Environmental Bowtie Risk Analysis

User Manual & Technical Documentation

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Contents

1 Executive Summary

The **Environmental Bowtie Risk Analysis** application (version 5.3.0) is a comprehensive R Shiny web application designed for environmental risk assessment using bowtie diagrams enhanced with Bayesian network integration. This production-ready edition provides a robust platform for analyzing marine biodiversity threats and ecosystem services impacts through probabilistic modeling.

1.1 Key Features

- **Interactive Bowtie Diagram Creation**: Visual risk assessment with drag-and-drop functionality
- **Guided 8-Step Workflow**: Step-by-step wizard for systematic risk analysis
- **Bayesian Network Integration**: Probabilistic modeling of environmental risks
- **Multi-Language Support**: English and French interfaces
- **12 Environmental Scenarios**: Pre-configured templates for common risk scenarios
- **Vocabulary Database**: 189 environmental elements (53 activities, 36 pressures, 74 controls, 26 consequences)
- **Export Capabilities**: Excel, RDS, and visual export options
- **Network Deployment Ready**: Configured for local network and production deployment

1.2 What's New in Version 5.3.0

1.2.1 UI/UX Improvements

- Vertically aligned environmental scenario selectors
- New Vocabulary Statistics card with real-time element counts
- Enhanced 3-column layout for better information density
- Improved responsive design

1.2.2 Bug Fixes

- Fixed Option 2b scenario generation error
- Resolved case-sensitivity issues for Linux deployment
- Corrected file references in deployment scripts
- Enhanced error handling with graceful fallbacks

1.2.3 Deployment Framework

- Complete Linux compatibility
- Windows PowerShell validation scripts
- Comprehensive deployment documentation
- Updated directory structure validation

1.2.4 Codebase Quality

- Cleaned up backup and temporary files
- Organized test files and utilities
- Enhanced .gitignore configuration
- Production-ready file structure

2 Getting Started

2.1 System Requirements

2.1.1 Minimum Requirements

- **Operating System**: Windows 10+, macOS 10.14+, Ubuntu 18.04+, Debian 10+, CentOS 7+
- **R Version**: 4.3.0 or higher
- **Memory**: 4 GB RAM
- **Disk Space**: 2 GB free space
- **Display**: 1280x720 minimum resolution
- **Browser**: Modern web browser (Chrome 90+, Firefox 88+, Safari 14+, Edge 90+)

2.1.2 Recommended Requirements

- **R Version**: 4.4.3 or higher
- **Memory**: 8 GB RAM or more
- **Disk Space**: 5 GB free space
- **Display**: 1920x1080 or higher
- **Network**: Required for deployment and collaboration features

2.1.3 Required R Packages

Core Packages (18):

```
shiny, bslib, DT, readxl, openxlsx
ggplot2, plotly, dplyr, visNetwork
shinycssloaders, colourpicker, htmlwidgets, shinyjs
bnlearn, gRain, igraph, DiagrammeR, Rgraphviz
```

All packages are automatically installed when the application starts for the first time.

2.2 Installation

2.2.1 Quick Start (Local Development)

1. **Clone or download** the application files
2. **Navigate** to the application directory
3. **Run** the application:

```r
# Option 1: Using start_app.R (recommended)
Rscript start_app.R

# Option 2: Using app.R
source("app.R")
```

4. **Access** the application at `http://localhost:3838`

2.2.2 Network Deployment

For team collaboration and network access:

```
# Start with network access
Rscript start_app.R
```

Access from: - **Local machine**: `http://localhost:3838` - **Network**: `http://[YOUR_IP]:3838`

2.2.3 Production Deployment (Linux)

For production deployment on Linux servers:

```
cd deployment
chmod +x *.sh
sudo ./check_deployment_readiness.sh
sudo ./deploy_shiny_server.sh --install-deps --backup
```

Access at: `http://[server-ip]:3838/bowtie_app/`

3 User Interface Overview

3.1 Main Navigation

The application features a modern Bootstrap 5 interface with the following main tabs:

3.1.1 1. Data Upload Tab

Upload or generate environmental risk data with three options: - **Option 1**: Upload Excel file (custom data) - **Option 2**: Generate from environmental scenarios (focused bowtie) - **Option 2b**: Generate with multiple controls (comprehensive bowtie)

3.1.2 2. Guided Workflow Tab

8-step wizard for creating bowtie diagrams: 1. Project Setup 2. Central Problem Definition 3. Threats & Causes 4. Preventive Controls 5. Consequences 6. Protective Controls 7. Review & Validate 8. Finalize & Export

3.1.3 3. Bowtie Diagram Tab

Interactive visualization of risk pathways with: - Zoomable and pannable network diagram - Color-coded risk elements - Interactive node selection - Export to PNG capability

3.1.4 4. Bayesian Network Tab

Probabilistic risk analysis with: - Network structure visualization - Conditional probability tables - Risk inference queries - Critical path identification

3.1.5 5. Data Table Tab

Editable data grid with: - Filtering and sorting - In-line editing - Bulk operations - Export capabilities

3.1.6 6. Risk Matrix Tab

Visual risk assessment showing: - Probability vs. Impact matrix - Risk categorization - Priority ranking - Mitigation recommendations

3.1.7 7. Vocabulary Management Tab

Manage environmental elements: - Activities (53 items) - Pressures (36 items) - Controls (74 items) - Consequences (26 items)

3.1.8 8. Help Tab

Comprehensive help and documentation

4 Working with Environmental Scenarios

4.1 Available Scenarios

The application includes 12 pre-configured environmental scenarios:

4.1.1 Core Environmental Scenarios (5)

1. **Marine Pollution from Shipping & Coastal Activities**
   - Focus: Maritime pollution, port operations, shipping impacts
   - Elements: Commercial shipping, ballast discharge, oil spills
   - Consequences: Marine ecosystem degradation, water quality issues
2. **Industrial Contamination through Chemical Discharge**
   - Focus: Industrial processes, chemical waste, manufacturing
   - Elements: Heavy metals, toxic waste, groundwater contamination
   - Consequences: Human health impacts, soil degradation
3. **Oil Spills from Maritime Transportation**
   - Focus: Petroleum transportation, tanker operations
   - Elements: Hydrocarbon pollution, surface contamination
   - Consequences: Coastal habitat destruction, economic losses
4. **Agricultural Runoff Causing Eutrophication**
   - Focus: Fertilizer application, livestock farming
   - Elements: Nutrient pollution, pesticide contamination
   - Consequences: Algal blooms, oxygen depletion, fish kills
5. **Overfishing and Commercial Stock Depletion**
   - Focus: Commercial fishing, marine resource depletion
   - Elements: Overharvesting, bycatch, habitat destruction
   - Consequences: Ecosystem imbalance, species extinction

4.1.2 Martinique-Specific Scenarios (7)

6. **Coastal Erosion and Beach Degradation**
7. **Sargassum Seaweed Influx Impacts**
8. **Coral Reef Degradation and Bleaching**
9. **Watershed Pollution from Agriculture**
10. **Mangrove Forest Degradation**
11. **Hurricane and Tropical Storm Impacts**
12. **Marine Tourism Environmental Pressures**

4.2 Using Scenarios

4.2.1 Option 2: Focused Bowtie Generation

Generates a clean, focused bowtie with: - **1 preventive control** per activity-pressure combination - ~**20-30 data rows** - **Ideal for**: Initial assessments, presentations, training

Steps: 1. Go to **Data Upload** tab 2. Scroll to **Option 2** 3. Select an environmental scenario 4. Click **"Generate Data"** 5. View results in **Bowtie Diagram** tab

4.2.2 Option 2b: Comprehensive Bowtie

Generates a detailed bowtie with: - **2-3 preventive controls** per activity-pressure combination - ~**40-90 data rows** - **Ideal for**: Detailed planning, compliance, risk management

Steps: 1. Go to **Data Upload** tab 2. Scroll to **Option 2b** 3. Select an environmental scenario 4. Click **"Multiple Controls"** 5. Review comprehensive analysis

5 Guided Workflow System

5.1 Overview

The Guided Workflow provides an 8-step wizard for systematic bowtie creation using the application's vocabulary database.

5.2 Step-by-Step Guide

5.2.1 Step 1: Project Setup

Purpose: Define basic project information

Fields: - Project Name - Description - Risk Assessor Name - Date - Environmental Scenario Template (optional)

Actions: - Fill in all required fields - Select a scenario template if applicable - Click **"Next Step"** to proceed

5.2.2 Step 2: Central Problem Definition

Purpose: Identify the core environmental problem

Fields: - Problem Statement - Problem Category - Geographic Scope - Temporal Scope

Tips: - Be specific and measurable - Focus on one central problem - Consider spatial and temporal boundaries

5.2.3 Step 3: Threats & Causes

Purpose: Identify activities and pressures leading to the problem

Process: 1. **Select Activities** (from 53 options) - Use search functionality - Select relevant human activities - Click "Add Activity"

2. **Select Pressures** (from 36 options)
    - Choose environmental pressures
    - Link to activities
    - View activity-pressure connections table

Vocabulary Integration: - Real-time search through all activities - Empty search widgets for immediate typing - Duplicate prevention - Visual feedback with data tables

5.2.4 Step 4: Preventive Controls

Purpose: Identify measures to prevent or reduce threats

Process: 1. Review selected threats from Step 3 2. Search through 74 available controls 3. Select appropriate preventive measures 4. Assign controls to specific threats 5. View controls table with assignments

Control Categories: - Technical controls - Procedural controls - Policy-based controls - Monitoring systems

5.2.5 Step 5: Consequences

Purpose: Identify potential environmental impacts

Process: 1. Search through 26 consequence categories 2. Select relevant environmental impacts 3. Assess severity levels 4. Link consequences to central problem 5. Review consequence hierarchy

Impact Types: - Ecosystem impacts - Biodiversity impacts - Human health impacts - Economic impacts - Social impacts

5.2.6 Step 6: Protective Controls

Purpose: Identify mitigation and recovery measures

Process: 1. Review selected consequences 2. Select protective mitigations 3. Assign recovery controls 4. Define escalation factors (if applicable) 5. Complete bowtie structure

Mitigation Types: - Emergency response - Damage limitation - Recovery measures - Restoration activities

5.2.7 Step 7: Review & Validate

Purpose: Verify completeness and consistency

Checks: - All required elements present - Logical connections established - No orphaned elements - Severity levels assigned - Complete pathways defined

Actions: - Review summary statistics - Validate connections - Make final adjustments - Confirm readiness to export

5.2.8 Step 8: Finalize & Export

Purpose: Export completed analysis

Export Options: 1. **Export to Main App** - Transfers data to main application - Opens Bowtie Diagram tab - Enables all analysis features

2. **Download Excel File**
    - Saves complete dataset
    - Compatible with main app upload
    - Includes all metadata
3. **Generate Report**
    - Creates summary document
    - Includes visualizations
    - Export as PDF/HTML

Completion: - Workflow complete notification - Option to start new project - Return to any step for revisions

6 Data Upload and Management

6.1 Supported Data Formats

6.1.1 Excel Files (.xlsx, .xls)

Required Columns:

```
Activity, Pressure, Preventive_Control, Central_Problem,
Consequence, Protective_Mitigation
```

Optional Columns:

```
Escalation_Factor, Activity_Category, Pressure_Category,
Control_Category, Consequence_Category, Risk_Level,
Probability, Impact, Notes
```

Example Structure:

```
Activity                   | Pressure           | Preventive_Control
Commercial shipping        | Oil spills         | Spill containment systems
Port operations           | Chemical pollution | Waste treatment facility
...
```

6.1.2 CSV Files (.csv)

Same structure as Excel, comma-separated values.

6.1.3 RDS Files (.rds)

R data format for saving/loading complete analyses including: - Data - Settings - Workflow state - Analysis results

6.2 Data Validation

The application performs automatic validation:

- Required columns present
- Data types correct
- No empty required fields
- Logical relationships valid
- Duplicate check
- Vocabulary compatibility

Validation Errors are displayed with: - Error type - Row/column location - Suggested fix - Option to auto-correct

6.3 Data Export Options

6.3.1 1. Excel Export

- Full dataset with all columns
- Formatted for readability
- Compatible with re-upload
- Includes metadata sheet

6.3.2 2. RDS Export

- Complete R data structure
- Preserves all settings
- Fastest load time
- Recommended for large datasets

6.3.3 3. CSV Export

- Universal compatibility
- Text-based format
- Easy integration with other tools
- No formatting preservation

6.3.4 4. Visual Exports

- PNG images of diagrams
- PDF reports
- HTML interactive views

7 Bayesian Network Analysis

7.1 Overview

The Bayesian Network feature converts bowtie diagrams into probabilistic models for advanced risk analysis.

7.2 Key Concepts

7.2.1 Conditional Probability Tables (CPTs)

Each node in the network has probabilities: - **Root nodes**: Prior probabilities - **Intermediate nodes**: Conditional probabilities given parents - **Consequence nodes**: Final outcome probabilities

7.2.2 Probabilistic Inference

Calculate: - **Forward propagation**: Activity → Pressure → Problem → Consequence - **Backward reasoning**: Given consequence, what's the most likely cause? - **Risk scenarios**: "What if" analysis with control failures

7.3 Using Bayesian Analysis

7.3.1 Step 1: Convert Bowtie to Bayesian Network

1. Load or create bowtie data
2. Go to **Bayesian Network** tab
3. Click **"Create Bayesian Network"**
4. View network structure

7.3.2 Step 2: Set Probabilities

Default Probabilities (can be customized): - Activities: 0.3 (30% likelihood) - Pressures: 0.5 (50% given activity) - Controls: 0.7 (70% effectiveness) - Consequences: 0.6 (60% given problem)

Custom Probabilities: 1. Select node in network 2. Edit probability table 3. Update values 4. Recalculate network

7.3.3 Step 3: Run Inference Queries

Query Types:

1. **Marginal Probability**: What's the probability of a specific consequence?
2. **Conditional Probability**: Given evidence, what's the updated probability?
3. **Most Probable Explanation**: What's the most likely pathway?
4. **Sensitivity Analysis**: Which factors have the most impact?

Example Queries:

```
# Probability of marine ecosystem degradation
P(Consequence = "Marine ecosystem degradation")

# Probability given oil spill occurred
P(Consequence | Pressure = "Oil spills")

# Most likely cause given consequence observed
argmax P(Activity | Consequence = "Water quality deterioration")
```

7.3.4 Step 4: Identify Critical Paths

The application automatically identifies: - **Highest risk pathways**: Combinations with highest probability - **Critical control points**: Controls with most impact - **Vulnerable nodes**: Elements with cascading effects

Critical Path Visualization: - Highlighted in red on network diagram - Probability values displayed - Recommended interventions shown

7.3.5 Step 5: Risk Propagation Analysis

Analyze how risks spread through the system: 1. Select starting point (activity or pressure) 2. View propagation probabilities 3. Identify amplification points 4. Assess control effectiveness

7.4 Interpretation Guidelines

7.4.1 Risk Levels

- **High Risk**: P $>$ 0.7 ($>$70%)
- **Medium Risk**: 0.4 P 0.7 (40-70%)
- **Low Risk**: P $<$ 0.4 ($<$40%)

7.4.2 Decision Making

Use Bayesian analysis to: - Prioritize interventions - Allocate resources efficiently - Evaluate control strategies - Monitor risk trends - Communicate uncertainty

8 Risk Matrix and Visualization

8.1 Risk Matrix Overview

The Risk Matrix provides a visual representation of risks based on two dimensions: - **Probability**: Likelihood of occurrence (Low, Medium, High) - **Impact**: Severity of consequences (Low, Medium, High)

8.2 Matrix Categories

8.2.1 Low Risk (Green Zone)

- **Probability**: Low
- **Impact**: Low to Medium
- **Action**: Monitor, routine management

8.2.2 Medium Risk (Yellow Zone)

- **Probability**: Medium
- **Impact**: Low to High
- **OR**
- **Probability**: Low to High
- **Impact**: Medium
- **Action**: Develop mitigation plans, regular review

8.2.3 High Risk (Red Zone)

- **Probability**: High
- **Impact**: Medium to High
- **OR**
- **Probability**: Medium to High
- **Impact**: High
- **Action**: Immediate intervention required, priority management

8.3 Using the Risk Matrix

1. **View Matrix**
    - Go to Risk Matrix tab
    - See all risks plotted
    - Color-coded by severity
2. **Filter Risks**
    - By category
    - By probability range
    - By impact level
    - By central problem
3. **Detailed Analysis**
    - Click on risk point
    - View complete pathway
    - See mitigation options

- Access recommendations

4. **Export Matrix**
   - Save as PNG image
   - Include in reports
   - Share with stakeholders

8.4 Visualization Features

8.4.1 Bowtie Diagram Customization

Color Schemes: - Activities: Blue - Pressures: Red - Preventive Controls: Green - Central Problem: Purple - Protective Mitigations: Cyan - Consequences: Orange - Escalation Factors: Yellow

Layout Options: - Hierarchical (default) - Circular - Force-directed - Custom positioning

Interaction: - Zoom and pan - Node selection - Hover for details - Export view

8.4.2 Network Visualization

Bayesian Network Display: - Directed acyclic graph (DAG) - Probability values on edges - Node size by importance - Interactive exploration

8.4.3 Data Table Visualization

Features: - Sortable columns - Filterable rows - Editable cells - Bulk operations - Export selection

9 Advanced Features

9.1 Vocabulary Management

9.1.1 Understanding the Vocabulary Database

The application includes a comprehensive vocabulary of 189 environmental elements:

- **53 Activities**: Human actions causing environmental pressures
- **36 Pressures**: Environmental stressors resulting from activities
- **74 Controls**: Measures to prevent or mitigate risks
- **26 Consequences**: Environmental impacts and outcomes

9.1.2 Viewing Vocabulary Statistics

Located in the Data Upload tab: - Real-time element counts - Category breakdown - Total available elements - Last update timestamp

9.1.3 Adding Custom Vocabulary

1. Go to **Vocabulary Management** tab
2. Select category (Activities, Pressures, Controls, Consequences)
3. Click **"Add New Element"**
4. Fill in details:
    - Name
    - Description
    - Category/hierarchy
    - Synonyms
    - Related elements
5. Click **"Save"**
6. Element available immediately

9.1.4 Editing Vocabulary

1. Select element from list
2. Click **"Edit"**
3. Modify fields
4. Click **"Update"**
5. Changes reflected across application

9.1.5 Importing Vocabulary

Import from Excel files: 1. Prepare Excel file with columns: - `hierarchy`, `id`, `name`, `description` 2. Go to Vocabulary Management 3. Click **"Import from Excel"** 4. Select file 5. Map columns 6. Import and validate

9.2 Multi-Language Support

9.2.1 Switching Languages

1. Look for language selector (top-right corner)
2. Available languages:
    - English
    - Français
3. Click to switch
4. Interface updates immediately

9.2.2 Supported Elements

Translated: - UI labels and buttons - Tab names - Help text - Error messages - Notifications - Field labels

Not Translated: - User data (your inputs) - Vocabulary elements (environmental terms) - Custom notes

9.2.3 Adding Translations

For developers: 1. Edit `translations_data.R` 2. Add new language code 3. Translate all keys 4. Update language selector 5. Test thoroughly

9.3 Batch Processing

9.3.1 Processing Multiple Scenarios

1. Prepare scenario list
2. Use batch import feature
3. Configure processing options
4. Run batch analysis
5. Export combined results

9.3.2 Automated Reporting

1. Define report template
2. Select scenarios
3. Configure output format
4. Generate batch reports
5. Download ZIP file with all reports

9.4 API Integration (Advanced)

9.4.1 REST API Endpoints

For programmatic access:

```
# Start API mode
shiny::runApp(port = 3838, host = "0.0.0.0", launch.browser = FALSE)

# Endpoints
GET  /api/scenarios          # List available scenarios
POST /api/analyze            # Submit analysis
GET  /api/results/{id}       # Retrieve results
GET  /api/export/{id}/{fmt}  # Export data
```

9.4.2 Python Integration Example

```
import requests

# Submit analysis
response = requests.post('http://localhost:3838/api/analyze', json={
    'scenario': 'marine_pollution',
    'options': {'controls': 'multiple'}
})

# Get results
results = requests.get(f"http://localhost:3838/api/results/{response.json()['id']}")
```

10 Troubleshooting

10.1 Common Issues

10.1.1 Issue: Application Won't Start

Symptoms: - Error loading packages - Port already in use - R version mismatch

Solutions:

1. **Check R Version**:

```
R.version.string  # Should be >= 4.3.0
```

2. **Install Missing Packages**:

```
source("requirements.R")
```

3. **Free Port 3838**:

```
# Windows
netstat -ano | findstr :3838
taskkill //F //PID <PID>

# Linux/Mac
lsof -i :3838
kill -9 <PID>
```

10.1.2 Issue: Data Upload Fails

Symptoms: - File not recognized - Validation errors - Missing columns

Solutions:

1. **Check File Format**:
   - Must be .xlsx, .xls, or .csv
   - Use template provided in Help tab
2. **Verify Required Columns**:

```
Activity, Pressure, Preventive_Control,
Central_Problem, Consequence, Protective_Mitigation
```

3. **Check Data Quality**:
   - No completely empty rows
   - No special characters in headers
   - Consistent data types

10.1.3 Issue: Bayesian Network Errors

Symptoms: - Network creation fails - Inference errors - Circular dependencies

Solutions:

1. **Check Data Structure**:
   - No circular relationships
   - All nodes have valid connections
   - Probability values between 0 and 1
2. **Validate Bowtie**:
   - Complete pathways
   - No orphaned elements
   - Logical flow maintained
3. **Reset Network**:
   - Clear cache
   - Recreate network
   - Reload data

10.1.4 Issue: Guided Workflow Stuck

Symptoms: - Cannot proceed to next step - Data not saving - Export fails

Solutions:

1. **Complete Required Fields**:
   - All mandatory fields filled
   - At least one element in each category
   - Validation passing
2. **Clear Cache**:

```
source("utils/clean_workflow_cache.R")
```

3. **Restart Workflow**:
   - Save progress to Excel
   - Start new workflow
   - Import saved data

10.1.5 Issue: Performance Slow

Symptoms: - Slow loading - Laggy interactions - Timeout errors

Solutions:

1. **Check System Resources**:
   - Close other applications
   - Free memory (need 4GB+)
   - Check CPU usage

2. **Reduce Data Size**:
   - Filter unnecessary rows
   - Limit scenario scope
   - Export and re-import
3. **Clear Browser Cache**:
   - Force refresh (Ctrl+F5)
   - Clear browser data
   - Try different browser

10.1.6 Issue: Export Not Working

Symptoms: - Download fails - Corrupted files - Missing data

Solutions:

1. **Check File Permissions**:
   - Write access to download folder
   - Sufficient disk space
2. **Try Different Format**:
   - If Excel fails, try CSV
   - If RDS fails, try Excel
3. **Export Smaller Subset**:
   - Filter data
   - Export in batches
   - Combine manually

10.2 Getting Help

10.2.1 Built-in Help

1. **Help Tab**: Comprehensive in-app documentation
2. **Tooltips**: Hover over ? icons for quick help
3. **Examples**: Sample datasets provided

10.2.2 Community Support

- **GitHub Issues**: Report bugs and request features
- **Documentation**: Full docs at project repository
- **Email Support**: Contact Marbefes team

10.2.3 Diagnostic Information

When reporting issues, include: - Version number (5.3.0) - Operating system - R version - Error messages (full text) - Steps to reproduce - Screenshots if applicable

11 Appendices

11.1 Appendix A: Keyboard Shortcuts

Shortcut	Action
`Ctrl + S`	Save current data
`Ctrl + E`	Export data
`Ctrl + Z`	Undo last action
`Ctrl + Y`	Redo action
`Ctrl + F`	Find/Search
`Ctrl + +`	Zoom in diagram
`Ctrl + -`	Zoom out diagram
`Ctrl + 0`	Reset zoom
`Esc`	Close modal/dialog
`Tab`	Next field
`Shift + Tab`	Previous field

11.2 Appendix B: File Locations

11.2.1 Application Structure

```
bowtie_app/
  app.R                          # Main launcher
  global.R                       # Configuration
  ui.R                           # User interface
  server.R                       # Server logic
  config.R                       # Settings
  CAUSES.xlsx                    # Activities & Pressures
  CONSEQUENCES.xlsx              # Consequences
  CONTROLS.xlsx                  # Controls
  deployment/                    # Deployment scripts
  tests/                         # Test suite
  docs/                          # Documentation
  data/                          # User data storage
  www/                           # Static assets
```

11.2.2 Data Files Location

- **Linux**: `/srv/shiny-server/bowtie_app/data/`
- **Windows**: `[AppDir]/data/`
- **Network**: Accessible via web interface

11.2.3 Log Files

- **Application**: `[AppDir]/logs/app.log`
- **Shiny Server**: `/var/log/shiny-server/bowtie_app/`
- **Error Log**: `[AppDir]/logs/error.log`

11.3 Appendix C: Environmental Scenarios Reference

11.3.1 Scenario: Marine Pollution

Central Problem: Marine pollution from shipping activities

Key Elements: - Activities: Commercial shipping, port operations, oil transportation - Pressures: Chemical pollution, oil spills, ballast discharge - Controls: Spill containment, waste treatment, monitoring systems - Consequences: Ecosystem degradation, water quality deterioration

Use Cases: Ports, shipping routes, coastal development

11.3.2 Scenario: Agricultural Runoff

Central Problem: Agricultural runoff causing eutrophication

Key Elements: - Activities: Fertilizer application, livestock farming, intensive agriculture - Pressures: Nutrient pollution, fertilizer runoff, pesticide contamination - Controls: Best management practices, buffer zones, treatment wetlands - Consequences: Eutrophication, algal blooms, oxygen depletion

Use Cases: Agricultural watersheds, river basins, coastal zones

11.3.3 Scenario: Industrial Contamination

Central Problem: Industrial contamination through chemical discharge

Key Elements: - Activities: Manufacturing, chemical processing, mining operations - Pressures: Heavy metals, toxic waste, groundwater contamination - Controls: Waste treatment, containment systems, monitoring - Consequences: Human health impacts, soil degradation, water pollution

Use Cases: Industrial areas, manufacturing sites, mining regions

[Additional scenarios follow similar structure…]

11.4 Appendix D: Glossary

Activity: Human action that generates environmental pressures

Bayesian Network: Probabilistic graphical model representing causal relationships

Bowtie Diagram: Risk visualization showing causes, controls, consequences

Central Problem: Core environmental issue being analyzed

Consequence: Environmental or social impact resulting from the problem

CPT (Conditional Probability Table): Probabilities defining Bayesian network relationships

Escalation Factor: Event or condition that weakens controls

Mitigation: Measure to reduce consequence severity

Pathway: Sequence from activity through to consequence

Pressure: Environmental stressor resulting from human activity

Preventive Control: Measure to prevent problem occurrence

Protective Control: Measure to limit consequences

Risk: Combination of probability and impact

Scenario: Pre-configured set of environmental risk elements

Vocabulary: Database of standardized environmental terms

11.5 Appendix E: Version History

11.5.1 Version 5.3.0 (November 2025) - Current

- Production-ready release
- UI/UX improvements (vertical alignment, vocabulary statistics)
- Bug fixes (Option 2b, case-sensitivity)
- Linux deployment compatibility
- Cleaned codebase structure
- Comprehensive documentation

11.5.2 Version 5.2.0 (November 2025)

- Modern framework edition
- Enhanced testing infrastructure
- Performance improvements
- Advanced benchmarking

11.5.3 Version 5.1.0 (September 2025)

- Network deployment ready
- Enhanced scenarios
- Improved guided workflow
- Multi-language support

11.5.4 Version 5.0.0 (August 2025)

- Complete redesign
- Bayesian network integration
- Guided workflow system
- Vocabulary management

[Earlier versions…]

11.6 Appendix F: References

11.6.1 Standards and Guidelines

- ISO 31000:2018 - Risk Management
- IEC 31010:2019 - Risk Assessment Techniques
- ISO 14001:2015 - Environmental Management Systems

11.6.2 Scientific Literature

- Bowtie methodology for risk assessment
- Bayesian networks in environmental science
- Marine biodiversity conservation
- Ecosystem services valuation

11.6.3 Software and Tools

- R Statistical Software: https://www.r-project.org/
- Shiny Framework: https://shiny.rstudio.com/
- bnlearn Package: https://www.bnlearn.com/
- gRain Package: https://people.math.aau.dk/~sorenh/software/gR/

11.7 Contact Information

Project: Environmental Bowtie Risk Analysis **Version**: 5.3.0 **Organization**: Marbefes Team **Website**: [Project Repository] **Support**: [Support Email] **License**: [License Type]

End of User Manual

This document is subject to updates. Please check for the latest version.