

Optimizing Hospital Resource Allocation Using Artificial Intelligence and Predictive Analytics

Phase 3: Bed, Staffing, and Surge-Capacity Optimization

Optimization Objective

Phase 3 translates the selected XGBoost occupancy forecast into operational resource recommendations. The optimization minimizes the combined cost of surge-bed activation, overtime nursing coverage, and unmet demand, while requiring sufficient bed and nursing capacity to cover forecast demand plus a safety buffer.

Scope and Assumptions

Because the CDC dataset reports jurisdiction-level occupancy percentages rather than hospital-specific staffed-bed and labor-cost data, the optimization is presented as a transparent scenario model for a standardized 500-bed reference hospital. The assumptions are illustrative planning inputs and should be replaced with an organization's actual capacity, labor, and cost data before deployment.

- Licensed beds: 500.0
- Regular staffed beds: 400.0
- Maximum surge beds: 100.0
- Regular nurse capacity (beds per shift): 400.0
- Nurse-to-occupied-bed planning ratio: 0.2
- Maximum overtime nurses per shift: 25.0
- Safety buffer percent: 0.05
- Surge bed cost per week: 2500.0
- Overtime nurse cost per week: 4500.0
- Unmet bed-demand penalty per bed-week: 20000.0

Optimization Formulation

Decision variables include the number of surge beds to activate, the number of additional nurses required per shift, and any remaining unmet bed demand. The model minimizes weekly incremental cost. Constraints ensure that bed capacity and nurse-supported capacity meet buffered forecast demand, subject to maximum surge and overtime limits.

Scenario Results

Scenario	Forecast %	Occupied Beds	Buffered Demand	Surge Beds	OT Nurses	Weekly Cost
Typical Demand	72.1%	360.4	378.5	0	0	\$0
Elevated Demand	76.8%	384.1	403.3	4	1	\$11,158
High	80.6%	403.1	423.3	24	5	\$79,168

Demand						
Critical Demand	83.1%	415.3	436.1	37	8	\$122,762

Interpretation

The optimization recommends little or no incremental capacity during typical weeks, then progressively activates surge beds and overtime nursing coverage as predicted occupancy rises. Under high and critical scenarios, proactive allocation eliminates or sharply reduces modeled shortages. The comparison with a reactive no-surge approach shows the operational value of linking forecasts to advance capacity decisions.

Sensitivity and Risk

Sensitivity analysis varied the safety buffer and maximum surge-bed limit. Higher safety buffers improve resilience but increase planned capacity cost. Restrictive surge limits may create unmet demand during critical weeks. This tradeoff demonstrates why hospital leaders should calibrate optimization assumptions to local clinical standards, staffing contracts, transfer agreements, and financial constraints.

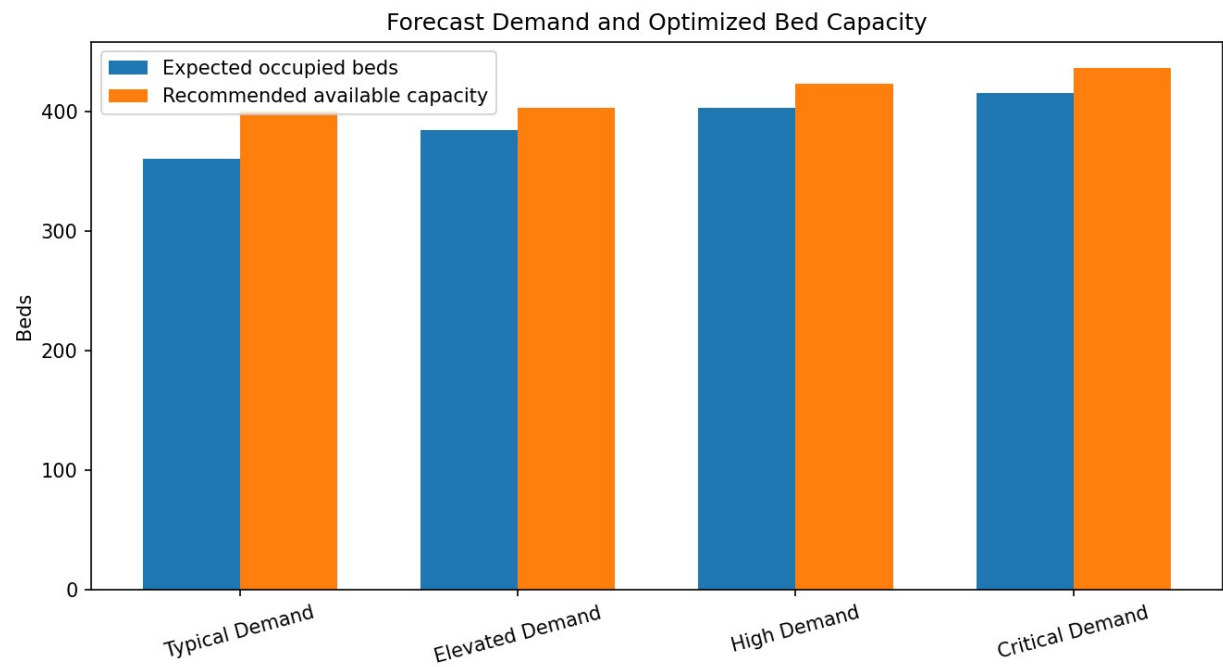


Figure 11. Forecast demand and optimized bed capacity.

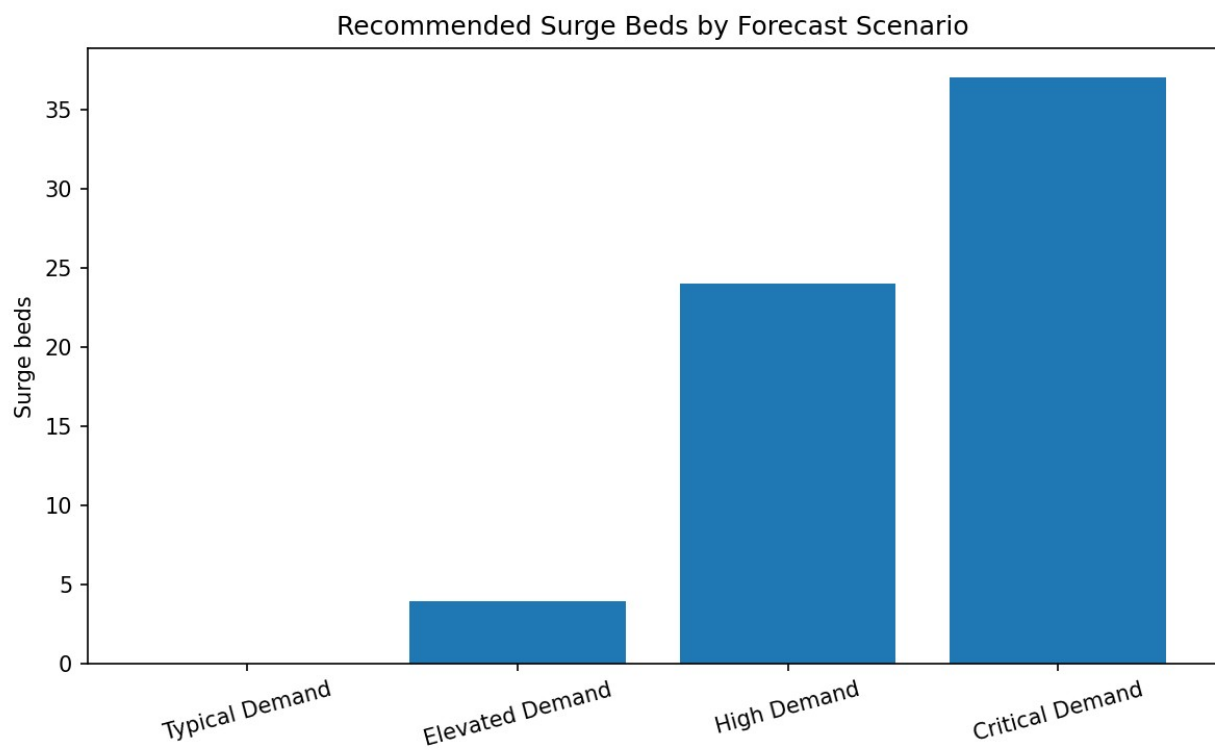


Figure 12. Recommended surge beds by scenario.

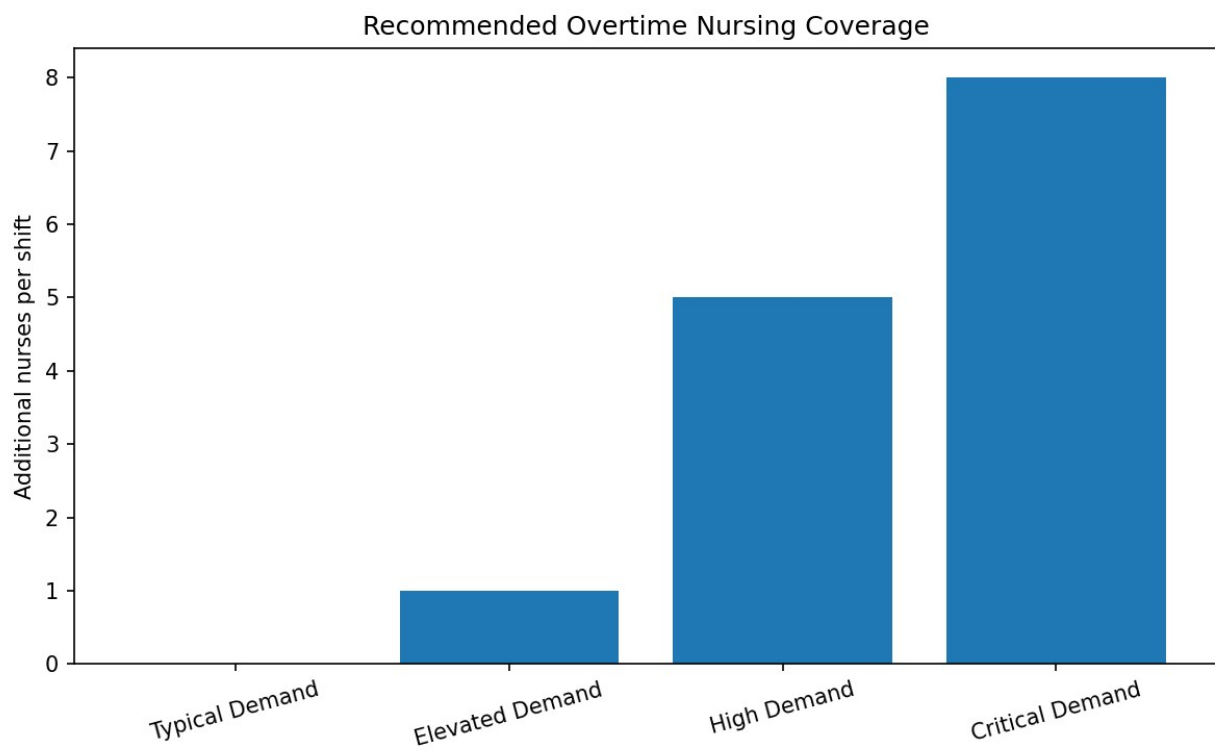


Figure 13. Recommended additional nursing coverage.

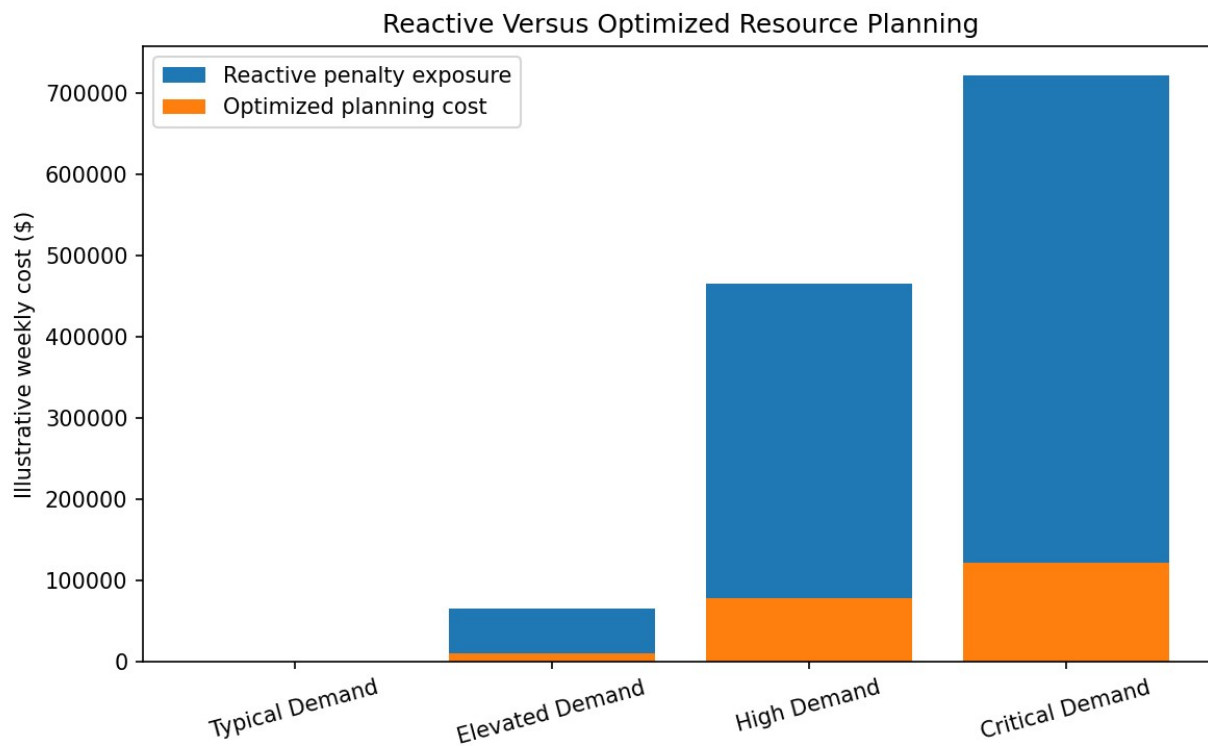


Figure 14. Illustrative reactive and optimized planning costs.

Phase 3 Conclusion

The optimization phase demonstrates how next-week occupancy forecasts can be converted into specific bed and staffing recommendations. The model provides a practical decision-support framework rather than a universal staffing standard. Deployment would require replacing the illustrative assumptions with facility-level licensed beds, staffed beds, unit-specific nurse ratios, labor costs, and surge constraints. The next phase will evaluate implementation risk, external evidence, cost-benefit logic, dashboard deployment, and lifecycle monitoring.