# The importance of the concept of time in the design of data structures: A literature review within the framework of the LMD system

[1]Faustin PADINGANYI TSHIOMBELA, [2]Jonathan NKIWA MONKILA, [3]CedricK KWETE KWETE

[123]Lecturer-Researcher
[123]ISS-KIN, DRC

***Abstract*—Database designers and administrators regularly encounter difficulties when managing enterprise data due to poorly adapted structures, particularly when dealing with temporal data (specific to an academic year, semester, or month). Based on the MERISE method and document analysis, this study proposes a modeling approach that integrates the temporal variable at the conceptual level within the LMD system framework. Applying this method to the academic transcript management of students at the Higher Institute of Statistics of Kinshasa (ISS/KIN) highlighted the structural limitations of a static Conceptual Data Model (CDM). The results demonstrate that incorporating associations containing temporal attributes (such as course scheduling, credit transfers, and annual enrollments) guarantees historical traceability, prevents data overwrite, and enables the accurate generation of past, present, and future academic records.**

***Index Terms*—Design, Data structure, Notion of Time, MERISE, CDM, LMD system, Historical traceability, Temporal database**

## I. Introduction

To automate organizational management, computer scientists must design data structures capable of accurately reflecting the real world. The MERISE methodology remains one of the most widely used frameworks for information systems analysis and design across Francophone Africa and Europe. However, in its traditional application at the conceptual phase, the Conceptual Data Model (CDM) tends to offer an essentially static representation of information semantics, capturing an organization's state at a single point in time rather than its evolution.

In academic environments governed by the LMD (Licence-Master-Doctorat) framework—such as the Higher Institute of Statistics of Kinshasa (ISS/KIN)—this static paradigm poses severe operational challenges. The LMD reform introduces dynamic academic trajectories characterized by course credit accumulation, semester-based validation, retakes, equivalence waivers, and variable course allocations across academic years.

A recurring problem lies in accounting for time-related attributes during the conceptual modeling phase. This challenge does not pertain to organizational workflows or process execution timing (covered at the Organizational Data Model level), but rather to identifying the precise conceptual location of attributes that retain the historical progression of management data. Failing to explicitly model temporal occurrences from the design stage leads to critical vulnerabilities:

- **Historical data overwrite:** Updated records (e.g., a changed grade or updated credit weight) overwrite prior valid states.
- **Archival and retrieval friction:** Inability to reconstruct accurate academic transcripts for past academic years.

- **Semantic drift in queries:** Database queries fail to reflect the evolving regulatory and structural reality of the institution.
- **Calculation errors:** Failure to apply time-bound evaluation rules, GPA updates, and credit validation criteria accurately.

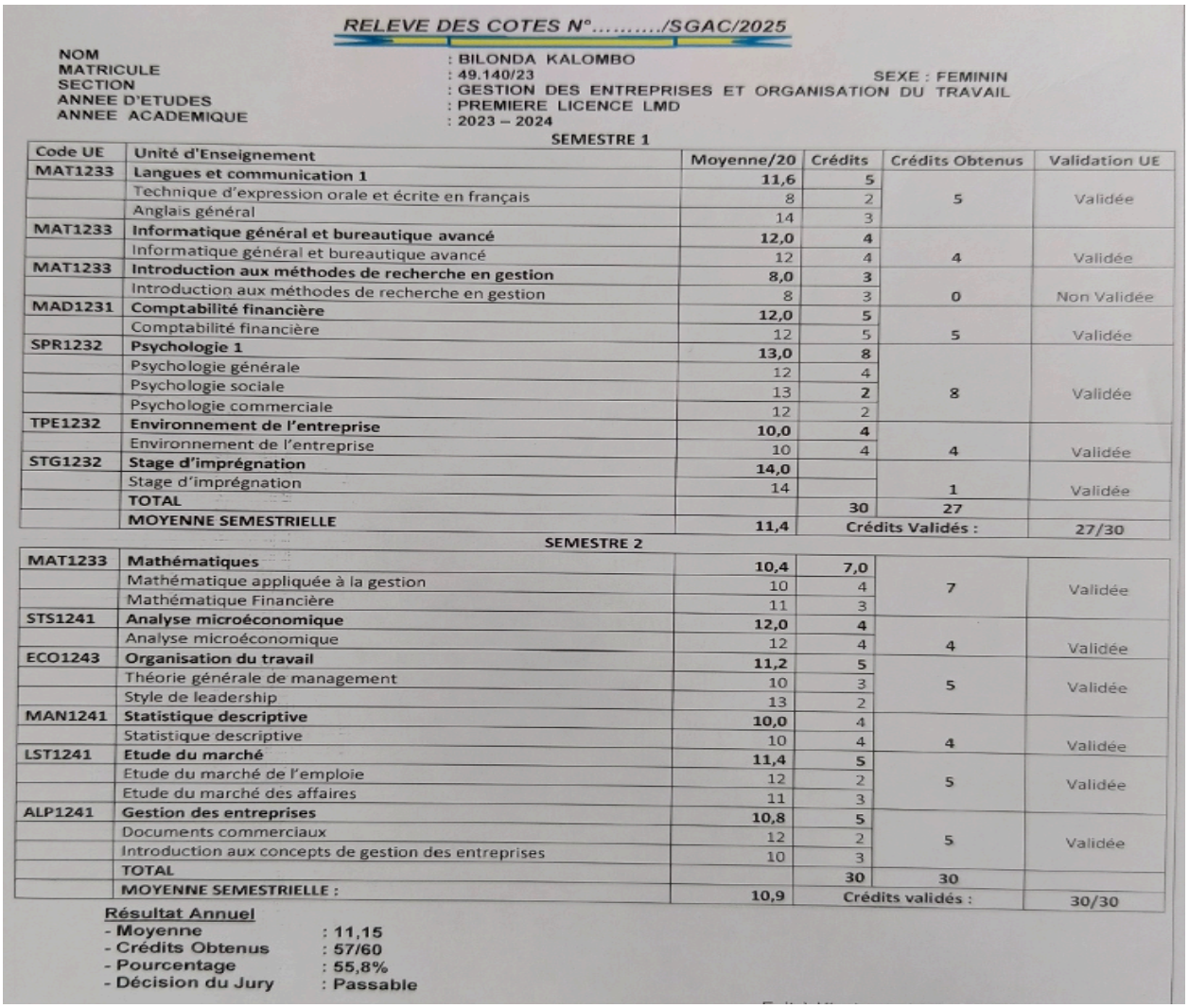
The objective of this study is to demonstrate how systematic document analysis combined with temporal extensions of the MERISE methodology allows designers to integrate the temporal dimension into the CDM, thereby ensuring the sustainability, consistency, and historical integrity of academic databases in the LMD system.

## II. Methods

This study adopts a qualitative and structural system design methodology based on document engineering and conceptual data modeling within the MERISE framework, adapted to the administrative constraints of the LMD system.

### 2.1 Study Setting and Empirical Materials

The research was conducted at the Higher Institute of Statistics of Kinshasa (ISS/KIN), focusing on the academic deliberation and grade management process. The primary empirical support used for modeling was the official academic transcript (*Relevé de notes*) of student **BILONDA KALOMBO** (Registration Number: 49.140/23), enrolled in the First Bachelor's Degree (*Licence 1 LMD*) for the **2023–2024 academic year**.



RELEVE DES COTES N°...../SGAC/2025

NOM : BILONDA KALOMBO
MATRICULE : 49.140/23 SEXE : FEMININ
SECTION : GESTION DES ENTREPRISES ET ORGANISATION DU TRAVAIL
ANNEE D'ETUDES : PREMIERE LICENCE LMD
ANNEE ACADEMIQUE : 2023 – 2024

SEMESTRE 1

| Code UE | Unité d'Enseignement | Moyenne/20 | Crédits | Crédits Obtenus | Validation UE |
|---|---|---|---|---|---|
| MAT1233 | Langues et communication 1 | 11,6 | 5 | 5 | Validée |
| | Technique d'expression orale et écrite en français | 8 | 2 | | |
| | Anglais général | 14 | 3 | | |
| MAT1233 | Informatique général et bureautique avancé | 12,0 | 4 | 4 | Validée |
| | Informatique général et bureautique avancé | 12 | 4 | | |
| MAT1233 | Introduction aux méthodes de recherche en gestion | 8,0 | 3 | 0 | Non Validée |
| | Introduction aux méthodes de recherche en gestion | 8 | 3 | | |
| MAD1231 | Comptabilité financière | 12,0 | 5 | 5 | Validée |
| | Comptabilité financière | 12 | 5 | | |
| SPR1232 | Psychologie 1 | 13,0 | 8 | 8 | Validée |
| | Psychologie générale | 12 | 4 | | |
| | Psychologie sociale | 13 | 2 | | |
| | Psychologie commerciale | 12 | 2 | | |
| TPE1232 | Environnement de l'entreprise | 10,0 | 4 | 4 | Validée |
| | Environnement de l'entreprise | 10 | 4 | | |
| STG1232 | Stage d'imprégnation | 14,0 | | 1 | Validée |
| | Stage d'imprégnation | 14 | | | |
| | TOTAL | | 30 | 27 | |
| | MOYENNE SEMESTRIELLE | 11,4 | Crédits Validés : | | 27/30 |

SEMESTRE 2

| | | | | | |
|---|---|---|---|---|---|
| MAT1233 | Mathématiques | 10,4 | 7,0 | 7 | Validée |
| | Mathématique appliquée à la gestion | 10 | 4 | | |
| | Mathématique Financière | 11 | 3 | | |
| STS1241 | Analyse microéconomique | 12,0 | 4 | 4 | Validée |
| | Analyse microéconomique | 12 | 4 | | |
| ECO1243 | Organisation du travail | 11,2 | 5 | 5 | Validée |
| | Théorie générale de management | 10 | 3 | | |
| | Style de leadership | 13 | 2 | | |
| MAN1241 | Statistique descriptive | 10,0 | 4 | 4 | Validée |
| | Statistique descriptive | 10 | 4 | | |
| LST1241 | Etude du marché | 11,4 | 5 | 5 | Validée |
| | Etude du marché de l'emploie | 12 | 2 | | |
| | Etude du marché des affaires | 11 | 3 | | |
| ALP1241 | Gestion des entreprises | 10,8 | 5 | 5 | Validée |
| | Documents commerciaux | 12 | 2 | | |
| | Introduction aux concepts de gestion des entreprises | 10 | 3 | | |
| | TOTAL | | 30 | 30 | |
| | MOYENNE SEMESTRIELLE : | 10,9 | Crédits validés : | | 30/30 |

Résultat Annuel
- Moyenne : 11,15
- Crédits Obtenus : 57/60
- Pourcentage : 55,8%
- Décision du Jury : Passable

Figure1: Transcript of grades for student BILONDA KALOMBO

### 2.2 Five-Stage Conceptual Engineering Approach

To systematically derive a temporally enriched Conceptual Data Model (CDM), a five-stage document analysis protocol was applied:

#### 1. Document Inventory & Structural Breakdown

A exhaustive extraction was performed on every field present on the physical transcript. Attributes were cataloged into metadata (header identifiers), administrative descriptors, and instructional evaluation records.

#### 2. Attribute Normalization & Derivative Elimination

To respect the first normal form (1NF) at the conceptual level, all calculated or derived fields were isolated and eliminated from storage consideration.

- **Eliminated attributes:** Total Credits Earned , Weighted Average , Pass/Fail Percentage, and Jury Decisions (*e.g., Satisfaisant, Admis*).
- **Retained elementary attributes:** Raw marks, fundamental course identifiers, credit coefficients, student personal metadata, and institutional session codes.

### 3. Entity-Relationship Specification

Remaining atomic attributes were grouped into independent real-world entities. Primary keys (identifiers), intrinsic properties, and semantic relationships were established:

- **Entities:** STUDENT (Matricule), COURSE (Code_Course), TEACHER (ID_Teacher), ACADEMIC_YEAR (Code_Year).
- **Associations:** Structural mapping of N-ary relationships reflecting enrollments, teaching assignments, and evaluation events, including minimum and maximum cardinalities (0,1, 1,1, 1,N, 0,N).

### 4. Temporal Integration & Relation Restructuring

Attributes exhibiting state variation over time—such as grades obtained across multiple exam sessions or course credit allocation across different academic curricula—were extracted from static entities.

To preserve historical accuracy and prevent record overwriting:

1. Dynamic attributes were migrated to association relationships.
2. The temporal variable Academic_Year (AnneeAcademique) was elevated to a functional key component within N-ary associations (EVALUATE, ALLOCATE).

### 5. Automated Diagramming via Mocodo

The final conceptual structures were validated and compiled using the **Mocodo** declarative modeling framework, enabling precise visual representation of entities, attributes, association cardinalities, and migrated temporal keys.

**Table 1 : Comparative Structural Summary**

| Phase | Input / Focus | Primary Technique | Output Artifact |
|---|---|---|---|
| **Stage 1 & 2** | Physical Transcript | Document Parsing & Formula Filtering | Normalized Atomic Attribute List |
| **Stage 3** | Atomic Attributes | MERISE Normalization & Cardinality Rules | Static Conceptual Data Model |
| **Stage 4** | Time-variant Attributes | Temporal Key Injection (AnneeAcademi | Dynamic / Temporal Association Schema |

| | | | |
|---|---|---|---|
| | | que) | |
| **Stage 5** | Formal Model Rules | Declarative Scripting (Mocodo Tool) | Validated CDM Vector Diagrams |

## III. Results

### 3.1 Data Dictionary and Entity Extraction

Following the systematic parsing of student **BILONDA KALOMBO**'s academic transcript (Registration No. 49.140/23) and the removal of calculated fields (such as cumulative GPAs and jury verdicts), the normalized elementary data dictionary was established. Nine core entities were identified, each defined by a primary key (identifier) and intrinsic, non-temporal properties:

Table 2 : Data Dictionary and Entity Extraction

| **Entity** | **Primary Key (#)** | **Attributes** | **Description** |
|---|---|---|---|
| **Student** | #matrEtudi | nameStudy, postNameStudy, firstnameStudy, sexStudy, civilstatus, datBirthStudy | Demographic profile of the student |
| **Section** | #codeSect | libeSect | Academic department (*e.g., Statistics, Demography*) |
| **Promotion** | #promocode | libePromo | Cohort level (*e.g., Licence 1, Licence 2*) |

| | | | |
|---|---|---|---|
| **Teaching Unit (UE)** | #EUcode | libeUE, maxUE, creditUE | Major subject cluster under LMD |
| **Constituent Element (EC)** | #codeEC | libeEC, maxEC, creditEC | Individual course module within a UE |
| **Semester** | #codSem | libeSem | Temporal academic term (*e.g., Semester 1, Semester 2*) |
| **Nationality** | #codeNation | libeNation | Country of origin classification |
| **Option** | #codOpt | libOpt | Specialization track |
| **Academic Year** | #anneeAcad | libeAnnee | Institutional timeline anchor (*e.g., 2023–2024*) |

### 3.2 Diagnostic of Static Model Limitations

A critical evaluation of the traditional static Conceptual Data Model (CDM) revealed two structural vulnerabilities when deployed within the dynamic framework of the LMD system at ISS/KIN:

**1. Curricular Volatility & Inability to Reconstruct Legacy Curricula**

Higher education curricula continuously evolve. Historical programming languages (*e.g., Fortran, COBOL, QBasic*) have been phased out, replaced, or relocated across different cohort levels over time. In a static CDM, linking a course directly to a cohort level (*Promotion*) overwrites previous institutional offerings. As a result, the database cannot accurately reconstruct the exact curriculum assigned to a student five years prior.

**2. Deferred Credit Retention (*Rattrapage*) Ambiguity in LMD**

The LMD framework allows non-linear progression: a student may advance to a higher cohort level while carrying unvalidated credits (*UE/EC non validées*). Under a standard assessment association (EVALUATE), logging a retake attempt in a subsequent academic year either overwrites the original failing mark or creates duplicate, ambiguous records without clear temporal sequence.

### 3.3 Proposed Conceptual Temporal Data Model (Temporal CDM)

To resolve these vulnerabilities, the conceptual architecture was extended by introducing two temporally explicit, dynamic associations that incorporate the temporal dimension at the conceptual level.

#### 1. Dynamic Curriculum Association (PROGRAM)

Positioned between **Constituent Element (EC)**, **Promotion**, and **Academic Year**, this N-ary association decouples course offerings from static cohorts:

- **Association Name:** PROGRAM
- **Carried Attributes:** dateProgrammer, anneeAcademique
- **Impact:** Guarantees that curriculum alterations in Year N+1 do not alter the historical record of course offerings provided in Year N.

#### 2. Deferred Credit Recovery Association (COMPLETE)

Positioned between **Student**, **Constituent Element (EC)**, and **Academic Year**, this association manages retakes and long-term credit accumulation:

- **Association Name:** COMPLETE
- **Carried Attributes:** dateCompleter, anneeAcadCompleter, gradeObtained, validationStatus
- **Impact:** Explicitly tracks credit validation across multiple academic sessions without altering original academic transcripts.

### 3.4 Mocodo Structural Specification

The proposed Temporal CDM was formalized using the **Mocodo** declarative language, yielding the following conceptual structure:

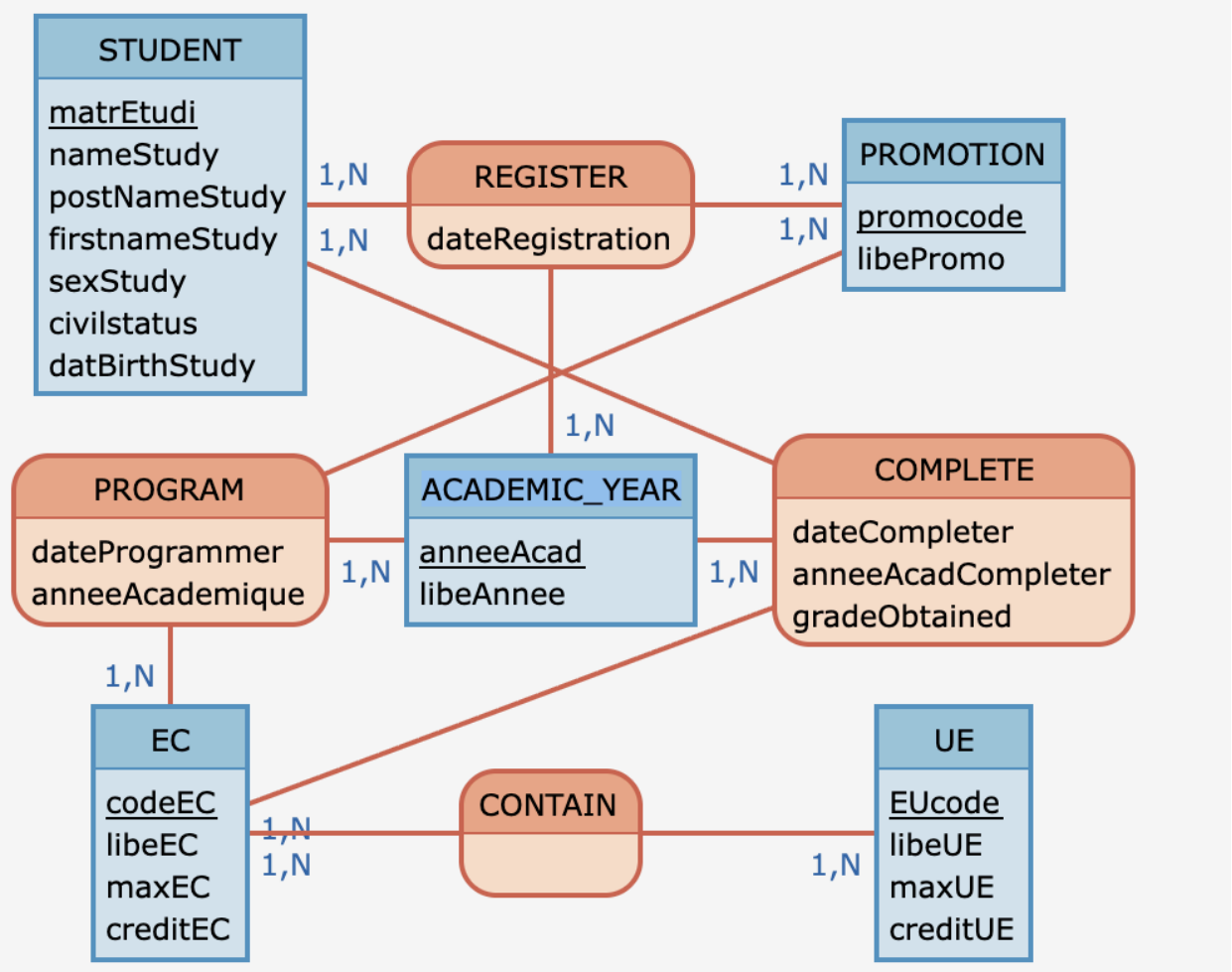



Figure2 : Presentation of the Time-Related Conceptual Data Model

## IV. Discussion

The explicit integration of the temporal dimension into the Conceptual Data Model (CDM) addresses a longstanding challenge in academic database engineering: maintaining historical fidelity in volatile administrative environments. By elevating temporal variables from post-hoc physical database timestamps to core conceptual associations, this study demonstrates how information systems can evolve from static state repositories into true **enterprise memory systems**.

### 4.1 Theoretical Implications: Temporal Extensions in MERISE

Traditional MERISE conceptual modeling often treats time as an external parameter or isolates temporal mechanics within the Organizational Data Model (ODM) and Process Model (MOT). At the CDM level, entities and relationships are conventionally modeled under the assumption of a continuous present.

However, as demonstrated by the case of the Higher Institute of Statistics of Kinshasa (ISS/KIN), academic data semantics are inherently time-bound. Decoupling course modules (EC) from static cohorts (Promotion) through the PROGRAM association demonstrates that:

- **Functional Dependencies are Time-Variant:** A course offering is not functionally dependent on a cohort alone, but on the composite key (Code_EC, Code_Promotion, Academic_Year).
- **Associations as Temporal Carriers:** In MERISE, when an attribute's value changes over time

without altering the identity of the participating entities, that attribute must reside inside an n-ary data-bearing association constrained by a temporal key (anneeAcademique).

### 4.2 Practical Impact on LMD Governance and Academic Archiving

The adoption of the LMD (Licence-Master-Doctorat) framework across African and European higher education institutions introduces dynamic student pathways characterized by credit capitalization, multi-session resits, and flexible course retakes (*rattrapages*).

Table 3 : Practical Impact on LMD Governance and Academic Archiving

| **Operational Aspect** | **Static CDM Approach** | **Temporal CDM Approach** | **Practical Benefit for ISS/KIN** |
|---|---|---|---|
| **Curriculum Evolution** | Overwrites past course structures when new courses replace legacy subjects (*e.g., Fortran vs. Python*). | Stores curriculum offerings per Academic_Year in the PROGRAM association. | Enables exact reconstruction of historical course catalogs and credit weights for any past year. |
| **Credit Accumulation** | Replaces unvalidated marks or creates ambiguous duplicate records. | Tracks attempts via the COMPLETE association using anneeAcadCompleter. | Preserves student assessment history across multiple years without data corruption. |
| **Transcript Authenticity** | Re-calculates past GPAs using present credit structures. | Queries exact temporal snapshots of legacy credit allocations. | Ensures legal immutability and auditability of official academic transcripts. |

### 4.3 Methodological Synthesis: Combining Bottom-Up and Systemic Analysis

From a methodological standpoint, relying strictly on a bottom-up approach—such as document analysis of a single academic transcript—carries inherent risks. Document engineering isolates fields visible on paper at a single instance in time, which can lead to static relational schemas.

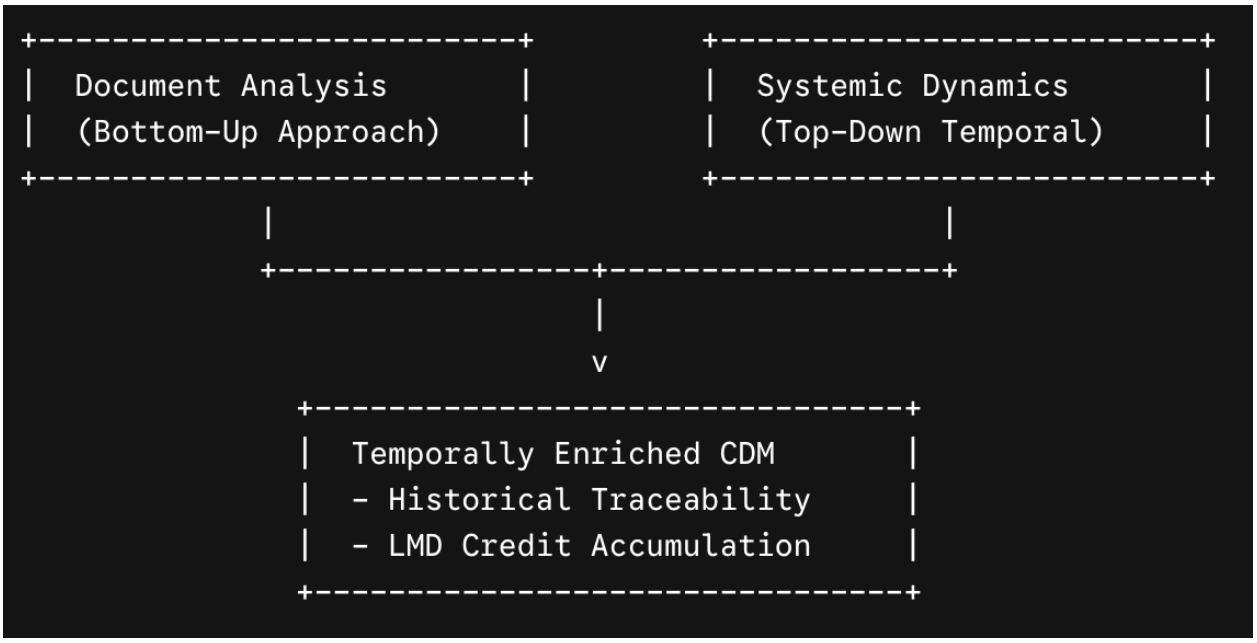



Figure3 : Combining Bottom-Up and Systemic Analysis

By complementing document analysis with systemic analysis of organizational temporal dynamics, database designers can anticipate structural shifts before physical implementation. This hybrid strategy ensures that the derived Logical Data Model (LDM / *MLD*) and Physical Data Model (PDM / *MPD*) inherit structural resilience, eliminating the need for costly database refactoring or ad-hoc patching.

## V. Conclusion

This study demonstrates that embedding the temporal dimension directly at the conceptual modeling phase within the MERISE framework provides a robust solution to structural data degradation, historical overwrite, and archival friction in academic information systems. By shifting from a static Conceptual Data Model (CDM) to a temporally enriched architecture, database engineering can effectively bridge the gap between fixed conceptual modeling and the dynamic reality of organizational workflows.

Applied to the academic deliberation processes at the Higher Institute of Statistics of Kinshasa (ISS/KIN), the proposed model successfully reconciles legacy record-keeping with the flexible requirements of the LMD (Licence-Master-Doctorat) system. By decoupling dynamic attributes—such as annual course offerings (PROGRAM) and multi-year credit retention (COMPLETE)—from static entities, the system establishes a durable **enterprise memory architecture**.

**Key Takeaways & Contributions**

1. **Historical Traceability & Audit Integrity:** The introduction of time-bearing n-ary associations guarantees that legacy curricula, historical credit weights, and prior student evaluations remain immutable over time, enabling precise retroactive transcript generation.
2. **LMD System Alignment:** The model handles non-linear academic trajectories—such as credit capitalization, deferred resits, and multi-session course validations—without requiring ad-hoc relational patches or data duplication.
3. **Methodological Synthesis:** Combining document engineering (bottom-up parsing of official transcripts) with systemic temporal analysis (top-down evaluation of institutional evolution) ensures long-term database resilience and consistency.

### Recommendations & Future Research

For database administrators and system architects in higher education institutions undergoing LMD reforms, this study outlines three key recommendations:

1. **Enforce Temporal Keys at Conceptual Design:** Avoid relying solely on physical database timestamps; model temporal dependencies directly within association keys during the conceptual phase.
2. **Standardize Migration Rules for Logical Models (LDM/MLD):** Ensure that the transition from a temporal CDM to a Relational Logical Data Model preserves composite primary keys (Code_EC, Code_Promotion, Academic_Year) to maintain functional integrity.
3. **Future Work:** Further research should explore the physical optimization and query performance of temporally enriched relational schemas when handling high-volume analytical workloads (*OLAP*) and real-time automated degree auditing.

## References

[1] Date, C. J., Darwen, H., & Lorentzos, N. A. (2002). *Temporal data and the relational model: A detailed investigation into the application of interval types, relation values, explicit timestamps, and other attribute values to the processing of temporal data*. Morgan Kaufmann. https://doi.org/10.1016/B978-1-55860-855-9.X5000-0

[2] Edelweiss, N., & Oliveira, J. P. M. (1993). An object-oriented temporal model. *Lecture Notes in Computer Science*, *685*, 51–63. https://doi.org/10.1007/3-540-56777-1_4

[3] Elmasri, R., & Navathe, S. B. (2015). *Fundamentals of database systems* (7th ed.). Pearson.

[4] Gregersen, H., & Jensen, C. S. (1999). Temporal entity-relationship models—a survey. *IEEE Transactions on Knowledge and Data Engineering*, *11*(3), 464–497. https://doi.org/10.1109/69.774104

[5] Jensen, C. S., & Snodgrass, R. T. (1999). Temporal data management. *IEEE Transactions on Knowledge and Data Engineering*, *11*(1), 36–44. https://doi.org/10.1109/69.755613

[6] Ngoubou, R. C. (2024). Contribution of the MERISE-Type Conceptual Data Model to the construction of indicators for monitoring and evaluating the effectiveness of vocational training. *Journal of Software Engineering and Applications*, *17*(8), 612–625. https://doi.org/10.4236/jsea.2024.178035

[7] Rochfeld, A., & Tardieu, H. (1983). MERISE: An information system design methodology. *Information & Management*, *6*(3), 143–148. https://doi.org/10.1016/0378-7206(83)90033-1

[8] Snodgrass, R. T. (1992). Temporal databases. *IEEE Computer*, *25*(9), 11–12. https://doi.org/10.1109/2.156378

[9] Tardieu, H., Rochfeld, A., & Colletti, R. (1983). *La méthode MERISE: Principes et outils*. Éditions d'Organisation.

[10] Theodoulidis, B., & Loucopoulos, P. (1991). The temporal dimension in information modelling. *ACM Computing Surveys*, *23*(4), 453–486. https://doi.org/10.1145/125487.125489