Requirement Traceability Matrix

Requirements Traceability Matrix (RTM)

Utility Billing System

RTM Legend

- **FR** - Functional Requirement
- **NFR** - Non-Functional Requirement
- **LINQ** - Mandatory LINQ usage
- **TC** - Test Case

RTM Table

Req ID	Requirement Description	Module	Backend API	Frontend Page	LINQ Usage
FR-01	User registration	Auth	POST /api/auth/register	Register Page	-
FR-02	User login with JWT	Auth	POST /api/auth/login	Login Page	-
FR-03	Role-based access control (RBAC)	Auth	Secured APIs	All Pages	-
FR-04	Consumer registration and profile management	Consumer	POST /api/auth/register GET /api/user/{id} PUT /api/user/{id}	Register Page Profile View	-
FR-05	Store utility connection details (type, meter number, tariff plan)	Connection	POST /api/connection GET /api/connection/{id}	Connection Management /admin/connections	-
FR-06	Monthly meter reading entry	Meter Reading	POST /api/meterreading	Meter Reading Entry /billing/meter-readings/entry	-
FR-07	Previous vs current reading validation	Meter Reading	POST /api/meterreading GET /api/meterreading/previous/{connectionId}	Meter Reading Entry	-
FR-08	Consumption unit calculation	Meter Reading	POST /api/meterreading	Meter Reading Entry	-
FR-09	Auto bill generation based on consumption and tariff	Billing	POST /api/bill/generate POST /api/bill/generate/batch	Bill Generation /billing/bill-generation	-
FR-10	Apply taxes, fixed charges, and penalties to bills	Billing	POST /api/bill/generate	Bill Generation	-

Req ID	Requirement Description	Module	Backend API	Frontend Page	LINQ Usage
FR-11	Bill lifecycle management (Generated → Due → Paid → Overdue)	Billing	POST /api/bill/generate POST /api/bill/{id}/pay	Bill Generation View Bills	-
FR-12	Record payments (cash / online – mock)	Payment	POST /api/bill/{id}/pay	View Bills /consumer/bills	-
FR-13	Outstanding balance calculation	Payment	GET /api/payment/my GET /api/bill/outstanding	Payment History Outstanding Balances	LINQ-02
FR-14	Payment history view	Payment	GET /api/payment/my	Payment History /consumer/payments	-
FR-15	Monthly revenue report	Reports	GET /api/report/monthly-revenue-by-billing	Reports & Analytics /admin/reports /account-officer/dashboard	LINQ-01
FR-16	Outstanding dues report	Reports	GET /api/bill/outstanding GET /api/report/summary	Reports & Analytics Outstanding Balances	LINQ-02
FR-17	Consumption by utility type	Reports	GET /api/report/consumption	Reports & Analytics	LINQ-03
FR-18	Consumer-wise billing summary	Reports	GET /api/bill/consumers/summary	Consumer Billing Summary /account-officer/billing-summary	LINQ-04
FR-19	Bill generation notification	Notifications	Background Service	Notification Center	-
FR-20	Due date reminders	Notifications	Background Service	Notification Center	-
FR-21	Admin: Manage users	Admin	GET /api/user POST /api/user PUT /api/user/{id} DELETE /api/user/{id}	User Management /admin/users	-
FR-22	Admin: Manage utility types	Admin	GET /api/utilitytype POST /api/utilitytype PUT /api/utilitytype/{id} DELETE /api/utilitytype/{id}	Utility Types /admin/utilities	-
FR-23	Admin: Manage tariffs	Admin	GET /api/tariff POST /api/tariff PUT /api/tariff/{id} DELETE /api/tariff/{id}	Tariff Plans /admin/tariffs	-
FR-24	Admin: Manage billing cycles	Admin	GET /api/billingcycle POST /api/billingcycle PUT /api/billingcycle/{id} DELETE /api/billingcycle/{id}	Billing Cycles /admin/billing	-
FR-25	Consumer: View bills and invoices	Consumer	GET /api/bill/my GET /api/bill/my/{id}	View Bills /consumer/bills	-
FR-26	Consumer: View payment history	Consumer	GET /api/payment/my	Payment History /consumer/payments	-

Req ID	Requirement Description	Module	Backend API	Frontend Page	LINQ Usage
FR-27	Consumer: View consumption details	Consumer	GET /api/report/consumption/my GET /api/report/dashboard	Consumption Details Dashboard /consumer/consumption	-
FR-28	Billing Officer: Enter meter readings	Billing Officer	POST /api/meterreading	Meter Reading Entry /billing/meter-readings/entry	-
FR-29	Billing Officer: Generate bills	Billing Officer	POST /api/bill/generate POST /api/bill/generate/batch	Bill Generation /billing/bill-generation	-
FR-30	Account Officer: Track payments	Account Officer	GET /api/payment/audit	Track Payments /account-officer/payments	-
FR-31	Account Officer: Track outstanding balances	Account Officer	GET /api/bill/outstanding	Outstanding Balances /account-officer/outstanding	LINQ-02

Mandatory LINQ Requirements

Req ID	LINQ Requirement	Module	Backend API	LINQ Operation	Test Case ID	Status
LINQ-01	Total revenue per month	Reports	GET /api/report/monthly-revenue-by-billing	GroupBy(), Sum()	TC-L1	Impleme
LINQ-02	Outstanding dues calculation	Payment/Reports	GET /api/bill/outstanding GET /api/report/dashboard/summary	Where(), Sum()	TC-L2	Impleme
LINQ-03	Average consumption	Reports	GET /api/report/average-consumption	GroupBy(), Average()	TC-L3	Impleme
LINQ-04	Consumer-wise billing summary	Reports	GET /api/bill/consumers/summary	GroupBy(), Sum(), Count()	TC-L4	Impleme
LINQ-05	Filter bills by status	Billing	GET /api/bill/outstanding GET /api/bill/pending	Where()	TC-L5	Impleme
LINQ-06	Sort bills and payments	Billing/Payment	GET /api/bill/my GET /api/payment/my	OrderBy(), OrderByDescending()	TC-L6	Impleme
LINQ-07	Consumption by utility type	Reports	GET /api/report/consumption	GroupBy(), Sum()	TC-L7	Impleme

Non-Functional Requirements (NFR)

Req ID	Requirement Description	Module	Implementation	Test Case ID	Status
NFR-01	RESTful API design	All	All controllers follow REST conventions	TC-N1	Implemented
NFR-02	Centralized exception handling	All	GlobalExceptionMiddleware	TC-N2	Implemented
NFR-03	Secure handling of consumer and billing data	All	JWT authentication, role-based access, DTOs	TC-N3	Implemented
NFR-04	Maintainable and scalable codebase	All	Clean architecture, services, interfaces	TC-N4	Implemented
NFR-05	DTO usage to avoid exposing entities	All	46 DTOs in Models/Dto/	TC-N5	Implemented

Req ID	Requirement Description	Module	Implementation	Test Case ID	Status
NFR-06	Global exception handling middleware	All	GlobalExceptionMiddleware.cs	TC-N6	Implemented
NFR-07	Configuration via appsettings.json	All	JWT, database config in appsettings.json	TC-N7	Implemented
NFR-08	Angular modular architecture	Frontend	Feature modules by role	TC-N8	Implemented
NFR-09	Route guards for role-based access	Frontend	authGuard, loginGuard	TC-N9	Implemented
NFR-10	HTTP interceptor for JWT token	Frontend	authInterceptor	TC-N10	Implemented
NFR-11	Angular Reactive Forms	Frontend	Used in all forms	TC-N11	Implemented
NFR-12	Angular Material / Bootstrap	Frontend	Angular Material installed	TC-N12	Implemented

Test Case Mapping

Authentication & Authorization Tests

- **TC-01**: User registration test (AuthControllerTests.cs)
- **TC-02**: User login with JWT test (AuthControllerTests.cs)
- **TC-03**: Role-based access control test (AuthorizationTests.cs)

Consumer & Connection Tests

- **TC-04**: Consumer registration and profile management test (UserControllerTests.cs)
- **TC-05**: Connection management test (ConnectionControllerTests.cs)

Meter Reading Tests

- **TC-06**: Meter reading entry test (MeterReadingControllerTests.cs)
- **TC-07**: Reading validation test (MeterReadingServiceTests.cs)
- **TC-08**: Consumption calculation test (MeterReadingServiceTests.cs)

Billing Tests

- **TC-09**: Bill generation test (BillControllerTests.cs, BillServiceTests.cs)
- **TC-10**: Bill calculation (taxes, charges, penalties) test (BillCalculationServiceTests.cs)
- **TC-11**: Bill lifecycle test (BillServiceTests.cs)

Payment Tests

- **TC-12**: Payment recording test (PaymentControllerTests.cs, PaymentServiceTests.cs)
- **TC-13**: Outstanding balance calculation test (PaymentServiceTests.cs)
- **TC-14**: Payment history test (PaymentControllerTests.cs)

Reports Tests

- **TC-15**: Monthly revenue report test (ReportControllerTests.cs, ReportServiceTests.cs)
- **TC-16**: Outstanding dues report test (ReportControllerTests.cs, ReportServiceTests.cs)
- **TC-17**: Consumption by utility test (ReportControllerTests.cs, ReportServiceTests.cs)
- **TC-18**: Consumer billing summary test (AccountOfficerServiceTests.cs)

Notification Tests

- **TC-19**: Bill generation notification test (Background service)
- **TC-20**: Due date reminder test (Background service)

Admin Tests

- **TC-21**: User management test (UserControllerTests.cs, UserServiceTests.cs)
- **TC-22**: Utility type management test (UtilityTypeControllerTests.cs, UtilityTypeServiceTests.cs)
- **TC-23**: Tariff management test (TariffControllerTests.cs, TariffServiceTests.cs)
- **TC-24**: Billing cycle management test (BillingCycleControllerTests.cs, BillingCycleServiceTests.cs)

Consumer Tests

- **TC-25**: View bills test (BillControllerTests.cs)
- **TC-26**: Payment history test (PaymentControllerTests.cs)
- **TC-27**: Consumption details test (ReportControllerTests.cs)

Billing Officer Tests

- **TC-28**: Meter reading entry test (MeterReadingControllerTests.cs)
- **TC-29**: Bill generation test (BillControllerTests.cs)

Account Officer Tests

- **TC-30**: Track payments test (PaymentControllerTests.cs, AccountOfficerServiceTests.cs)
- **TC-31**: Track outstanding balances test (BillControllerTests.cs, AccountOfficerServiceTests.cs)

LINQ Tests

- **TC-L1**: Monthly revenue LINQ test (ReportServiceTests.cs, AccountOfficerServiceTests.cs)
- **TC-L2**: Outstanding dues LINQ test (PaymentServiceTests.cs, AccountOfficerServiceTests.cs)
- **TC-L3**: Average consumption LINQ test (ReportServiceTests.cs)
- **TC-L4**: Consumer billing summary LINQ test (AccountOfficerServiceTests.cs)
- **TC-L5**: Filter bills by status LINQ test (BillServiceTests.cs)
- **TC-L6**: Sort bills and payments LINQ test (BillServiceTests.cs, PaymentServiceTests.cs)
- **TC-L7**: Consumption by utility LINQ test (ReportServiceTests.cs)

Non-Functional Tests

- **TC-N1**: RESTful API design test (All controller tests)
- **TC-N2**: Exception handling test (GlobalExceptionMiddleware)
- **TC-N3**: Security test (AuthorizationTests.cs)
- **TC-N4**: Code architecture test (Code review)
- **TC-N5**: DTO usage test (Code review)
- **TC-N6**: Exception middleware test (Integration tests)
- **TC-N7**: Configuration test (appsettings.json validation)