FlexTime Scheduling Platform
Final Comprehensive Report

Executive Summary

The FlexTime Scheduling Platform is an AI-driven solution designed specifically for the Big 12 Conference to optimize athletic scheduling across multiple sports. This comprehensive report integrates all findings, specifications, and recommendations for the development and implementation of the platform.

The FlexTime system aims to transform months of manual scheduling work into minutes by leveraging advanced constraint programming and optimization algorithms. Key objectives include reducing travel costs, maximizing postseason bid opportunities, and providing collaborative workflows for all stakeholders.

This report synthesizes the requirements analysis, functional specifications, technical architecture, UI/UX design, and development roadmap into a cohesive implementation plan that aligns with the Big 12 Conference's preferences and requirements. The platform is designed to be completed by August 2025, providing ample time for implementation before the next athletic season.

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Introduction

Project Background

The Big 12 Conference requires a sophisticated scheduling system to manage the complex task of creating optimal athletic schedules across multiple sports. The current manual process is time-consuming, often taking months to complete, and may not fully optimize for important factors such as travel costs, competitive balance, and postseason opportunities.

The FlexTime Scheduling Platform addresses these challenges by providing an AI-driven solution that can generate optimized schedules in minutes while balancing numerous constraints and considerations.

The system is designed to be collaborative, allowing input from conference administrators, university administrators, and coaches.

Project Scope

The FlexTime Scheduling Platform encompasses:

- Multi-user authentication and role-based access control
- Conference and sport configuration
- Team and venue management
- Constraint definition and management
- AI-powered schedule generation
- Schedule visualization and comparison
- Travel impact analysis
- Manual adjustment capabilities
- Notification and collaboration features
- Import and export functionality

The system will be implemented as a web-based application with a potential mobile companion app in future phases. The platform will integrate with existing systems for calendaring, venue management, and athletic department operations.

Project Objectives

1. Reduce travel costs across the conference through optimized scheduling
2. Maximize postseason bid opportunities through strategic game placement
3. Transform months of manual scheduling work into minutes using AI optimization
4. Provide collaborative workflows for all stakeholders
5. Support multi-sport scheduling with specialized constraints
6. Enable data-driven decision-making through analytics and visualization
7. Ensure compliance with NCAA regulations and conference policies
8. Deliver a user-friendly interface that requires minimal training

Requirements Analysis

Key Stakeholders

- **Conference Administrators**: Responsible for overall scheduling strategy and final approval
- **University Administrators**: Manage institution-specific scheduling needs and constraints
- **Coaches**: Provide input on team-specific considerations and review proposed schedules
- **Student-Athletes**: Indirectly affected by travel schedules and game spacing

- **Fans and Media Partners**: Consumers of the final schedule

Core Functional Requirements

Authentication & Role-Based Access Control
- SSO integration for educational institutions
- Multi-factor authentication
- Hierarchical permission structure (Conference > University > Team)
- Row-level security for data access
- Comprehensive audit trail

Conference & Sport Setup
- Support for all 12 Big 12 sports
- Sport-specific templates and rule sets
- Season date configuration
- Member school management
- Custom parameter configuration

Venue Management
- Multi-venue support
- Availability calendar integration
- Booking rules and conflict detection
- Facility requirements tracking
- Geographic data for travel calculations

Constraint Management
- Hard and soft constraint definition
- Custom rule creation via YAML/JSON DSL
- Real-time conflict warnings
- Weighting system for prioritization
- Support for rivalries, blackouts, travel limitations, and NCAA rules

AI Schedule Generation
- Hybrid CP-SAT + heuristics approach
- Generation of 3-5 scheduling scenarios
- Processing time ≤ 5 minutes
- Progress indication during generation
- Cancellation capability for long-running processes

Schedule Visualization & Comparison
- Calendar and list view toggle
- Side-by-side comparison of scenarios
- Travel metrics visualization
- Interactive filtering and sorting
- Highlighting of key differences

Travel Impact Analysis
- Distance and cost calculations
- Away game counts and streaks
- Geographic visualization

- Soft-warning highlights for potential issues
- Regional game clustering optimization

Manual Adjustments
- Drag-and-drop interface for schedule modifications
- Instant validation of changes
- Comprehensive audit logging
- Conflict detection and resolution

Notifications & Collaboration
- In-app notification inbox
- WebSocket push notifications
- Email integration
- Preference center for notification settings
- Batching capabilities for notifications

Import/Export Capabilities
- CSV template support
- Asynchronous export processing
- Multiple export formats (CSV, PDF, ICS)
- API feed for integration with other systems
- 24-hour rollback capability

Technical Requirements

System Architecture
- Multi-agent architecture with specialized agents
- Microservices topology with clear service boundaries
- Event-driven communication via message broker
- Kubernetes deployment with autoscaling
- Comprehensive observability stack

Data Management
- PostgreSQL for primary data storage
- Analytics replica for reporting
- Redis for queuing and caching
- S3 for file storage and exports
- Row-level security for multi-tenant isolation

Integration Requirements
- WebSocket gateway for live updates
- RESTful API with Swagger documentation
- SSO integration capabilities
- Calendar system integration (Google Calendar, Outlook)
- Webhook support for external notifications

Non-Functional Requirements
- Performance: Schedule generation in ≤ 5 minutes
- Scalability: Support for concurrent users during peak scheduling periods

- Security: Row-level security, audit logging, MFA
- Reliability: Circuit breaker patterns, dead letter queues
- Observability: Prometheus/Grafana, ELK stack, Jaeger (OTEL)

Design Constraints
- Black and white color scheme for all visual elements
- Big 12 logo displayed in black and white
- Multi-agent architecture for specialized task handling
- Completion deadline of August 2025

Functional Specification

User Roles and Permissions

Conference Administrator
Description: Oversees all scheduling activities across the conference.

Permissions:
- Create and manage conference workspace
- Configure global settings and parameters
- Define conference-wide constraints and rules
- Access and modify all schedules
- Approve and publish final schedules
- Manage user roles and permissions
- View comprehensive analytics and reports

University Administrator
Description: Manages scheduling for a specific institution.

Permissions:
- View and manage institution-specific settings
- Define institution-specific constraints and preferences
- Access and modify schedules for institution's teams
- Provide input on schedule proposals
- View institution-specific analytics and reports
- Manage venue information for the institution

Coach
Description: Provides input and reviews schedules for specific teams.

Permissions:
- View team-specific schedules
- Provide input on team constraints and preferences
- Request specific scheduling considerations
- View team-specific analytics
- Receive notifications about schedule changes

Functional Modules

Authentication and Access Control

The authentication and access control module provides secure, role-based access to the system with the following key features:

- Single Sign-On (SSO) integration with educational institutions
- Multi-factor authentication for enhanced security
- Role-based access control with hierarchical permissions
- Comprehensive audit logging of security events
- Session management with configurable timeout settings

The system will enforce appropriate access restrictions based on user roles, ensuring that users can only access data and functions relevant to their responsibilities.

Conference and Sport Setup

The conference and sport setup module enables configuration of the Big 12 Conference workspace and sport-specific parameters:

- Conference profile creation with branding elements
- Academic year and season definition
- Sport-specific templates for all 12 Big 12 sports
- Season structure definition (pre-season, regular season, post-season)
- NCAA compliance date checking

Administrators can configure each sport with appropriate parameters, rule sets, and scheduling constraints, ensuring that the system is tailored to the specific needs of each sport.

Team and Venue Management

The team and venue management module supports comprehensive management of teams and venues:

- Team profile management with team-specific information
- Multi-venue configuration and availability tracking
- Venue availability calendar with booking rules
- Conflict detection and resolution for venue scheduling
- Geographic data for travel calculations

The system will maintain accurate information about teams and venues, ensuring that scheduling decisions are based on up-to-date data.

Constraint Management

The constraint management module provides a flexible system for defining and managing scheduling constraints:

- Step-by-step constraint wizard for guided constraint creation
- Hard and soft constraint definition with weight assignment
- Custom constraint definition using YAML/JSON DSL
- Rivalry and traditional matchup management
- NCAA compliance rule enforcement

The system will validate constraints in real-time, detecting conflicts and providing warnings when constraints may be difficult to satisfy simultaneously.

AI Schedule Generation

The AI schedule generation module is the core of the FlexTime platform, providing sophisticated optimization capabilities:

- Scheduling algorithm configuration with customizable parameters
- Hybrid CP-SAT + heuristics approach for efficient optimization
- Generation of 3-5 distinct scheduling scenarios
- Progress indication and cancellation capability
- Scenario metadata and explanation for decision transparency

The system will generate multiple scheduling options, each optimized for different priorities, allowing stakeholders to compare and select the most appropriate schedule.

Schedule Visualization and Comparison

The schedule visualization and comparison module provides intuitive tools for reviewing and comparing schedules:

- Calendar and matrix view options for schedule display
- Side-by-side comparison of multiple scheduling scenarios
- Interactive filtering and analysis tools
- Comparative metrics for objective evaluation
- Highlighting of key differences between scenarios

Users can explore schedules from different perspectives, gaining insights into the strengths and weaknesses of each option.

Travel Impact Analysis

The travel impact analysis module provides detailed analysis of travel patterns and costs:

- Travel distance calculation and visualization
- Geographic visualization of travel routes
- Travel optimization recommendations
- Away game streak management
- Comparative analysis across scenarios

The system will help identify opportunities to reduce travel costs and minimize student-athlete time away from campus.

Postseason Insights

The postseason insights module provides analysis of schedule impact on postseason opportunities:

- NET/RPI projection based on schedule characteristics
- Custom "Postseason Score" metric for scenario comparison
- Competitive balance analysis
- Historical performance integration
- Identification of high-impact games

The system will help maximize postseason bid opportunities through strategic game placement and scheduling.

Manual Adjustments

The manual adjustments module enables fine-tuning of generated schedules:

- Drag-and-drop interface for intuitive schedule modifications
- Real-time constraint validation during adjustments
- Comprehensive change audit logging
- Collaborative editing with conflict resolution
- Impact analysis for proposed changes

Users can make manual adjustments to address specific needs while maintaining the overall quality of the schedule.

Notifications and Collaboration

The notifications and collaboration module facilitates communication and coordination:

- In-app notification center with customizable preferences
- Email and push notification integration
- Comment and discussion threads attached to schedules
- @mention functionality for user references
- Approval workflow for schedule review and publication

The system will keep all stakeholders informed and engaged throughout the scheduling process.

Import and Export

The import and export module enables data exchange with external systems:

- CSV template support for data import
- Multiple export formats (CSV, PDF, ICS)
- Direct integration with calendaring systems
- API access for programmatic integration
- Asynchronous processing for large exports

The system will seamlessly integrate with existing tools and systems used by the conference and member institutions.

Data Models

The FlexTime platform will use a comprehensive data model to represent all entities and relationships relevant to the scheduling process. Key entities include:

- Conference
- Institution
- Sport
- Team
- Venue
- Schedule
- Game
- Constraint
- User
- Rivalry
- ScheduleComment
- ScheduleApproval
- ScheduleVersion

Each entity will have appropriate attributes and relationships to support the functional requirements of the system. The data model will be implemented in PostgreSQL with appropriate indexing and optimization for performance.

Integration Points

The FlexTime platform will integrate with various external systems to provide a seamless experience:

- SSO Identity Providers (SAML 2.0, OAuth 2.0)
- Calendaring Systems (Google Calendar, Outlook, iCalendar)
- Venue Management Systems
- Athletic Department Systems

Internal service integrations will include:

- Notification Service
- Reporting Service
- Import/Export Service

- Comment Service

These integrations will be implemented using standard protocols and APIs, with appropriate error handling and retry mechanisms.

Technical Architecture

Architecture Principles

The FlexTime platform is built on modern, scalable technologies with a focus on reliability, performance, and maintainability. Key architecture principles include:

1. **Microservices-Based**: Decomposed into specialized, independently deployable services
2. **Event-Driven**: Asynchronous communication via message broker for resilience
3. **Multi-Agent System**: Specialized agents for different scheduling components
4. **Cloud-Native**: Designed for containerized deployment with Kubernetes
5. **Scalable**: Horizontal scaling capabilities for handling peak loads
6. **Observable**: Comprehensive monitoring, logging, and tracing
7. **Secure**: Multi-layered security with row-level isolation

System Layers

The system architecture is organized into the following layers:

Client Layer
- **Web Application**: React-based SPA with responsive design
- **Mobile App** (Future): React Native application for on-the-go access
- **API Consumers**: External systems consuming FlexTime APIs

Application Layer
- **API Gateway**: Entry point for all client requests
- **Microservices**: Core business functionality in specialized services
- **Agent System**: Intelligent components for scheduling optimization

Infrastructure Layer
- **Kubernetes + KEDA**: Container orchestration with autoscaling
- **RabbitMQ**: Message broker for event-driven communication
- **PostgreSQL**: Primary data storage with row-level security
- **Redis**: Caching and job queue management
- **S3 Storage**: Object storage for documents and exports
- **Observability Stack**: Monitoring, logging, and tracing tools

Service Topology

The system is composed of the following microservices:

api-svc
- **Purpose**: Primary API gateway and authentication service
- **Responsibilities**:
  - User authentication and authorization
  - API request routing and validation
  - Rate limiting and API key management
  - Request/response transformation

scheduler-svc
- **Purpose**: Core scheduling engine and optimization service
- **Responsibilities**:
  - Schedule generation job management
  - Agent orchestration
  - Algorithm execution and monitoring
  - Constraint validation and enforcement

notification-svc
- **Purpose**: Manages all system notifications and alerts
- **Responsibilities**:
  - Notification delivery across channels
  - User preference management
  - Notification batching and throttling
  - Delivery status tracking

import-svc
- **Purpose**: Handles data import and validation
- **Responsibilities**:
  - Template management
  - Data validation pipeline
  - Error reporting and correction
  - Import history and rollback

reporting-svc
- **Purpose**: Generates reports and analytics
- **Responsibilities**:
  - Report generation and formatting
  - Analytics calculations
  - Export processing
  - Historical data analysis

comment-svc
- **Purpose**: Manages collaborative discussions and feedback
- **Responsibilities**:
  - Comment storage and retrieval
  - Mention detection and notification
  - Thread management

  - Attachment handling

Multi-Agent Architecture

The FlexTime platform implements a multi-agent architecture for scheduling optimization, with specialized agents handling different aspects of the scheduling process:

Master Director Agent
- **Purpose**: Orchestrates the overall scheduling job lifecycle
- **Responsibilities**:
  - Job initialization and resource allocation
  - Agent coordination and communication
  - Error handling and recovery
  - Job completion and result aggregation

Scheduling Director Agent
- **Purpose**: Manages the scheduling workflow
- **Responsibilities**:
  - Workflow state management
  - Progress tracking and reporting
  - Event emission for status updates
  - Scheduling phase transitions

Algorithm Selection Agent
- **Purpose**: Determines optimal algorithm configuration
- **Responsibilities**:
  - CP-SAT profile selection
  - Parameter tuning based on problem characteristics
  - Resource requirement estimation
  - Algorithm performance monitoring

Constraint Management Agent
- **Purpose**: Handles constraint validation and enforcement
- **Responsibilities**:
  - Constraint parsing and normalization
  - Pre-solve feasibility checking
  - Conflict detection and resolution
  - Constraint prioritization

Schedule Optimization Agent
- **Purpose**: Executes core scheduling algorithms
- **Responsibilities**:
  - CP-SAT problem formulation
  - Solver execution and monitoring
  - Solution evaluation and refinement
  - Metadata generation for solutions

Travel Optimization Agent
- **Purpose**: Analyzes and optimizes travel patterns

- **Responsibilities**:
  - Distance and cost calculations
  - Travel pattern analysis
  - Geographic clustering
  - Post-solve travel optimization

Venue Management Agent
- **Purpose**: Handles venue availability and conflicts
- **Responsibilities**:
  - Venue calendar management
  - Conflict detection and resolution
  - Alternative venue suggestions
  - Booking rule enforcement

Notification Agent
- **Purpose**: Manages notification delivery
- **Responsibilities**:
  - Notification generation based on events
  - Delivery channel selection
  - User preference application
  - Notification batching and throttling

Data Management

Primary Database (PostgreSQL)
- **Purpose**: Main transactional database
- **Design Considerations**:
  - Row-level security for multi-tenant isolation
  - Schema design for flexible constraints
  - Indexing strategy for query performance
  - Partitioning for large tables

Analytics Database (PostgreSQL Read Replica)
- **Purpose**: Dedicated database for reporting and analytics
- **Design Considerations**:
  - Read-only replica of primary database
  - Optimized for analytical queries
  - Materialized views for common reports
  - Reduced indexing for bulk operations

Redis Cache and Queue
- **Purpose**: Caching and job queue management
- **Design Considerations**:
  - Cache invalidation strategy
  - Queue persistence and recovery
  - Memory management and eviction policies
  - Cluster configuration for high availability

S3 Object Storage
- **Purpose**: Document and file storage

- **Design Considerations**:
  - Bucket organization and naming
  - Lifecycle policies for retention
  - Access control and permissions
  - Versioning for critical documents

Communication Patterns

Synchronous Communication
- **REST APIs**: For direct client-server interaction
- **GraphQL** (Future): For flexible data querying

Asynchronous Communication
- **Message Broker (RabbitMQ)**: For event-driven communication
- **WebSockets**: For real-time updates

Deployment Architecture

Kubernetes Deployment
- **Namespace Organization**:
  - Production, staging, and development environments
  - Service-based namespace grouping
  - Resource quotas and limits
  - Network policies for isolation

- **Deployment Strategy**:
  - Rolling updates for zero-downtime deployment
  - Canary deployments for risk mitigation
  - Blue/green deployments for critical services
  - Rollback capabilities for failed deployments

CI/CD Pipeline
- **GitOps Approach**:
  - Infrastructure as Code with Terraform
  - Application deployment with ArgoCD
  - Git-based workflow for changes
  - Automated testing and validation

Observability

Monitoring (Prometheus/Grafana)
- **Metrics Collection**:
  - Service-level metrics (requests, latency, errors)
  - Business metrics (schedules, games, users)
  - Infrastructure metrics (CPU, memory, network)
  - Custom metrics for key processes

Logging (ELK Stack)
- **Log Management**:
  - Structured logging format

  - Log aggregation and indexing
  - Log retention policies
  - Log-based alerting

Distributed Tracing (Jaeger/OTEL)
- **Trace Collection**:
  - Request tracing across services
  - Span collection and sampling
  - Context propagation
  - Trace visualization

Security Architecture

Authentication and Authorization
- **Identity Management**:
  - SSO integration with educational institutions
  - Multi-factor authentication
  - JWT-based session management
  - Role-based access control

Data Security
- **Data Protection**:
  - Encryption in transit (TLS)
  - Encryption at rest
  - Data masking for sensitive information
  - Secure deletion policies

Audit and Compliance
- **Audit Logging**:
  - Comprehensive audit trail
  - Tamper-evident logging
  - Retention policies
  - Compliance reporting

Disaster Recovery and Business Continuity

Backup Strategy
- **Database Backups**:
  - Point-in-time recovery capabilities
  - Regular full and incremental backups
  - Cross-region replication
  - Backup validation and testing

Recovery Procedures
- **Recovery Time Objective (RTO)**:
  - Service-level recovery targets
  - Prioritized recovery sequence
  - Automated recovery procedures
  - Regular recovery testing

UI/UX Design

The FlexTime platform features a clean, intuitive user interface designed with the Big 12 Conference's black and white color scheme. The design prioritizes usability, accessibility, and responsiveness across devices.

Design Principles

1. **Clarity**: Clear information hierarchy and visual organization
2. **Consistency**: Uniform patterns and interactions throughout the application
3. **Efficiency**: Streamlined workflows for common tasks
4. **Accessibility**: WCAG 2.1 AA compliance for inclusive access
5. **Responsiveness**: Optimal experience across desktop, tablet, and mobile devices

Key Interfaces

Dashboard

The dashboard provides an overview of active schedules, recent activity, quick actions, schedule metrics, and upcoming deadlines. Key elements include:

- **Header**: Big 12 FlexTime logo, user menu, and notifications
- **Navigation**: Primary navigation menu with clear section indicators
- **Active Schedules**: List of schedules in progress with status indicators
- **Recent Activity**: Chronological feed of system activities
- **Quick Actions**: Prominent buttons for common tasks
- **Schedule Metrics**: Visual indicators of key performance metrics
- **Upcoming Deadlines**: Timeline of approaching deadlines

The dashboard is designed to provide at-a-glance information and quick access to frequently used functions.

Schedule Generation

The schedule generation interface guides users through the process of configuring and initiating schedule generation. Key elements include:

- **Configuration Panel**: Summary of sport, season, teams, venues, and constraints
- **Optimization Goals**: Visual representation of priority for each goal
- **Generation Options**: Settings for number of scenarios and processing time
- **Validation Panel**: Pre-generation validation checks with status

indicators
- **Progress Indication**: Visual and textual representation of generation progress
- **Generation Log**: Real-time updates on the generation process
- **Scenarios Found**: Summary of generated scenarios with key metrics

The interface provides transparency into the generation process and clear feedback on progress and results.

Constraint Wizard

The constraint wizard provides a structured approach to defining and managing scheduling constraints. Key elements include:

- **Constraint Types Panel**: Categorized buttons for different constraint types
- **Define Constraint Panel**: Form for configuring constraint parameters
- **Active Constraints Panel**: List of currently active constraints by category
- **Constraint Validation Panel**: Validation results with status indicators
- **Custom Constraint Builder**: Visual builder and YAML/JSON editor for advanced constraints

The wizard makes complex constraint definition accessible to users with varying technical expertise.

Schedule Comparison & Travel Impact

The schedule comparison interface enables detailed analysis and comparison of generated scenarios. Key elements include:

- **Scenario Selection Panel**: Checkboxes for selecting scenarios to compare
- **Comparison Metrics Panel**: Buttons for different metric categories
- **Side-by-Side Comparison Panel**: Direct comparison of key metrics
- **Travel Impact Visualization Panel**: Geographic map of travel routes
- **Team-by-Team Comparison Panel**: Detailed metrics for specific teams

The interface provides both high-level comparison and detailed analysis capabilities.

Manual Adjustments

The manual adjustments interface enables fine-tuning of schedules with immediate feedback. Key elements include:

- **Calendar Controls Panel**: View options and navigation controls
- **Calendar Display**: Interactive calendar with game information
- **Game Details Panel**: Information about selected games
- **Impact Analysis Panel**: Analysis of the impact of changes

The interface provides an intuitive drag-and-drop experience with real-time validation and feedback.

Responsive Behavior

All interfaces are designed to be responsive across different device sizes:

- **Desktop**: Full layout with multi-column panels
- **Tablet**: Adapted layout with stacked or collapsible panels
- **Mobile**: Single-column layout with simplified controls and progressive disclosure

Accessibility Features

The design incorporates numerous accessibility features:

- High contrast black and white design for readability
- Keyboard navigable interface with clear focus indicators
- Screen reader compatible elements with appropriate ARIA attributes
- Text alternatives for non-text content
- Sufficient color contrast for all text elements
- Resizable text without loss of functionality

Development Roadmap

Project Timeline Summary

Phase	Start Date	End Date	Duration
1. Project Initiation & Planning	June 1, 2025	June 15, 2025	2 weeks
2. Design & Architecture	June 16, 2025	June 30, 2025	2 weeks
3. Core Infrastructure Development	July 1, 2025	July 14, 2025	2 weeks
4. Feature Development	July 15, 2025	August 7, 2025	3.5 weeks
5. Integration & Testing	July 22, 2025	August 14, 2025	3.5 weeks
6. Deployment & Launch	August 15, 2025	August 22, 2025	1 week
7. Post-Launch Support	August 23, 2025	Ongoing	Ongoing

Phase 1: Project Initiation & Planning (June 1 - June 15, 2025)

This phase focuses on establishing the project foundation, including team formation, environment setup, and detailed planning.

Key Activities:
- Finalize project team and roles
- Establish development environments
- Set up project management tools and repositories
- Conduct kickoff meeting with stakeholders
- Refine requirements and acceptance criteria
- Develop sprint planning and backlog
- Finalize technology stack decisions

Deliverables:
- Project charter and scope document
- Finalized project plan with resource allocation
- Development environment setup
- Initial backlog and sprint plan
- Risk management plan

Phase 2: Design & Architecture (June 16 - June 30, 2025)

This phase involves detailed design and initial architecture implementation.

Key Activities:
- Finalize database schema design
- Complete API specifications
- Develop detailed UI/UX designs and prototypes
- Define integration points with external systems
- Set up Kubernetes infrastructure
- Configure CI/CD pipelines
- Implement database with row-level security

Deliverables:
- Detailed design documents
- Database schema
- API specifications
- UI/UX design assets
- Infrastructure as code templates
- CI/CD pipeline configuration

Phase 3: Core Infrastructure Development (July 1 - July 14, 2025)

This phase focuses on building the foundational services and frameworks.

Key Activities:
- Implement API gateway service

- Develop authentication and authorization service
- Create core data models and repositories
- Set up service mesh and communication patterns
- Implement basic logging and monitoring
- Develop agent system architecture
- Implement Master Director agent

Deliverables:
- Core microservices framework
- Authentication and authorization system
- Data access layer
- Agent system foundation
- Basic monitoring and logging

Phase 4: Feature Development (July 15 - August 7, 2025)

This phase involves implementing the core functional modules of the system.

Key Activities:
- Implement user management features
- Develop role-based access control
- Create conference and sport setup interfaces
- Implement team and venue management
- Develop constraint wizard interface
- Implement CP-SAT optimization algorithms
- Create schedule visualization components

Deliverables:
- User management and RBAC system
- Configuration management interfaces
- Constraint management system
- Scheduling optimization engine
- Visualization and analysis tools

Phase 5: Integration & Testing (July 22 - August 14, 2025)

This phase focuses on integrating all components and comprehensive testing.

Key Activities:
- Integrate all microservices
- Implement end-to-end workflows
- Develop notification system
- Create import/export services
- Conduct unit and integration testing
- Perform performance testing
- Execute security testing

Deliverables:

- Fully integrated system
- Test reports and documentation
- Performance optimization report
- Security assessment report
- User acceptance sign-off

Phase 6: Deployment & Launch (August 15 - August 22, 2025)

This phase involves deploying the system to production and launching it to users.

Key Activities:
- Deploy to production environment
- Conduct final verification
- Migrate initial data
- Configure monitoring and alerts
- Conduct user training sessions
- Execute go-live plan

Deliverables:
- Production deployment
- System documentation
- User training materials
- Go-live checklist completion
- Initial performance reports

Phase 7: Post-Launch Support (August 23, 2025 - Ongoing)

This phase involves ongoing support and enhancement of the system.

Key Activities:
- Monitor system performance
- Address user feedback
- Implement minor enhancements
- Provide technical support
- Plan for future feature development

Deliverables:
- Regular performance reports
- Issue resolution documentation
- Enhancement requests tracking
- Support documentation updates
- Future feature roadmap

Critical Path and Dependencies

The critical path for the project includes:
1. Database schema design and implementation
2. Agent system architecture development
3. CP-SAT optimization algorithm implementation

4. Integration of scheduling engine with constraint system
5. End-to-end testing and performance optimization

Key dependencies between components must be carefully managed to ensure timely delivery.

Resource Allocation

The project requires a dedicated team including:
- 1 Project Manager
- 1 Technical Architect
- 2 Backend Developers (Python/OR-Tools)
- 2 Frontend Developers (React)
- 1 DevOps Engineer
- 1 QA Engineer
- 1 UX Designer

Risk Management

Key risks and mitigation strategies include:
1. **Algorithm Performance**: Early prototyping and performance testing
2. **Integration Complexity**: Comprehensive integration testing
3. **Data Volume**: Database optimization and caching strategies
4. **User Adoption**: Intuitive UI design and comprehensive training
5. **Timeline Pressure**: Phased approach and prioritized backlog

Implementation Considerations

Technology Stack Recommendations

Based on the requirements and architecture, the following technology stack is recommended:

Frontend
- **Framework**: React with TypeScript
- **State Management**: Redux or Context API
- **UI Components**: Custom component library with black and white theme
- **Visualization**: D3.js for data visualization
- **Maps**: Leaflet or Google Maps API for geographic visualization
- **Calendar**: FullCalendar for schedule display
- **Forms**: Formik with Yup validation

Backend
- **API Framework**: Node.js with Express or NestJS for API services
- **Optimization Engine**: Python with OR-Tools for CP-SAT implementation
- **Database**: PostgreSQL with PostGIS extension
- **Caching**: Redis

- **Message Broker**: RabbitMQ
- **Object Storage**: S3-compatible storage (MinIO or AWS S3)

Infrastructure
- **Container Orchestration**: Kubernetes with KEDA
- **CI/CD**: GitLab CI or GitHub Actions with ArgoCD
- **Infrastructure as Code**: Terraform
- **Monitoring**: Prometheus and Grafana
- **Logging**: ELK Stack (Elasticsearch, Logstash, Kibana)
- **Tracing**: Jaeger with OpenTelemetry

Deployment Strategy

The recommended deployment strategy includes:

1. **Environment Separation**:
   - Development environment for active development
   - Staging environment for integration testing
   - Production environment for live operation

2. **Deployment Approach**:
   - GitOps workflow with infrastructure as code
   - Automated CI/CD pipeline for consistent deployments
   - Rolling updates for zero-downtime deployment
   - Canary deployments for high-risk changes

3. **Scaling Strategy**:
   - Horizontal pod autoscaling based on CPU/memory
   - KEDA scaling based on queue depth for processing services
   - Database read replicas for query-intensive workloads

4. **Backup and Recovery**:
   - Regular database backups with point-in-time recovery
   - Configuration backups in version control
   - Disaster recovery procedures with defined RTO/RPO

Integration Approach

The integration approach should focus on:

1. **API-First Design**:
   - Well-documented APIs with OpenAPI/Swagger
   - Versioned endpoints for backward compatibility
   - Consistent error handling and response formats

2. **Authentication Integration**:
   - SAML 2.0 and OAuth 2.0 support for SSO
   - JWT-based token management
   - Role mapping from identity providers

3. **Calendar System Integration**:
   - iCalendar feed generation
   - Direct API integration with Google Calendar and Outlook
   - Webhook support for bidirectional updates

4. **Venue Management Integration**:
   - API integration with institutional facility systems
   - Periodic synchronization of availability data
   - Conflict resolution protocols

Performance Optimization

To ensure optimal performance, the following strategies should be implemented:

1. **Database Optimization**:
   - Appropriate indexing strategy
   - Query optimization and monitoring
   - Connection pooling
   - Read replicas for reporting queries

2. **Caching Strategy**:
   - Redis caching for frequently accessed data
   - Browser caching for static assets
   - Cache invalidation based on data changes
   - Distributed caching for scalability

3. **Algorithm Optimization**:
   - Constraint pre-processing to reduce problem size
   - Heuristic approaches for initial solutions
   - Parallel processing for independent calculations
   - Time-bounded optimization with quality thresholds

4. **Frontend Performance**:
   - Code splitting and lazy loading
   - Optimized bundle size
   - Server-side rendering for initial load
   - Progressive enhancement for complex features

Security Considerations

Security should be a priority throughout implementation:

1. **Authentication and Authorization**:
   - Multi-factor authentication
   - Role-based access control
   - Session management and timeout
   - Secure credential storage

2. **Data Protection**:

   - Encryption in transit (TLS)
   - Encryption at rest
   - Data masking for sensitive information
   - Secure deletion policies

3. **API Security**:
   - Input validation and sanitization
   - Rate limiting and throttling
   - CSRF protection
   - Security headers

4. **Infrastructure Security**:
   - Network policies for service isolation
   - Regular security updates
   - Vulnerability scanning
   - Penetration testing

Testing Strategy

A comprehensive testing strategy should include:

1. **Unit Testing**:
   - Component-level testing
   - Mocking of dependencies
   - High code coverage for critical components
   - Automated test execution in CI pipeline

2. **Integration Testing**:
   - Service interaction testing
   - API contract testing
   - Database integration testing
   - Message broker integration testing

3. **End-to-End Testing**:
   - Workflow validation
   - UI automation testing
   - Cross-browser compatibility
   - Mobile responsiveness

4. **Performance Testing**:
   - Load testing for concurrent users
   - Stress testing for peak loads
   - Endurance testing for stability
   - Algorithm performance benchmarking

5. **Security Testing**:
   - Vulnerability scanning
   - Penetration testing
   - Authentication and authorization testing
   - Data protection validation

Conclusion and Recommendations

Summary of Findings

The FlexTime Scheduling Platform represents a significant advancement in collegiate athletic scheduling for the Big 12 Conference. The comprehensive analysis and design presented in this report demonstrate the feasibility and value of implementing an AI-driven scheduling solution that can transform months of manual work into minutes while optimizing for critical factors such as travel costs and postseason opportunities.

Key findings from the analysis include:

1. The multi-agent architecture provides a flexible and scalable approach to handling complex scheduling problems across different sports.

2. The CP-SAT optimization approach, combined with heuristics, can generate high-quality schedules within the target timeframe of 5 minutes.

3. The microservices architecture enables independent scaling and development of system components, enhancing maintainability and resilience.

4. The collaborative features of the platform support the involvement of all stakeholders in the scheduling process, ensuring that diverse needs and constraints are considered.

5. The black and white design aesthetic aligns with Big 12 Conference branding while providing a clean, accessible user interface.

Key Recommendations

Based on the analysis and design work, the following recommendations are provided:

1. **Phased Implementation**: Adopt the phased implementation approach outlined in the development roadmap, focusing first on core functionality and adding advanced features in subsequent phases.

2. **Early Algorithm Prototyping**: Begin prototyping the CP-SAT optimization algorithms early in the development process to validate performance and refine the approach.

3. **Stakeholder Involvement**: Engage key stakeholders throughout the development process, particularly during the design and testing phases, to ensure the system meets their needs and expectations.

4. **Performance Monitoring**: Implement comprehensive performance monitoring from the outset to identify and address bottlenecks early in the development process.

5. **User Training**: Develop a comprehensive training program for all user roles to ensure effective adoption and utilization of the system.

6. **Continuous Improvement**: Establish a feedback loop and enhancement process to continuously improve the system based on user experience and emerging requirements.

Future Enhancements

While the MVP provides comprehensive scheduling capabilities, several enhancements could be considered for future phases:

1. **In-season Rescheduling Engine**: Add capabilities for quickly rescheduling games due to weather, venue issues, or other emergencies.

2. **Mobile Companion App**: Develop a mobile application for on-the-go access to schedules and notifications.

3. **Enhanced Analytics Dashboard**: Expand analytics capabilities to include historical performance data, predictive modeling, and revenue projections.

4. **Machine Learning Enhancements**: Implement continuous model tuning and learning from historical scheduling decisions.

5. **Multi-sport Joint Scheduling**: Develop capabilities for optimizing schedules across multiple sports simultaneously, considering shared resources and travel opportunities.

6. **Attendance and Revenue Prediction**: Add predictive models for attendance and revenue to inform scheduling decisions.

Final Thoughts

The FlexTime Scheduling Platform represents a strategic investment in the operational efficiency and competitive advantage of the Big 12 Conference. By leveraging advanced AI optimization techniques within a user-friendly, collaborative platform, the system can significantly reduce the time and effort required for scheduling while improving outcomes for all stakeholders.

The comprehensive design and implementation plan presented in this report provides a solid foundation for successful development and deployment by the August 2025 deadline. With appropriate resources and stakeholder engagement, the FlexTime platform will transform the

scheduling process and deliver lasting value to the Big 12 Conference.

Appendices

Appendix A: Glossary of Terms

- **CP-SAT**: Constraint Programming - Boolean Satisfiability, an optimization approach
- **NET**: NCAA Evaluation Tool, a ranking system used for basketball
- **RPI**: Rating Percentage Index, a ranking system used in various college sports
- **RBAC**: Role-Based Access Control, a method of regulating access based on roles
- **DSL**: Domain-Specific Language, a specialized language for a particular domain
- **KEDA**: Kubernetes Event-Driven Autoscaling, a scaling mechanism based on events
- **SSO**: Single Sign-On, an authentication scheme that allows users to log in with a single ID
- **JWT**: JSON Web Token, a compact, URL-safe means of representing claims between two parties
- **OTEL**: OpenTelemetry, an observability framework for cloud-native software

Appendix B: Reference Documents

- FlexTime Spec Collegiate Scheduling App.md
- Requirements Analysis
- Functional Specification
- Technical Architecture
- UI/UX Wireframes
- Development Roadmap

Appendix C: Technical Diagrams

- Architecture Overview
- Microservices Architecture
- Multi-Agent Architecture
- Data Model
- Deployment Architecture
- Integration Architecture

Appendix D: UI/UX Wireframes

- Dashboard
- Schedule Generation
- Constraint Wizard
- Schedule Comparison & Travel Impact
- Manual Adjustments
