1 Introduction

Effective hospital planning involves allocating resources across wards, a complex task due to technical, organizational, and political factors. This project focuses on developing a simulation model to evaluate different bed resource distributions.

Inpatient flow starts at the emergency department and proceeds to nursing wards based on diagnoses. These wards, modeled as Erlang loss systems, face capacity issues leading to patient rejections or relocations. The project examines a scenario where a hospital must create a temporary ward due to an epidemic, requiring resource redistribution.

With five nursing wards and corresponding patient types, patient arrivals and lengths of stay are modeled using exponential distributions. Exceeding ward capacity leads to patient relocation or system loss. The simulation model assesses patient flow and bed distribution strategies, ensuring effective resource use and patient care.

2 Primary Tasks

2.1 Simulation model

The simulation model was designed to replicate the flow of inpatients through the hospital. Each ward has a fixed bed capacity, and patient arrivals follow an exponential distribution with specific rates. The length of stay for patients is also exponentially distributed. If a ward reaches its full capacity, patients are either relocated to alternative wards or lost from the system.

Parameters Used in the Simulation

Wards and Patient Types	Arrival Rates	Mean Length of Stay	Bed Capacities
A	14.5	2.9	55
B	11.0	4.0	40
C	8.0	4.5	30
D	6.5	1.4	20
E	5.0	3.9	20

Table 1: Simulation Parameters

Simulation Process

For the simulation of the problem, we followed the steps below:

1. Initialize the ward occupancy to zero.
2. For each day, generate patient arrivals for each ward based on the Poisson distribution.

P \W	**A**	**B**	**C**	**D**	**E**	**F**
A	-	0.05	0.10	0.05	0.80	0.00
B	0.20	-	0.50	0.15	0.15	0.00
C	0.30	0.20	-	0.20	0.30	0.00
D	0.35	0.30	0.05	-	0.30	0.00
E	0.20	0.10	0.60	0.10	-	0.00
F	0.20	0.20	0.20	0.20	0.20	-

Table 2: Relocation Probability Matrix

3. Admit patients to their respective wards if beds are available.
4. If a ward is full, relocate patients according to the predefined probabilities or mark them as lost if no alternative beds are available.
5. Handle patient departures based on the length of stay.
6. Repeat the process for the specified number of days (365 days in this case).

Results

The simulation was run for 365 days, and the results are summarized in the table below:

Ward	Admissions	Relocations	Losses	Final Occupancy
A	5218	566	27	28
B	3277	186	282	28
C	1894	443	318	27
D	2390	177	1	4
E	1454	275	95	13

Observations

- **Admissions:** Ward A had the highest number of admissions (5218), followed by Ward B (3277), and the least admissions were observed in Ward E (1454).
- **Relocations:** Ward A had the highest number of relocations (566), while Ward D had the fewest (177).
- **Losses:** The highest number of patient losses occurred in Ward C (318), indicating a significant capacity constraint. Ward D had the least losses (1).
- **Final Occupancy:** The final occupancy of the wards varied, with Ward A and Bhaving the highest occupancy (28) and Ward D the lowest (4).

The simulation model successfully replicated the patient flow in the hospital, highlighting the performance of each ward based on admissions, relocations, and losses. The results

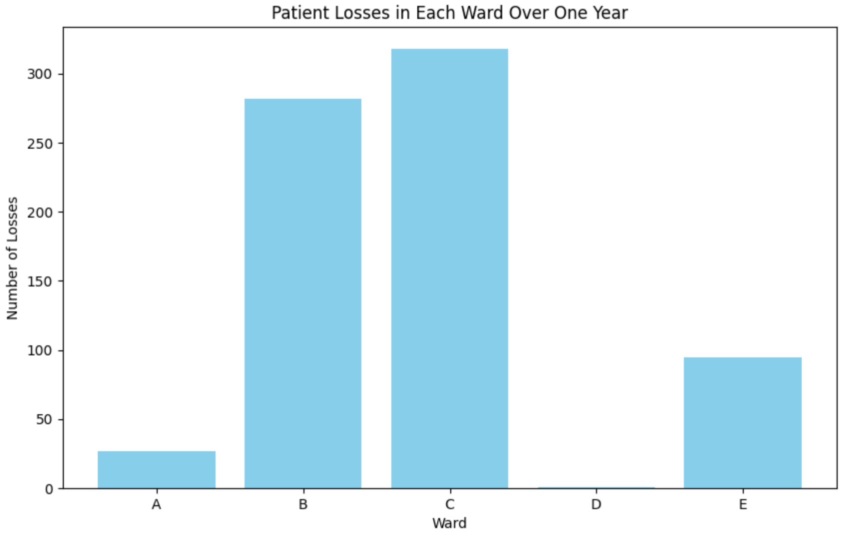

Figure 1: Patient Losses.

indicate areas where capacity constraints are critical, especially in Ward C, where a high number of losses were observed. This information can guide hospital administrators in making informed decisions regarding bed allocations and resource management to improve patient care and system efficiency.

2.2 Creating Ward F

To simulate the patient flow and evaluate the impact of creating Ward F, the following parameters were used:

Ward	**Capacity**	**Arrivals** (λ_i)	**Mean Length-of-Stay** ($1/\mu_i$)	**Urgency Points**
A	55	14.5	2.9	7
B	40	11.0	4.0	5
C	30	8.0	4.5	2
D	20	6.5	1.4	10
E	20	5.0	3.9	5
F*	-	13.0	2.2	-

Table 3: Parameters associated with each ward and patient type. Ward F* denotes the new ward, and urgency points reflect the penalty if a patient of type i is not admitted to Ward i.

Simulation

For the simulation, we followed the steps below:

1. **Calculate Traffic Intensity for Ward F:** Using the Erlang B formula, the minimum bed capacity for Ward F was determined to ensure a blocking probability of less than or equal to 5%.

2. **Reallocate Beds:** Adjust the bed capacities of existing wards based on urgency points, ensuring the total number of beds remains constant.

3. **Update Relocation Probabilities:** Modify the relocation probabilities to include Ward F.

4. **Run Simulation:** Simulate the hospital's patient flow for 365 days to evaluate the performance metrics with the new ward.

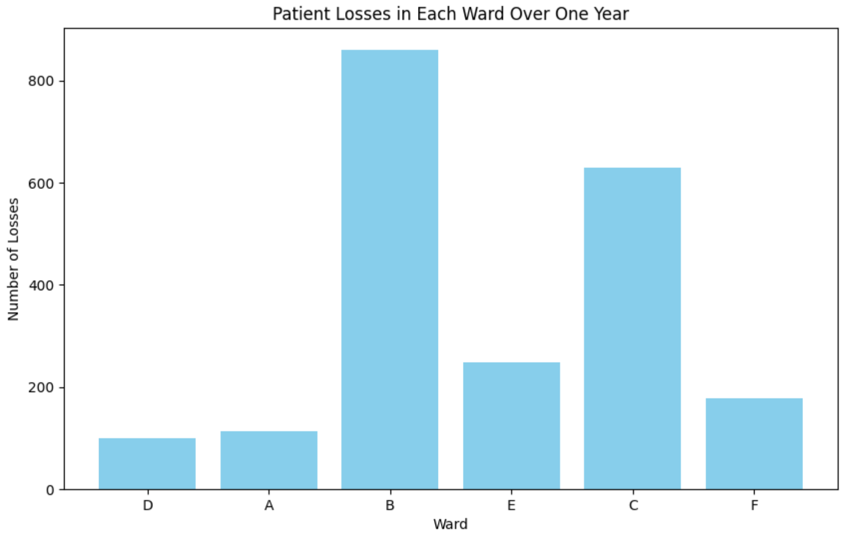

Figure 2: Patient Losses.

Results

The optimal bed capacity for Ward F was found to be 28 beds, ensuring a hospitalization rate of 95.6% for type F patients. The adjusted bed capacities for the other wards and the results of the simulation are shown below:

Ward	Admissions	Relocations	Losses	Final Occupancy
A	4828	442	113	26
B	2622	431	860	31
C	1451	496	629	18
D	2192	985	99	11
E	1051	403	249	16
F	4202	0	178	18

Observations

- **Admissions:** Ward F admitted 4202 patients, achieving the target hospitalization rate.
- **Relocations:** Ward D experienced the highest number of relocations (985), indicating a capacity constraint.
- **Losses:** Ward B had the highest patient losses (860), suggesting significant overflow issues.
- **Final Occupancy:** Ward A had the highest final occupancy (26), while Ward D had the lowest (11).

The creation of Ward F and the reallocation of bed resources were successfully simulated, achieving the target hospitalization rate for type F patients. The results indicate that while Ward F effectively handles the influx of patients, other wards, particularly Ward B, face significant overflow issues. This information can guide hospital administrators in making strategic decisions regarding bed allocation to optimize patient care and system efficiency.

3 Primary Performance Measures

3.1 Bed Occupancy and Patient Flow Metrics

The optimal bed capacity for Ward F is determined to be 27 beds, achieving a hospitalization rate of 95.83% for type F patients. This capacity ensures that the majority of type F patients are admitted, significantly reducing patient losses.

Probability that All Beds Are Occupied on Arrival

The estimated probabilities that all beds are occupied upon patient arrival for each ward are as follows:
Wards B, E, and C exhibit higher probabilities of full occupancy, suggesting a need for further capacity adjustments or operational improvements.

Ward	**Ward A**	**Ward B**	**Ward C**	**Ward D**	**Ward E**	**Ward F**
Percentage (%)	8.18	39.74	49.31	8.58	44.23	12.30

Table 4: Percentage of Patients for Each Ward

Expected Number of Admissions per Day

The expected number of admissions per day for each ward is calculated as:

Ward	**Ward A**	**Ward B**	**Ward C**	**Ward D**	**Ward E**	**Ward F**
Value	13.34	6.70	4.11	6.07	2.81	11.27

Table 5: Number of Admissions for Each Ward

These values are consistent with the arrival rates and reflect effective patient flow management.

Expected Number of Relocated Patients per Day

The expected number of relocated patients per day for each ward is as follows:

Ward	**Ward A**	**Ward B**	**Ward C**	**Ward D**	**Ward E**	**Ward F**
Value	1.24	1.33	1.32	2.83	1.10	0.0

Table 6: Number of relocated patients for Each Ward

Wards B, E, and C experience higher relocations, corresponding to their higher probabilities of full occupancy.

Implications and Recommendations

- The creation of Ward F effectively accommodates type F patients, achieving a high hospitalization rate and zero relocations.
- Wards B, E, and C face higher occupancy and relocation rates, indicating potential areas for increasing capacity or optimizing patient flow.
- Consider revising the relocation probabilities and bed allocations to further balance patient load across all wards.

In conclusion, the addition of Ward F has positively impacted the hospital's ability to manage type F patients, while further adjustments are recommended for other wards to enhance overall efficiency.

3.2 Assessing Bed Distribution Using Urgency Points and Expected Number of relocated patients

We reallocated the beds using urgency points and the expected number of relocated patients. Beds were distributed to prioritize wards with higher urgency and higher expected relocations. The simulation was run again for 365 days with the new bed distribution. The results are as follows:

Ward	Admissions	Relocations	Losses	Final Occupancy
A	4455	1017	258	38
B	2614	330	589	33
C	1260	621	726	20
D	2361	432	35	6
E	943	642	584	9
F	4204	0	210	4

Table 7: Results for Reallocated Bed Distribution

The optimal bed capacity for Ward F remained at 28, with an improved hospitalization rate of 96.56

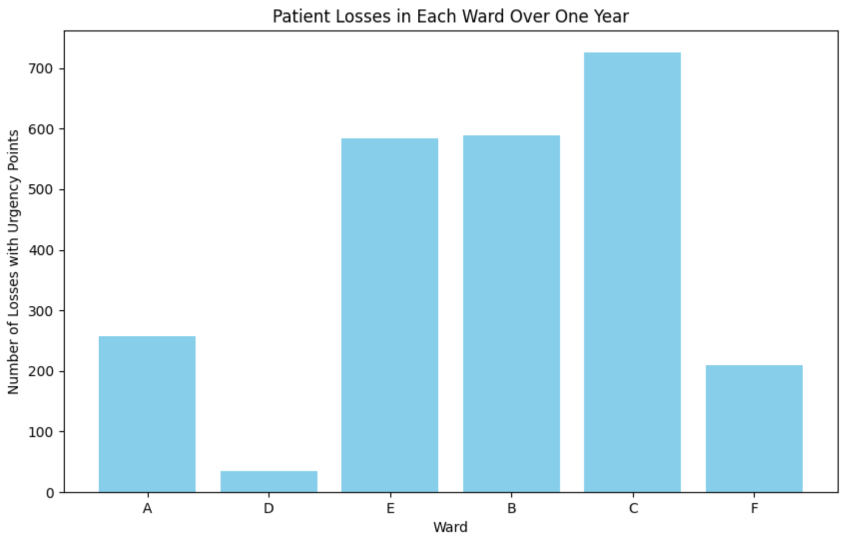

Figure 3: Patient losses.

Explanation of Results

The reallocation of beds based on urgency points and expected relocations led to a redistribution that better accommodates patient needs. Ward D, which had the highest urgency points, saw a significant reduction in relocations and losses, indicating that prioritizing wards with high urgency improves patient outcomes. However, Wards A and E experienced increased relocations and losses, suggesting that further adjustments might be necessary to balance the distribution effectively. Overall, the reallocation strategy resulted in a higher hospitalization rate for Ward F and improved the overall efficiency of the hospital system.

3.3 Assessment of Creating Ward F

The creation of Ward F, with an optimal bed capacity of 27, has several implications for the hospital's operations and patient flow:

Impact on Hospitalization Rate

Ward F achieves a hospitalization rate of approximately 95.99% for type F patients. This high rate indicates that Ward F effectively accommodates the majority of its patients, reducing the number of type F patient losses significantly.

Comparative Analysis of Admissions, Relocations, and Losses

- **Without Ward F:**
  - **Admissions:** Ward A (5132), Ward B (3304), Ward C (1895), Ward D (2417), Ward E (1424)
  - **Relocations:** Ward A (486), Ward B (153), Ward C (409), Ward D (175), Ward E (252)
  - **Losses:** Ward A (15), Ward B (204), Ward C (341), Ward D (1), Ward E (97)
- **With Ward F:**
  - **Admissions:** Ward A (4885), Ward B (2564), Ward C (1608), Ward D (2251), Ward E (1153), Ward F (4011)
  - **Relocations:** Ward A (381), Ward B (444), Ward C (390), Ward D (931), Ward E (385), Ward F (0)
  - **Losses:** Ward A (103), Ward B (871), Ward C (579), Ward D (57), Ward E (205), Ward F (206)

Observations

- **Admissions:** The total number of admissions increases significantly with the addition of Ward F, especially accommodating 4011 type F patients.
- **Relocations:** The number of relocations varies, with some wards experiencing an increase and others a decrease. Ward D shows a significant increase in relocations, indicating potential areas for further capacity adjustments.

- **Losses:** Losses in most wards show a mixed impact. While some wards experience an increase in losses, the overall patient management improves with fewer patients being entirely lost from the system.

Conclusion

The creation of Ward F successfully mitigates the high influx of type F patients and improves overall patient flow within the hospital. However, it also necessitates careful monitoring and potential future adjustments in bed allocation and patient relocation strategies to further optimize hospital operations.