# **Project Report : ER Wait Times Reduction (DMAIC)**

**Project title:** ER Total Wait Time Reduction — Evening Shift Focus  
 **Dataset:** Open-source ER\_Wait\_times (n ≈ 5,000 visits)  
 **Methodology:** Lean Six Sigma (DMAIC) + predictive modeling (XGBoost) + statistical testing  
 **Prepared by:** [Your name]  
 **Date:** (use current date)

## **Executive Summary**

This project used a DMAIC approach to analyze Emergency Room (ER) wait times and simulate interventions to reduce total wait time, with a focus on evening shift performance. Baseline analysis showed a mean overall wait time of **81.9 minutes** and an evening-shift mean of **99.00 minutes**. Using an XGBoost predictive model and what-if scenarios (adding nursing capacity and increasing specialist availability), the best simulated scenario reduced evening mean wait time to **89.84 minutes**, a **9.25% reduction** (≈ 9.16 minutes). The improvement is statistically significant by a Mann–Whitney U test (p = 0.022), though Cohen’s d indicates a small effect size (d = 0.11). The project narrowly missed the stated 10% evening reduction target; recommended next steps aim to bridge that gap and sustain improvements.

## **DEFINE**

**Problem statement:** Patients experience prolonged ER wait times, especially during evening hours, reducing satisfaction and throughput.  
 **Primary objective:** Achieve **≥10% reduction** in evening-shift total wait time (primary KPI). Secondary: reduce overall wait time and improve patient satisfaction.  
 **Y (output):** Total Wait Time (minutes)  
 **Key Xs (inputs):** Nurse-to-Patient Ratio, Specialist Availability, Time of Day (shift), Urgency Level, Facility size, registration/triage times.  
 **Scope:** Analysis performed on open-source ER\_Wait\_times dataset (≈5,000 records).

## **MEASURE**

**Data & cleaning**

* Records analyzed: **5,000** visits.
* Key fields: Visit Date, Time of Day, Urgency Level, Nurse-to-Patient Ratio, Specialist Availability, Time to Registration/Triage/Medical Professional, Total Wait Time, Patient Satisfaction.
* No major nulls; Visit Date parsed to datetime.

**Baseline metrics**

* Overall mean Total Wait Time = **81.9 minutes**
* Median = **60.0 minutes**
* Std dev = **68.1 minutes**
* Evening-shift mean = **99.00 minutes** (n ≈ 1,725 evening visits; 34.1% of test set)

**Distribution & diagnostics**

* Raw wait times are right-skewed (Shapiro-Wilk p < 0.05). Log-transform used for linear modeling.
* Pareto: major contributors to delay were Time to Medical Professional, Time to Triage, Time to Registration.
* Kruskal–Wallis test by Time-of-Day: p < 0.001 → significant differences between shifts.

## **ANALYZE**

**Statistical modeling**

* OLS on log(wait) (HC3 SE): R² ≈ 0.889. Key findings:  
  + Evening shift coefficient indicates ~22% longer waits vs baseline.
  + Urgency level strongly associated: Low-urgency patients wait much longer relative to high-urgency (large multiplicative effect).
  + Nurse-to-Patient Ratio coefficient suggested counterintuitive association (one-unit increase associated with ≈ +16% wait on log model) — interpreted as a likely marker of high patient volume per nurse rather than causal effect of more nurses.
* GLM (Gamma, log link) confirmed results and improved robustness.

**Root causes & process analysis**

* 5-Whys and FMEA identified top failure modes: provider unavailability/boarding (RPN 270), triage queueing (RPN 252), registration delays (RPN 240).
* Evening peaks (16:00–20:00) were not well forecasted; schedules lacked flexible staffing triggers.

## **IMPROVE — Modeling & What-If Simulation**

**Predictive model**

* XGBoost regressor trained on engineered features (20 features):  
  + Baseline test performance (tuned model): RMSE ≈ **17.08 min**, MAE ≈ **11.78 min**, R² ≈ **0.937** (explains ~93.7% variance).
  + Model used to run intervention simulations for the evening subset (n ≈ 341 in test set).

**Scenarios (evening shift) & results**

* **Baseline mean** (actual): **99.0029 min**
* **Scenario 1 — Add 2 nurses (simulated):** Predicted mean = **89.87 min** → Reduction = **9.13 min** → **9.23%**
* **Scenario 2 — Add 4 nurses (simulated):** Predicted mean = **89.87 min** → same as Scenario 1 (modeled effect plateau in these parameter steps)
* **Scenario 3 — Add 6 nurses + 20% more specialists:** Predicted mean = **89.84 min** → Reduction = **9.16 min** → **9.25%**

**Statistical testing**

* Two-sample t-test (predicted vs actual, alternative = less): t = -1.528, p = 0.064 (not significant at 0.05).
* Mann–Whitney U (non-parametric): U p = **0.022** → significant reduction distribution-wise.
* Cohen’s d effect size = **0.11** (small).

**Interpretation**

* The best simulated intervention yields ~9.2% reduction for evening shift (≈9.1 minutes). This is a meaningful improvement and statistically supported by a nonparametric test, but slightly below the 10% target. Model and simulation results suggest diminishing returns for the simple nurse-add scenarios modeled; combining operational changes (triage improvements, registration speed-ups) may reach or exceed 10%.

## **CONTROL & SUSTAIN**

**Immediate control actions**

* Implement a real-time dashboard (Power BI / Plotly) showing daily mean wait times, shift breakdowns, and nurse-to-patient ratio with control limits (I-chart).
* Add an automated staffing trigger: when predicted evening load exceeds threshold, float staff are called.

**SOPs & monitoring**

* Monthly review of average wait times and RPNs.
* Standardize triage and registration checklists to reduce process variance.
* Re-run the predictive model monthly and re-calibrate thresholds.

## **CONCLUSIONS & RECOMMENDATIONS**

**Conclusions**

* The project produced a robust predictive model (XGBoost, R² ≈ 0.937) and validated interventions via simulation.
* Simulated staffing + specialist interventions reduced evening mean wait from **99.00 → 89.84 minutes (≈9.25% reduction; ~9.16 min)**. Mann–Whitney U test supports the improvement (p = 0.022); effect size is small.
* The 10% evening-shift reduction target was narrowly missed (achieved ≈9.25%); however additional, targeted process changes are likely to close the gap.

**Top recommendations**

1. **Combine capacity + process improvements** — e.g., add nursing support *and* implement a fast-track triage lane for low-acuity cases; simulate combined effect.
2. **Automate staffing triggers** using the XGBoost model to forecast peak hours and call flexible staff dynamically.
3. **Improve registration/triage throughput** (Pareto top contributors) — target 20% reduction in triage time to amplify impact.
4. **Pilot combined interventions** for 2 months and monitor with the dashboard; report measured reductions and patient satisfaction changes.
5. **Reassess model & thresholds monthly**; refine scenarios to incorporate queuing dynamics (discrete-event simulation) for more realistic estimates.