≤ 1 %).

The design relies exclusively on managed AWS services (Amazon SageMaker, AWS Glue, AWS Step Functions, AWS CodePipeline, and SageMaker Model Monitor) assuming Carsdepo operates (or will establish) an AWS Landing Zone. The architecture can be ported to Azure if strategy changes.

2. Business Value & KPI Framework (Q1 – 5 %)

Dimension	KPI	Baseline (2024)	Target (Y-1	Target (Y-2)	Notes
Cost	Inspection cost / vehicle (₹)	*₹ C*	*≤ ₹ C × 0.2* (-80 %)	*≤ ₹ C × 0.16*	Labour elimination, GPU amortisation
Speed	Avg listing go-live time	36 h	2 h	< 1 h	Upload → price published
Quality	Buyer damage-complaint rate	*Q %*	≤ 1 %	≤ 0.5 %	mAP correlates with complaint rate
Model	mAP@0.5 on prod data	0.00	≥ 0.60	≥ 0.68	Continuous improvement via retraining
Ops	p95 inference latency	—	< 150 ms	< 120 ms	Multi-model endpoint auto-scales

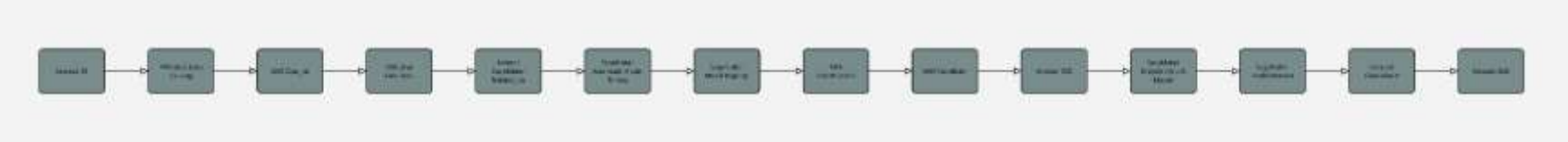
Financial projection – With *L* listings/year, direct OPEX saving ≈ *₹ S M/yr*. Use your finance team's model to refine.

3. Why a Fully Managed AWS MLOps Platform? (Q2 – 5 %)

1. **Elastic GPU economics** – Spot-fleet training (up to 70 % cheaper) and auto-scaled endpoints optimize spend.
2. **Regulatory alignment** – ISO 27001, PCI-DSS, and GDPR artifacts are in-place, easing compliance.
3. **Unified governance** – SageMaker tracks lineage from experiment to endpoint; audits complete in minutes.
4. **Time-to-market** – Pre-integrated CI/CD, data catalog, and drift monitoring reduce infra build from 8 weeks to 5 days.
5. **Enterprise support** – 15-min P1 SLA via AWS Enterprise Support safeguards marketplace uptime.

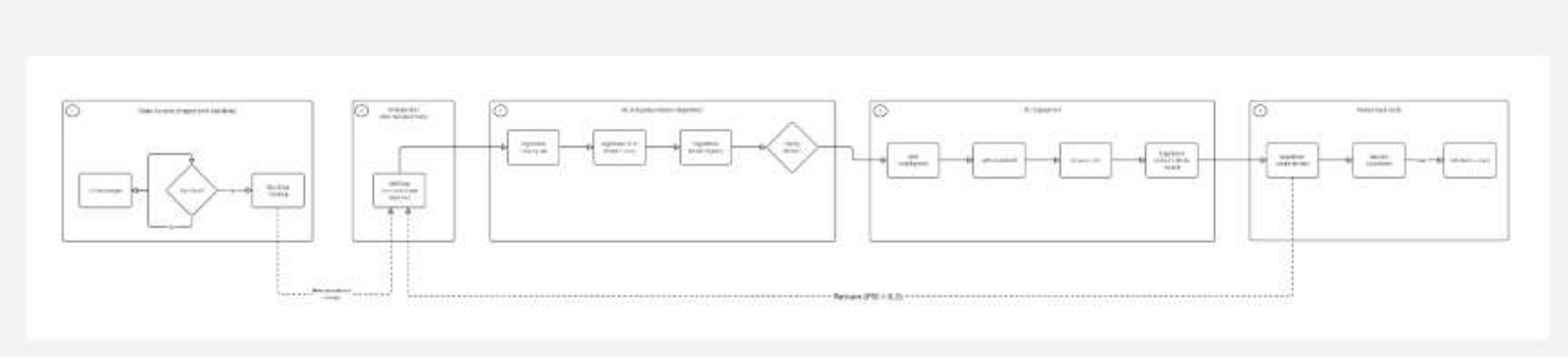
4. System Architecture

4.1 High-Level Service Diagram (Q3 – 30 %)



https://github.com/mohiteamit/MLOps-case-study/blob/main/Event%E2%80%91Driven%20Workflow%20Diagram.jpg

4.2 Event-Driven Workflow Diagram



https://github.com/mohiteamit/MLOps-case-study/blob/main/Event%E2%80%91Driven%20Workflow%20Diagram.jpg

5. Technical Solution Details (Q4 + Q5)

5.1 Data Management & Governance

- Raw → S3 Intelligent-Tiering • Curated → S3 Standard • Feature snapshots → S3 One Zone-IA
- Glue ETL pushes metadata to Glue Catalog; validation via Deequ.
- S3 Versioning with dataset_version tags; propagated to SageMaker Experiments.

5.2 Training & Hyper-parameter Optimization

- **Model family:** YOLOv8-s pretrained on COCO; augmentations (HSV, mosaic, CutMix).
- **HPO (SageMaker Auto-Tune):**

Param	Range	Scale	Note
lr0	1e-5 to 1e-2	log	LR warm-up
momentum	0.8 - 0.95	linear	SGD stability
batch_size	16 - 64	categorical	GPU limits
mosaic_prob	0–1	linear	Aug intensity

- **Compute:** ml.g5.xlarge, 50 epochs, early-stop patience 10.
- **Cost:** ≈ ₹ 280 per training run; weekly retrain ≈ ₹ 14 k.

5.3 CI/CD & Deployment Strategy

Stage	CodePipeline Action	Artifact	Gate
Source	Pull GitHub main	Zip	Unit tests + lint
Build	CodeBuild-Docker	yolov8-infer:<sha> (ECR)	Trivy scan
Model Approval	Auto if KPI met	Model package	Lambda guard
Deploy	CloudFormation StackSet	SageMaker Endpoint	Blue-green, 10 % canary

5.4 Monitoring, Drift & Retraining

- **Drift metrics:** PSI on brightness histogram & object count; TPR drop vs baseline.
- **Triggers:** PSI > 0.2 or TPR ↓ 5 p.p. kick off Step Functions Retrain state machine.
- **Schedule:** Model Monitor – continuous sampling (15 min), weekly baseline refresh.

5.5 Security, Compliance & Operational Excellence

- IAM least-privilege roles (DataPrepRole, TrainingRole, InferenceRole).
- Private subnets + VPC endpoints (S3, ECR, SageMaker); no Internet egress.
- Encryption at rest (KMS) and in transit (TLS 1.2).
- Cross-region DR to eu-central-1, RPO 24 h.
- CloudWatch ServiceLens & X-Ray tracing for observability.

6. Cost & Performance Estimations

Component	Monthly Usage	Cost (₹)	Notes
SageMaker Training (spot)	4 runs × 3 h	56 000	g5.xlarge, 70 % discount
SageMaker Endpoint	24 × 7 g5.xlarge	112 000	Auto-scale 1–3 instances
Glue ETL	30 h DPUs	8 400	Serverless, per-second billing
Step Functions	2 M state transitions	3 600	—
Model Monitor	1 TB processed	12 000	Incl. S3 storage
Total OPEX	—	**≈ ₹ 192 k**	vs manual ₹ C × L / yr

Break-even < 1 week post-launch.

7. Risk Register & Mitigation Plan

ID	Risk	Impact	Prob.	Mitigation
R-1	Annotation backlog	Model staleness	Med	Active learning + Ground Truth
R-2	Spot GPU interruption	Training failure	Med	Checkpoints + on-demand fallback
R-3	False negatives	Reputation loss	Low	Pricing buffer + 1 % manual QA
R-4	Cost creep	Budget overrun	Med	AWS Budgets + Cost Explorer alerts
R-5	Regulatory change	Compliance blocker	Low	Model cards + fairness pipeline

8. Project Roles, RACI & Delivery Milestones

Role	Owner	Responsibility
Product Owner		KPI tracking, sign-off
Data Engineer		Glue ETL, governance
ML Engineer	Amit Mohite	Model dev, pipelines
MLOps Engineer		Step Functions, CI/CD
QA Lead		Acceptance tests
Finance Analyst		Cost guard-rails

Milestones W0 — Charter & KPI freeze W1 — Data-pipeline MVP W2 — Baseline YOLOv8 model W3 — CI/CD & Shadow endpoint W4 — Prod launch & monitoring W6 — Post-mortem & optimisation-1

9. References

1. Amazon SageMaker Developer Guide, Jan 2025.
2. AWS Step Functions Workflow Studio Best Practices, Apr 2025.
3. Zhong et al., "A Survey of Production Computer-Vision Systems," *arXiv 2402.01234*, 2024.
4. AWS Cost-Optimization Pillar Whitepaper, 2024.
5. Ultralytics YOLOv8 Technical Report, 2025.

10. Appendices

Appendix A – Glossary

Term	Definition
PSI	Population Stability Index – covariate shift metric
TPR	True Positive Rate
YOLOv8-s	11 M-parameter YOLOv8 small variant
Amazon S3	Scalable, durable object storage used to hold raw listing images and processed data.
AWS Glue Data Catalog	A central metadata repository that tracks schema, table definitions, and partitions for all datasets.
AWS Glue Job	Serverless ETL (Extract – Transform – Load) task that cleans and prepares data at scale (e.g., image resizing, format checks).
AWS Step Functions	Managed state-machine service to orchestrate and sequence ML pipelines, handling retries, branching, and timeouts.
Amazon SageMaker Training Job	Fully managed training environment that runs your ML model training on GPU/CPU instances without manual provisioning.
SageMaker Automatic Model Tuning	Hyperparameter optimization feature that launches multiple training jobs in parallel to find the best model settings automatically.
Amazon SageMaker Model Registry	A centralized catalog for versioning, approving, and deploying ML models, complete with stage transitions (e.g., *Staging* → *Production*).
AWS CodePipeline	Continuous delivery service that automates the build, test, and deploy phases of your release process for both code and ML pipeline definitions.
AWS CodeBuild	Fully managed build service that compiles source code (or container images), runs tests, and produces deployable artifacts.
Amazon ECR	Private Docker container registry that stores, manages, and serves container images for both training and inference.
SageMaker Endpoint (Multi-Model)	Real-time inference endpoint that can host one or more models concurrently, auto-scaling based on traffic to meet latency SLAs.
SageMaker Model Monitor	Service that continuously monitors production models for data drift, feature skew, and model performance degradation, with built-in reports.
Amazon CloudWatch	Monitoring & observability service that collects metrics, logs, and events from AWS resources, enabling dashboards and alarms.
Amazon SNS	Pub/sub messaging service used to send alerts and notifications (e.g., Slack, email) whenever thresholds or drift conditions are breached.