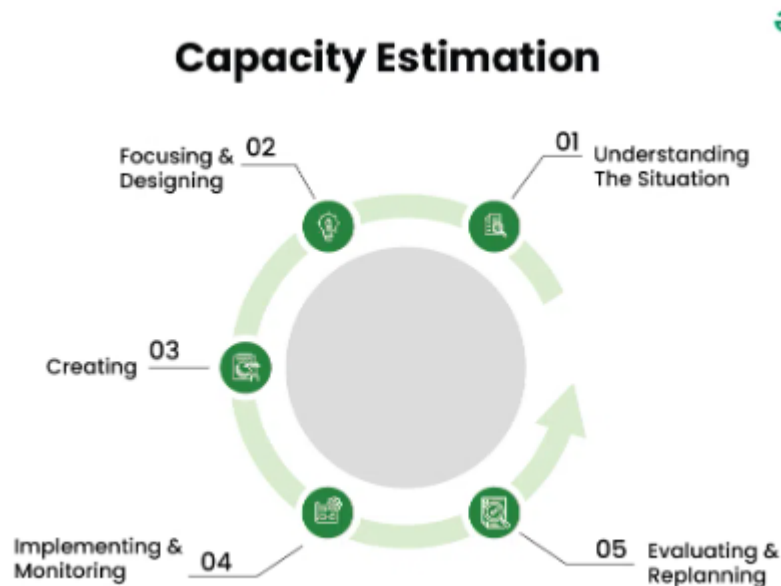# Capacity Estimation in Systems Design

Definition:

Capacity estimation predicts how much load a system can handle before performance degrades. It ensures scalability and prevents failures.

Key Factors Affecting Capacity

- **Hardware Resources** (CPU, RAM, Storage)
- **Software Efficiency** (Optimized algorithms, database queries)
- **Workload Characteristics** (Traffic patterns, peak load)
- **User Behavior** (Concurrent users, request rates)
- **Scalability** (Vertical vs. horizontal scaling)
- **Failure Scenarios** (Fault tolerance, redundancy)

Important Metrics

- **Daily Active Users (DAU)** – Total unique users per day
- **Queries Per Second (QPS)** – Requests processed per second
- **Storage Requirements** – Data volume growth
- **Error Rates** – Percentage of failed requests
- **Response Time** – Time taken per request
- **Concurrency** – Number of simultaneous users

Estimation Methods & Techniques

- **Traffic Analysis & Forecasting** – Studying trends & predicting future load

- **Stress & Load Testing** – Simulating peak usage
- **Historical Data Analysis** – Using past usage trends
- **Capacity Planning Tools** – Monitoring resource utilization

Component-wise Capacity Estimation

- **CPU & Memory** – Processing power, RAM usage
- **Storage** – Data growth & retention needs
- **Network Bandwidth** – Peak traffic handling
- **Database Resources** – Query load & concurrency

Case Study: E-Commerce Black Friday Sale

- **Estimate DAU:** 200,000 users
- **QPS:** 18.52 requests/sec
- **Storage Needs:** 1 TB/day
- **Concurrent Users:** 50,000 (25% of DAU)
- **Testing:** Load testing (Apache JMeter), stress testing (250,000 users)
- **Scaling:** Adding servers, optimizing caching

Challenges & Considerations

- Dynamic workload changes
- Unpredictable growth patterns
- Hardware/software limitations
- User behavior variability

Best Practices

- Start early in system design
- Collect accurate data
- Plan for scalability (horizontal/vertical scaling)
- Regularly update estimates based on trends

Tools for Capacity Estimation

- **Load Testing:** Apache JMeter, LoadRunner, Gatling
- **Monitoring:** Grafana, Prometheus, Datadog