

πby3

π - Ingest

PostgreSQL Source Connector – Snowflake Native App

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1 Introduction

This document outlines the requirements, architecture, and implementation details for the Pi-Ingest solution for PostgreSQL. The objective of this initiative is to deliver a secure, scalable, and reliable data ingestion framework—distributed as a Snowflake Native App—that enables seamless extraction of data from PostgreSQL databases into the consumer's Snowflake account for downstream analytics and operational monitoring.

The document serves as a single source of truth for all stakeholders involved in the project, including business users, data engineers, solution architects, testers, and project managers. It captures both functional and non-functional requirements, along with detailed backend and frontend implementation approaches within the Snowflake Native App Framework.

The Pi-Ingest solution leverages the Snowflake Native App distribution model and high-performance capabilities such as Snowpark Container Services (SPCS), Snowflake Image Repositories, and Reference Binding for secure secrets management and external access. This approach ensures that all logic is executed within an isolated, secure environment in the consumer's account, maintaining strict data governance and operational efficiency.

This initiative is part of the broader Pi-Snow roadmap and is designed to improve data ingestion reliability, observability, and scalability through a packaged application model. It follows the established Pi-Ingest framework while incorporating PostgreSQL-specific source connectivity, authentication, and data type mapping. The solution supports current and future reporting and analytics needs while minimizing manual configuration for the end user.

2 Key Considerations

This section outlines the foundational elements that influence the scope, planning, and execution of the Pi-Ingest PostgreSQL project, including scope boundaries, assumptions, dependencies, and risks.

2.1 Scope

The scope of this project includes the following:

- Data ingestion from PostgreSQL databases into Snowflake.
- Support for full and incremental data extraction.
- Data loading into raw and curated Snowflake layers.
- Execution of ingestion and transformation jobs using Snowpark Container Services (SPCS).
- Centralized logging and monitoring of ingestion and transformation job execution.

2.2 Out of Scope

- Data ingestion from sources other than PostgreSQL
- Advanced analytics, reporting, or dashboarding for business insights

2.3 Assumptions

Sr. No	Description	Implications, if not met
1	Active PostgreSQL account with read access to the required schemas/tables and IP access enabled for Snowflake egress	Unable to extract PostgreSQL data
2	Snowflake account with Enterprise edition and SPCS enabled	Application cannot be deployed or executed
3	Required Snowflake roles and permissions are available	Objects and services cannot be created
4	Snowflake network access to the PostgreSQL endpoint (host:port) is allowed on the account (Enterprise paid edition)	External connectivity will fail
5	PostgreSQL server accepts connections from Snowflake (pg_hba.conf / security group / firewall) and SSL settings are known	Connection is refused or rejected

2.4 Dependencies

Sr. No	Description	Owner	Implications, if not met
1	PostgreSQL credentials (user, password, database, host, port)	PostgreSQL DBA / Admin Team	Data extraction cannot be initiated
2	Application installation and granting of account-level privileges	Consumer AccountAdmin	App cannot provision infrastructure or execute jobs
3	Security approval and Reference Binding for Secrets and External Access	Consumer AccountAdmin	Application is blocked from connecting to PostgreSQL
4	Compute pool and warehouse availability (bound via references)	Consumer AccountAdmin	Job execution delays or failures

2.5 Risks

Sr. No	Description	Mitigation Strategy
1	Credential exposure or misconfiguration	Use Snowflake Secrets with Reference Binding so credentials remain encrypted and never leave the consumer account boundary
2	Consumer region incompatibility for SPCS	Validate Snowpark Container Services availability in the target consumer region prior to app installation
3	Load impact on the PostgreSQL production server	Use read replicas where possible, dynamic chunking, and off-peak schedules; limit concurrent table extractions
4	Data type incompatibility between PostgreSQL and Snowflake (e.g., arrays, JSONB, geometric types)	Apply documented type mapping (Section 5.6); unsupported types are cast to VARCHAR / VARIANT

3 Business Feature Details

This section outlines the key business functionalities delivered by the Pi-Ingest solution. Each feature is aligned with business objectives to ensure reliable, secure, and timely availability of PostgreSQL data for downstream analytics and operational monitoring.

3.1 Business Process Flow

The Pi-Ingest solution enables end-to-end movement of structured data from PostgreSQL into Snowflake. PostgreSQL data is securely extracted using a PostgreSQL driver over an approved External Access Integration and ingested into Snowflake. The data is validated, transformed as required, and stored in structured layers to support analytics and reporting.

Processed data and operational metadata are made available for downstream consumption and monitoring, ensuring transparency and reliability of data ingestion processes.

3.2 RBAC & UBAC

Role Based Access Control (RBAC) and User Based Access Control (UBAC) are implemented to ensure secure and governed access to data within Snowflake.

RBAC

- Access is granted based on predefined roles (e.g., Data Engineer, Data Analyst, Read-Only User)
- Roles control access to databases, schemas, tables, views, and compute resources

UBAC

- User access is mapped to roles based on business needs
- Access is provisioned following the principle of least privilege

3.3 Refresh Schedule

- **Full Load:** Initial one-time historical data load
- **Incremental Load:** Scheduled periodic refreshes based on Last Extracted Time (watermark column such as `updated_at` or an incrementing key)
- **Refresh Frequency:** Daily / Hourly (configurable based on business requirements)
- **Failure Handling:** Failed loads are logged and can be re-run without duplicating data

3.4 Monitoring & Operational Visibility

The solution includes monitoring and logging capabilities to provide visibility into ingestion and transformation activities.

- Execution status of ingestion and transformation jobs is captured centrally
- Success and failure details are logged for audit and troubleshooting
- Operational metrics such as load duration and record counts are tracked
- Consumers can configure Snowflake Alerts on top of the logging tables to enable timely resolution of critical ingestion failures

4 Technical Feature Details

This section outlines the technical interpretation of the business features. It translates business needs into technical components, ensuring alignment between business goals and system capabilities within the Snowflake Native App Framework. It includes data modeling, transformation logic, and the integration of Snowflake-native compute resources.

4.1 Technical Architecture

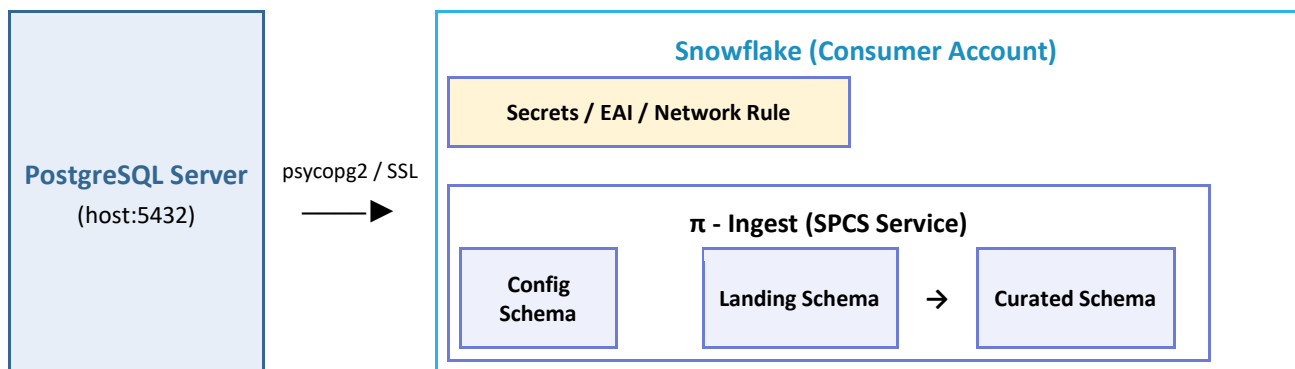


Fig. Pi-Ingest (PostgreSQL) Architecture

The solution follows a Snowflake Native App architecture, where all application logic, container images, and database objects are bundled into an Application Package and installed directly into the consumer's Snowflake account.

- **PostgreSQL Connectivity:** Acts as the source system; data is extracted using a PostgreSQL driver (psycopg2) over Snowflake External Access Integrations (EAI) to the configured host and port (default 5432).
- **Execution Engine:** Ingestion and transformation logic are executed using Snowpark Container Services (SPCS), providing a high-performance, isolated environment for Python-based processing.
- **Secure Credential Management:** PostgreSQL credentials are stored as Snowflake Secrets and linked to the application via Reference Binding, ensuring they never leave the consumer's security perimeter.
- **Dynamic Chunking:** The extraction chunk size is calculated at runtime from the source table's row count and column count, so no chunk-size setting is stored in the configuration tables.
- **Data Tiering:** Extracted data is landed into an internal Landing Schema before transformation logic is applied to move data into final curated schemas within the application instance.
- **Automated Provisioning:** Ingestion jobs are orchestrated using Snowflake Tasks to trigger the SPCS service on a configurable schedule.

4.2 RBAC & UBAC

Access control is implemented using Application Roles defined within the Native App, which are then mapped to the consumer's account-level roles to ensure governed access.

- **Application Roles:** Defines internal roles (e.g., APP_ADMIN) that control access to the application's internal schemas, stored procedures, and compute pools.

- **Consumer Mapping:** The consumer account administrator maps these Application Roles to their own internal business roles (Data Engineer, Analyst) using Snowflake's RBAC.
- **Data Isolation:** Sensitive PostgreSQL objects are stored in restricted schemas, ensuring that only authorized roles can view raw or curated datasets.

4.3 Logging & Monitoring

Logging and monitoring are implemented to track data ingestion, health, and operational issues.

- **Audit Logging:** Ingestion job execution status and container logs are captured in the `CONFIG_PG_INGEST` schema.
- **Data Reconciliation:** Record counts and load timestamps are captured for every run to ensure data parity between PostgreSQL and Snowflake.
- **Error Handling:** Detailed error logs are generated for failed queries, connection errors, or container crashes, providing the consumer with self-service troubleshooting capabilities.

4.4 Secrets & Secure Access Management

This solution implements secure credential management and controls external connectivity to PostgreSQL without exposing sensitive information in the application code or to the application provider.

- **Consumer-Owned Secrets:** PostgreSQL authentication details are stored as Snowflake Secrets within the consumer's account and linked to the application via Reference Binding, ensuring the provider never has access to the raw credentials.
- **External Access Integration (EAI):** Outbound connectivity to PostgreSQL is managed through an EAI reference. This allows the consumer to define and audit the specific network rules and hosts the application is permitted to access.
- **Secure Reference at Runtime:** Internal secure functions and procedures programmatically access the bound secrets only at the moment of execution, maintaining a high level of security isolation.
- **Zero-Hardcoding Policy:** No credentials, tokens, or sensitive endpoint configurations are hardcoded within the application package or its metadata files, meeting Snowflake's strict security review requirements.
- **RBAC-Governed Security:** Access to the required secrets and network integrations is governed through the application's internal roles, which the consumer maps to their account-level RBAC for centralized control.

4.4.1 PostgreSQL Secrets Management

- **Secret Type:** PostgreSQL credentials are stored as Snowflake `GENERIC_STRING` secrets.
- **Payload:** Secrets include user, password, database, host, port (and optionally `sslmode`).
- **Provider Isolation:** Secrets are bound to the application through references at runtime; the application logic uses them without ever exposing the raw values to the application provider.
- **Access Control:** Access to create and manage these secrets is restricted using the consumer's Snowflake RBAC.

4.4.2 Network Rule Configuration

- **Egress Control:** Egress network rules (MODE = EGRESS, TYPE = HOST_PORT) allow outbound access only to the approved PostgreSQL host and port.
- **Whitelisting:** The PostgreSQL endpoint ("your_host:5432") is explicitly whitelisted to prevent unauthorized data egress.
- **Granular Security:** Network rules ensure that the application's container services can only communicate with the verified PostgreSQL endpoint.

4.4.3 External Access Integration

- **Reference Binding:** The application requests access to a consumer-defined EAI through Reference Binding, allowing the consumer to audit and approve connectivity.
- **Security Association:** The EAI explicitly links the approved Network Rules and PostgreSQL Secrets into a single security context.
- **Restricted Execution:** Only the authorized internal services and secure functions within the application instance are permitted to use the integration.
- **Governance:** The integration is enabled and governed by the consumer's RBAC, providing a "kill-switch" capability at the account level.

4.4.4 Secure Function for Credential Access

- Secure functions reference Snowflake Secrets internally.
- External Access Integration is used to allow outbound connections within the function.
- The function returns connection parameters to the service without exposing credentials.
- Only authorized roles can execute the secure function.

5 Technical Details - Backend

The secure, versioned instance of the Pi-Ingest app installed in the consumer account encapsulates all internal schemas used to store configurations, operational logs, raw landing data, and curated PostgreSQL datasets.

5.1.1 Database Details in Snowflake Environment

Sr. No	Object Name	Object Type	Description
1	PI_INGEST_APP	APPLICATION DATABASE	The secure, versioned instance of the Pi-Ingest app installed in the consumer account. It encapsulates all internal schemas used to store configurations, operational logs, raw landing data, and curated PostgreSQL datasets.

5.2 Schema Details

5.2.1 Schema Details in Snowflake Environment

Sr. No	Layer	Object Name	Object Type	Description
1	Configuration	CONFIG_PG_INGEST	SCHEMA	Internal application schema used to store ingestion job metadata, control tables, and configuration for the Pi-Ingest framework.
2	Logs	CONFIG_PG_INGEST	SCHEMA	Internal application schema that captures audit trails, error logs, and operational telemetry for all ingestion and transformation activities.
3	Raw	LANDING_PG_INGEST	SCHEMA	Internal staging schema where raw data extracted from PostgreSQL is initially landed before processing.
4	Curated	PG_INGEST	SCHEMA	Target analytics schema containing the final transformed, cleansed, and curated PostgreSQL datasets ready for business consumption.

5.3 Table Details

5.3.1 Table Details in Snowflake Environment

Sr. No	Layer	Object Name	Object Type	Description
1	Configuration	CONFIG_PG_INGEST.JOB_CONFIGS	TABLE	Internal metadata table containing ingestion job parameters, refresh schedules, and PostgreSQL configuration details.
2	Configuration	CONFIG_PG_INGEST.TABLE_CONFIGS_DAILY	TABLE	Internal application table where the ingestion tables' metadata is stored for extraction logic (source schema/table, target table, load type, watermark column).
3	Logs	CONFIG_PG_INGEST.AUDIT_LOG	TABLE	Operational telemetry table tracking every execution status, run IDs, record counts, and ingestion timestamps.

Sr. No	Layer	Object Name	Object Type	Description
4	Logs	CONFIG_PG_INGEST.ERROR_LOG	TABLE	Exception handling table capturing detailed error messages, connection/query failure codes, and stack traces for troubleshooting.
5	Raw	LANDING_PG_INGEST.<SOURCE_TABLE>	TABLE	Internal staging table containing the raw, unmodified data extracted from the PostgreSQL source table (one per configured table).
6	Curated	PG_INGEST.<TARGET_TABLE>	TABLE	Final presentation table containing cleaned and structured data ready for downstream analytics.

5.4 Objects Details

5.4.1 Object Details in Snowflake Environment

Sr. No	Object Name	Object Type	Description
1	CONFIG_PG_INGEST.PG_GET_SECRETS	PROCEDURE	Stored procedure that uses Reference Binding to safely retrieve PostgreSQL connection details from consumer-owned secrets.
2	CREATE_PG_FUNCTION	PROCEDURE	Initialization procedure that instantiates the secure functions and services during app setup.
3	PG_INGEST_SERVICE	SERVICE	Snowpark Container Service (SPCS) instance that executes the core Pi-Ingest Python logic (pg_ingest.py) within an isolated compute environment.

5.5 Snowflake Container Services (SPCS) Deployment

This section describes the backend deployment of the application using Snowpark Container Services within the Snowflake Native App Framework.

- **Packaging:** The ingestion logic is containerized using Docker and bundled into the Application Package.
- **Image Security:** Docker images are stored in an internal Application Image Repository, which is scanned by Snowflake for security vulnerabilities prior to app distribution.
- **Service Instantiation:** Snowflake Services are created within the Application Instance in the consumer account to run the containerized logic.

- **Isolated Compute:** The service executes ingestion and transformation jobs within an isolated, Snowflake-managed environment, ensuring the consumer's data never leaves their Snowflake security boundary.
- **Reference-Based Configuration:** Resource requirements and environment-specific configurations (warehouse, secret, EAI, compute pool) are managed through the application's manifest and service specifications.

5.5.1 Compute Pool Configuration

- A dedicated compute pool is created for Pi-Ingest execution.
- The compute pool is configured with fixed minimum and maximum nodes to control resource usage.

Sr. No	Object Name	Object Type	Description
1	PI_INGEST_COMPUTE_POOL	COMPUTE POOL	An account-level compute resource provisioned by the consumer and bound to the application to provide the physical infrastructure for the ingestion service.

5.5.2 Snowflake Service Details

The ingestion logic is executed as a Snowpark Container Service (SPCS) within the secure boundary of the Application Instance.

- **Internal Service:** Internal Snowflake services are instantiated within the application instance to run the containerized Pi-Ingest logic.
- **Infrastructure Binding:** The services execute on the consumer-provisioned compute pool and warehouse, linked to the application via Reference Binding.
- **Secure Egress:** PostgreSQL connectivity is enabled by binding a consumer-defined External Access Integration (EAI) to the service at runtime.
- **Lifecycle Management:** Service controls (Start, Suspend, Resume) are managed through the application's secure stored procedures, allowing automated orchestration and centralized logging.

Sr. No	Service Name	Description
1	PG_INGEST_SERVICE	Executes the primary daily batch ingestion and transformation jobs within the application container.

6 Troubleshooting Scenarios & Recommendations

This section outlines common technical issues that may arise during system operation along with recommended steps for diagnosis and resolution.

Scenario	Description	Possible Causes	Recommended Actions
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Scenario	Description	Possible Causes	Recommended Actions
Ingestion failure	Ingestion job does not complete	Data type mismatch; table or column renamed in source; statement timeout	Review ERROR_LOG, update ingestion logic or type mapping, verify TABLE_CONFIGS_DAILY entries
Connectivity error	Application fails to authenticate or connect to PostgreSQL	Reference binding for Secret or EAI missing/invalid; credentials expired; wrong host or port	Verify and re-bind application references in Settings; validate PostgreSQL secret values; confirm network rule host:port

7 Glossary

This section defines key terms, acronyms, and technical language used throughout the document. It ensures a common understanding among all contributors and stakeholders.

Term	Definition
Application Instance	The deployed manifestation of the application within the Consumer's Snowflake account, encapsulating all data, logic, and metadata.
Consumer Account	The Snowflake account where the Pi-Ingest application is installed, configured, and executed.
DAG	Directed Acyclic Graph – a representation of the workflow orchestration logic, defining the sequence and dependencies of ingestion tasks.
EAI	External Access Integration – a Snowflake security object that allows the application to securely communicate with external PostgreSQL endpoints.

8 Reference Artifacts & Editable Links

This section provides direct access to project artifacts and reference documentation. These resources are maintained in shared locations to ensure version control and collaborative updates.

Asset Type	Description	Official Doc Link
Snowflake Documentation	Official Snowflake documentation portal	https://docs.snowflake.com
Getting Started	Guide for onboarding and initial setup with Snowflake	Get Started - Snowflake Documentation

Asset Type	Description	Official Doc Link
User Guides	Deep documentation covering Snowflake usage, warehouses, tables, and data loading	Using Snowflake Snowflake Documentation
Architecture & Core Concepts	Explains Snowflake's distributed architecture and core platform design	Snowflake key concepts and architecture Snowflake Documentation
Integration / Connectors	Official docs related to connectors, drivers, and integrating external systems	Guides - Snowflake Documentation
ETL / Data Loading Patterns	Guidance on Snowpipe, bulk loads, and third party integration methods	All Partners
Snowflake Container Services (SPCS)	Overview and concepts for running containerized workloads	https://docs.snowflake.com/en/developer-guide/snowpark-container-services/overview
Compute Pools	Configuring and managing compute pools	https://docs.snowflake.com/en/developer-guide/snowpark-container-services/working-with-compute-pool
Image Repository	Storing and managing Docker images in Snowflake	https://docs.snowflake.com/en/developer-guide/snowpark-container-services/working-with-registry-repository
External Access Integration	Secure outbound network access from Snowflake	https://docs.snowflake.com/en/sql-reference/sql/create-external-access-integration
Network Rules	Defining egress network rules	https://docs.snowflake.com/en/sql-reference/sql/create-network-rule
Snowflake Secrets	Secure storage and usage of credentials	https://docs.snowflake.com/en/sql-reference/sql/create-secret
Secure Functions	Protecting sensitive logic and credentials	https://docs.snowflake.com/en/sql-reference/sql/create-function

9 Appendix

This section includes supporting information, usage guidelines, and references.

9.1 Usage Guidelines for Contributors

- Follow established naming conventions for Snowflake objects, application roles, and manifest-defined references.
- Ensure all ingestion and transformation jobs write detailed execution telemetry to the internal `CONFIG_PG_INGEST` schema.
- All container images must undergo a mandatory security scan and patch update before a new Application Version or Patch is published.
- Do not modify the `setup.sql` or `manifest.yml` files without an approved change request and versioning plan.

9.2 Environment Deployment Guide

This section provides guidance for installing and configuring the Pi-Ingest PostgreSQL application instance within a consumer environment.

9.2.1 Prerequisites

- **Snowflake Account:** Enterprise Edition (or higher) with Snowpark Container Services (SPCS) enabled in the target region.
- **Administrative Privileges:** The installing user must have a role with `ACCOUNTADMIN` or the ability to grant `CREATE COMPUTE POOL` and `BIND SERVICE ENDPOINT` to the application.
- **Security Objects:** PostgreSQL credentials must be stored as a Snowflake Secret (`GENERIC_STRING`) within the consumer account.
- **Network Governance:** Pre-defined Network Rules and an External Access Integration (EAI) must be available for Reference Binding to permit PostgreSQL egress.

9.2.2 Deployment Steps

The deployment of a Snowflake Native App follows a provider-consumer model. The following steps outline the end-to-end process:

- **Image Provisioning (Provider):** Build and push the Pi-Ingest PostgreSQL Docker images to the Image Repository within the Application Package.
- **Version Creation (Provider):** Define the application logic in the `setup.sql` and `manifest.yml` files, then create a new Application Version.
- **App Installation (Consumer):** Install the Application Instance from the Snowflake Marketplace or a Private Listing.
- **Reference Binding (Consumer):** Securely bind account-level objects (PostgreSQL Secret, External Access Integration, Warehouse) to the application's required references via the Settings UI or SQL.
- **Privilege Granting (Consumer):** Grant the application the `CREATE COMPUTE POOL` and related privileges to allow the app to manage its own infrastructure.
- **App Initialization (Consumer):** Execute the internal application procedures (e.g., `CALL CREATE_PG_FUNCTION()`) to instantiate the secure functions and services.

9.2.3 Environment Configuration

- **Service Isolation:** Separate Snowpark Container Services are instantiated for different ingestion schedules.

- **Metadata Management:** Run-specific parameters are configured within the application's internal metadata tables (JOB_CONFIGS and TABLE_CONFIGS_DAILY_DAILY) in CONFIG_PG_INGEST.
- **Role Mapping:** Access control is enforced by mapping Application Roles (e.g., APP_ADMIN) to the consumer's existing Snowflake RBAC structure.

9.2.4 Validation

Once the installation is complete, the following checks ensure the application is operational:

- **Reference Verification:** Confirm that all required references (Secret, EAI, Compute Pool, Warehouse) show a status of 'ASSOCIATED'.
- **Service Status:** Verify that the Snowpark Container Service status is RUNNING using the application's monitoring procedures.
- **Ingestion Health:** Confirm successful data extraction and transformation by reviewing the AUDIT_LOG table.
- **Log Validation:** Ensure that container logs and error entries are correctly populated in the CONFIG_PG_INGEST schema.
- **Availability:** Confirm that all application objects (tables, views, and procedures) are visible and accessible to authorized consumer roles.

10 Support & Contact Information

10.1 Technical Support

For issues related to ingestion failures, connectivity troubleshooting, or bug reporting, the Pi-Snow Support Team is available to assist:

- **Email:** Admin@Pibythree.com, Alliance@Pibythree.com

Note: As this is a Snowflake Native App, please ensure you have checked the internal CONFIG_PG_INGEST.ERROR_LOG table before reaching out, as this will help our team expedite your request.

10.2 Business & Sales Inquiries

For inquiries regarding the broader Pi-Snow roadmap, licensing for additional PostgreSQL objects, or custom integration needs:

- **Contact:** Alliance@pibythree.com
- **Website:** www.pibythree.com

10.3 Documentation & Feedback

To access the latest version of this document or to provide feedback on the application's performance, visit the Pi Accelerators by PibyThree documentation portal.

10.4 Customization & Full Product

This can be configured and customized to support a wide range of structured databases / RDBMS. For implementation, please contact us.