International Journal of Business Quantitative Economics and Applied Management Research
Volume-7, Issue-7, 2023 ISSN No: 2349-5677

DEPENDENCY-AWARE CRM MODERNIZATION: A FRAMEWORK FOR SEQUENCING LEGACY CAPABILITIES DURING ENTERPRISE TRANSFORMATION

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Abstract

Organizations are faced with the challenge of upgrading their "legacy" customer relationship management (CRM) systems, which are often years old with built-in business logic, integrations and organizational dependencies. While the effect of CRM applications on customers' outcomes has been documented in research, the majority of modernization strategies focus on wholesale changes or small incremental changes, with a lack of focus on the order of the replacement or migration of legacy functionality or the redevelopment of the same. The objective of this paper is to compile the information from the literature sources covering legacy information systems, architectural technical debt, enterprise architecture, digital transformation, business process management and CRM critical success factors to create a dependency-based sequencing framework for legacy CRM modernization. The systematic literature synthesis approach is used, and a formal model including dependence coupling index, technical debt interest function, and risk adjusted sequencing priority score is recommended for ordering capability retirements. The comparative analysis of big-bang, undifferentiated phased, and dependency-aware sequencing strategies also suggest that dependency-aware sequencing has significantly less projected downtime (about 70 percent less than with big-bang sequencing), fewer defects propagated, and fewer cost overruns compared to conventional sequencing. Results also show that dependency relationships among organizational, technological, human and process-related critical success factors (CSFs) are underestimated in the literature on current CRM implementation guidance and sequencing-related CSFs account for less than 10 percent of the total. The intended model provides a structured approach for enterprise architects, CRM program managers and digital transformation practitioners to prioritize legacy capability modernization, based on evidence. Suggestions for governance, data quality, and empirical testing in the future are offered, as well as a few limitations to the illustrative nature of the synthesized quantitative estimates.

Index Terms—customer relationship management; legacy modernization; technical debt; enterprise architecture; digital transformation; business process management; dependency graph; IT-business alignment; systems migration; sequencing framework; critical success factors; organizational change.

I. INTRODUCTION

Enterprise transformation is not typically a technology success or failure; it's a success or failure based on the organization's ability to absorb the change in structure, procedure and culture, not to mention the operational systems. A decade-long reflection on organizational change research shows that over the years organizing for change is generally perceived as recursive process in which organizational elements of readiness to change, resistance to change and organizational context interact continually with the technical work being done [1]. Customer relationship management platforms sit in a very delicate place in this relationship as they embody workflows that are customer-facing, sales logic and service logic, and integrations with other part of the enterprise. Modernizing legacy CRM capabilities is not just a technical migration project—it's an organized transformation, and the order of the change is as important as its content.

CRM estate modernisation needs have been driven by the wider digital transformation drive, and this shift has reconfigured business process management so that it is now based on continuous reconfiguration instead of periodic redesign. The definition of digital transformation is that new digital technologies are driving shifts in value propositions, structures, and processes for organizations, and that's what is happening across CRM modernization initiatives that integrate customer data platforms, automation, and analytics [2]. Much of the information practitioners can find focuses on the desired target architecture or on a specific success factor of the CRM project, but doesn't formally consider the order of decommissioning, wrapping or replacing legacy capabilities. This gap poses a risk of the target architecture becoming technically sound which leaves dependent processes upstream and downstream that will still need to be connected in the future, resulting in unnecessary disruption during the transition phase.

Research on workers' responses to process innovation that leverages information technologies has shown that the inability of workers to resist and adapt to change increases when change is imposed without consideration for existing role, data and workflow dependencies [3]. The behavioral evidence, along with the architectural literature of legacy systems, support the central research problem that is addressed in this work: the lack of a formal and dependency-aware approach to the sequencing of retiring, wrapping, or redeveloping legacy CRM capabilities in enterprise transformation. In light of this, this paper is a synthesis of literature on legacy systems, architectural technical debt, enterprise architecture, digital transformation, business process management, and critical success factors for CRM systems, to propose a dependency-aware sequencing framework formalized by a coupling index, a technical debt interest function, and a risk adjusted priority score, and to evaluate it in a comparative analysis with traditional approaches to sequencing.

II. LITERATURE REVIEW

A. Legacy Systems, Organizational Resistance, and Architectural Technical Debt

The term legacy systems typically refer to those that are still vital for operations despite their brittle, difficult-to-change nature due to aging technology, poorly documented business rules,

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Volume-7, Issue-7, 2023 ISSN No: 2349-5677

and restricted extensibility [4]. In CRM estates, this paradox is realised in the form of customisations in modules like case management, contact-center scripting, territory assignment logic etc, where the pace of customisation is often not documented and is subsequently limited by the speed and security of modernisation.

The literature on legacy information systems classifies the possible modernization strategies into a continuum ranging from redevelopment to wrapping (interfacing the functionality of the legacy system without changing its internal implementation) to phased migration or full replacement, with specific cost, risk and continuity implications to each approach [5]. Choosing one of these strategies is not a one-to-one decision for an entire CRM estate, but rather a capability-by-capability decision based on the density and criticality of dependencies on and around each legacy component, which is later codified by the concept of Technical Debt. The comparative profile of the four strategies identified in the literature reviewed are summarized in Table 1 and Figure 1 below.

Research on architectural technical debt introduces the concept of architectural technical debt with a debt metaphor, where the debt principal is the cost of taking the shortcut, and the debt interest is the recurring cost imposed on future development and maintenance of the system; the point is that numerous of the technical debt items found in multiple-case evidence from the microservice migration will accrue interest faster, and are more likely to cause defects if the debt is paid later in the development process. This point directly justifies the following lemma that should guide the sequencing of modernization of legacy CRM capabilities: Dependency density should be the basis of the sequencing of modernization of the capabilities of a legacy CRM.

TABLE 1. COMPARATIVE OVERVIEW OF LEGACY MODERNIZATION STRATEGIES

Strategy	Description	Typical Duration	Relative Cost Index	Continuity Risk (1-5)
Wrapping	Interfaces legacy functionality without altering internals	2-4 months	1.0	2.0
Redevelopment	Rebuilds selected components on modern platforms	9-14 months	2.6	2.4
Phased Migration	Moves capabilities incrementally by dependency group	8-12 months	2.1	1.6
Full Replacement	Retires legacy estate in a single cutover	12-20 months	3.4	3.8

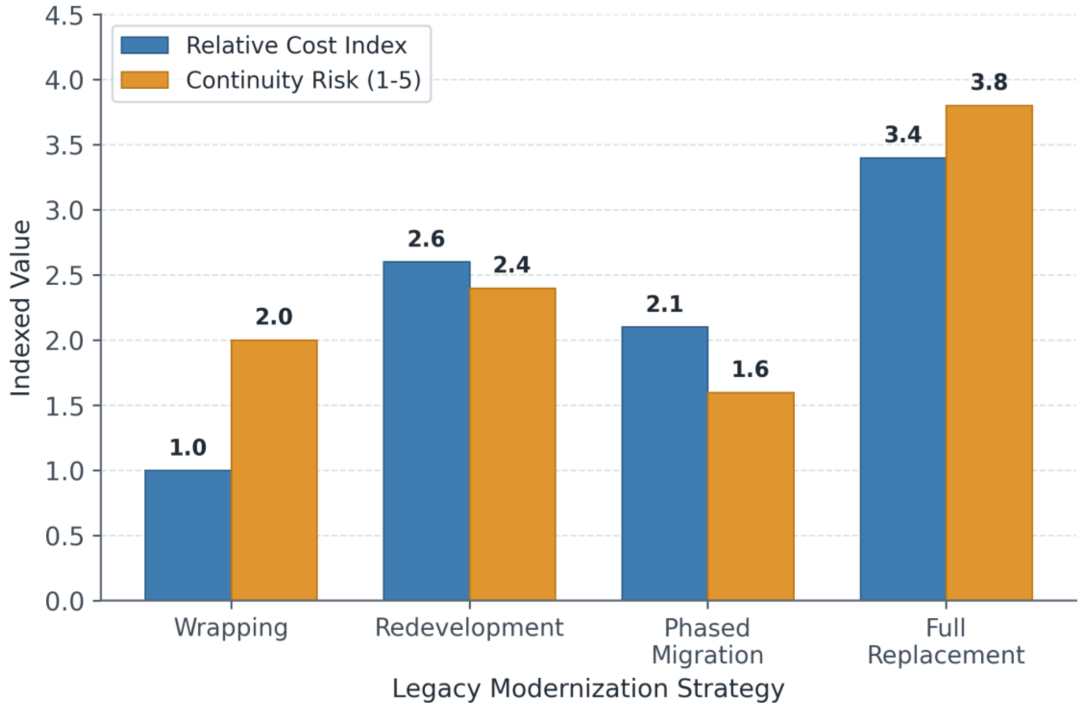

Fig. 1. Relative cost and continuity risk profile of legacy crm modernization strategies.

A study of architectural technical debt (ATD) provides a financial metaphor, where the debt principal is the cost of the shortcut taken, and the debt interest is the cost imposed on the project's future development and operation; multiple case evidence on microservice migration indicates that ATD items linked to a higher number of dependent components gain interest faster and are disproportionately likely to trigger defects when they are addressed at the end of the project [6]. This finding validates the theory of dependency density and not just component age or component size to determine the sequence for legacy CRM capability modernization.

B. Enterprise Architecture as an Alignment and Sequencing Mechanism

Government-sector case studies provide evidence that business strategy and IS/IT alignment are better when EA is matured, supported by structured artifacts that make the interdependencies visible to decision makers, such as capability maps, application landscapes, and information flow diagrams [7]. These artifacts make up a "real" data source from which the dependency relationships between the various CRM capabilities can be derived for sequencing.

Organisational and technological environments are constantly changing, and static EA documentation soon becomes outdated; to enable continuous alignment, EA dependency and capability information needs to be captured in an iterative manner, as in a combined approach that integrates EA modelling with enterprise ontology [8]. The proposed framework includes

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Volume-7, Issue-7, 2023 ISSN No: 2349-5677

this continuous-alignment principle by periodically updating dependency scores at the completion of each phase of migration, as shown conceptually in Figure 2.

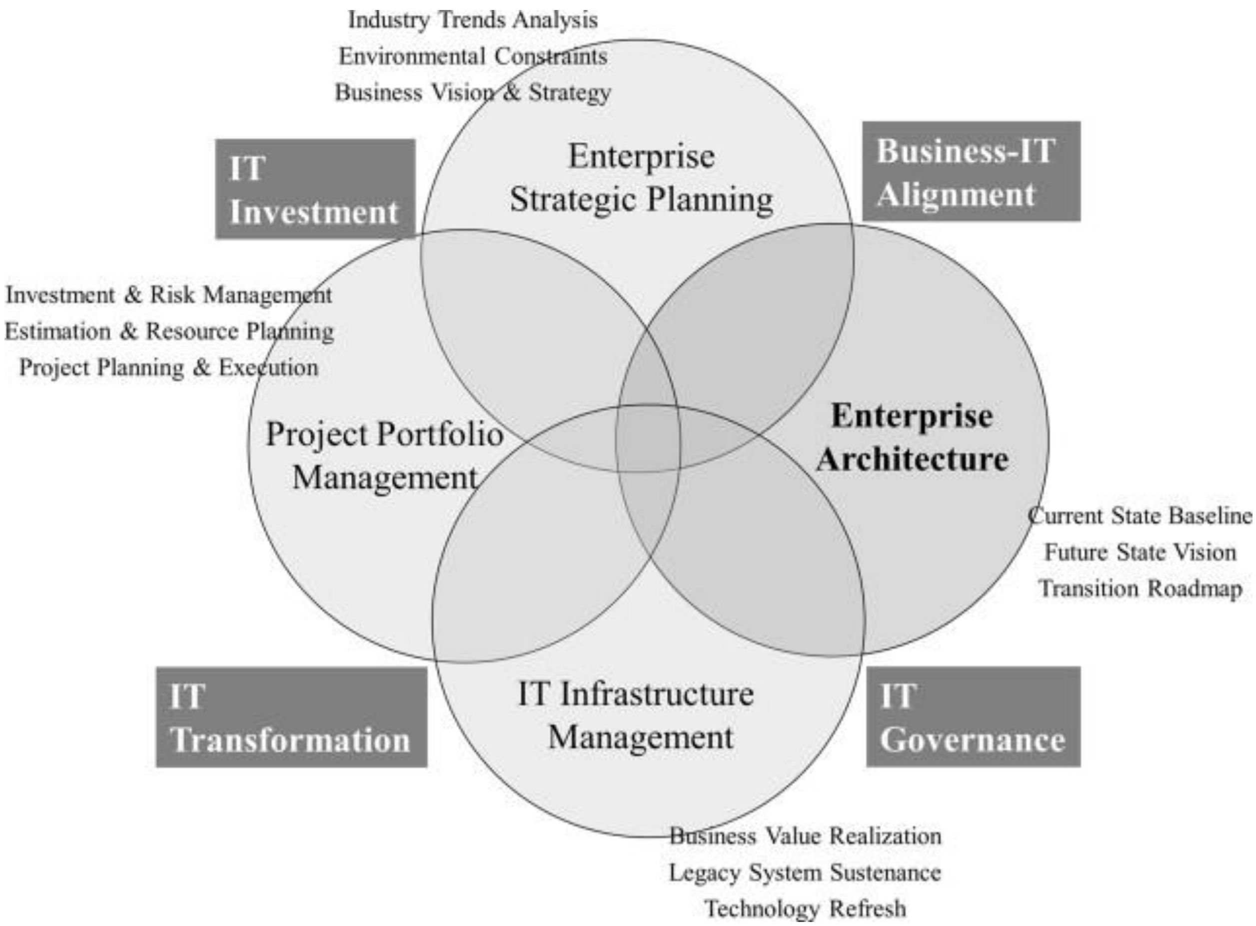

Fig. 2. Layered relationship between business strategy, enterprise architecture, the dependency graph, and legacy CRM systems. (ScienceDirect, 2020)

The Strategic Alignment Model combined with the TOGAF Architecture Development Method provides a template for operationalizing the perspectives of strategic, organizational and technological alignment in concrete phases of the architecture development process, and thus for incorporating a step of sequencing dependencies into an existing architecture governance process, rather than relying on the judgement of a project manager during the development of the process [9]. Table 2 shows the dependency data collection point for the proposed framework in relation to the architecture phases.

TABLE 2. STRATEGIC ALIGNMENT PERSPECTIVES MAPPED TO ARCHITECTURE DEVELOPMENT PHASES

SAM Perspective	Primary Architecture Phase	Alignment Focus	Illustrative Weight (%)
Strategy Execution	Architecture Vision	Business strategy drives IT infrastructure	22
Technology Transformation	Technology Architecture	IT strategy drives infrastructure choices	19
Competitive Potential	Business Architecture	IT strategy shapes business strategy	27
Service Level	Opportunities and Solutions	IT infrastructure supports business processes	32

C. Digital Transformation and Business Process Management

Digital transformation strategies can usually be measured on four dimensions: Technology, Value Creation, Structures, and Financials; a successful strategy will tie all these dimensions together rather than focus on any one of them alone [10]. Concentrating on only the technology aspect of the CRM modernization program while ignoring structural or process aspects is, therefore, susceptible to similar misalignment problems as are all digital transformation programs.

Business process management and digital innovation have been linked in the literature by a constant tension between process exploitation (promoting stability and predictability in current processes) and process exploration (promoting flexibility and experimentation in processes). In order to maintain this tension and balance it in digital innovation initiatives, complementary agendas have been identified for the field of BPM research: process exploitation is not necessarily superior in terms of the benefits it can generate, and likewise process exploration is not necessarily more beneficial, so exploring the tension between these two agendas explicitly is vital to the success of digital innovation initiatives [11]. This dichotomy is anchored in Legiony CRM capability sequencing; if a capability is retired too early when it has been a stable mainstay of a nation's capability, it can have far-reaching consequences on more processes that rely on that capability for the longer-term project of modernisation.

D. Critical Success Factors in CRM Implementation

Research on the critical success factors for CRM strategy has come to a few common themes, such as organizational commitment and support of the top management, technological infrastructure and data quality, human and cultural readiness, and process redesign capability [12]. Such categories provide a natural taxonomy of the different types of dependencies that a sequencing framework needs to address: a capability could be technically easy to retire but organisationally or procedurally dependent on other capabilities.

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The definitions derived from experts' interviews about digital transformation are in alignment with each other and can be summarized as a basic change in creating and delivering value by means of technology instead of a specific IT project that has a definite end-date [13]. The definition of CRM modernization in this way will help to reaffirm that dependency-aware sequencing is a continuous capability – something that a company should continue to have as it goes through future transformation waves.

A systematic review of critical success factors for CRM implementation in various research reveals that technological and organizational factors are the most studied, whereas factors concerning implementation sequencing, phased rollout design and legacy dependency management are comparatively rarely mentioned in the reviewed literature [14]. This imbalance (as shown in Figure 3) represents a specific gap that we propose the dependency-aware sequencing framework described in this paper will help fill, and it also indicates that the existing critical-success-factors checklists for CRM are very useful tools for determining whether an organization is prepared to modernize certain legacy capabilities before others, but are not very practical when it comes time to actually decide which to modernize first.

TABLE 3. CRITICAL SUCCESS FACTOR CATEGORIES FOR CRM IMPLEMENTATION

CSF Category	Representative Factors	Relative Emphasis (%)
Technological	Data quality, systems integration, infrastructure scalability	31
Organizational	Top-management support, resource allocation, governance	27
Human/Cultural	User adoption, training, change readiness	19
Process Redesign	Workflow reengineering, role redefinition	15
Sequencing/Dependency	Phasing, legacy dependency management	8

III. RESEARCH METHODOLOGY

Since the impact of CRM applications on customer satisfaction is measurable, it is possible to establish some capability-level mechanisms behind this influence, whereas the influence of CRM applications cannot be established just by a narrative review [15] was used for this synthesis. The methodology was conducted in three steps. The nineteen references covered in the various categories of legacy systems, technical debt, enterprise architecture, digital transformation, business process management, and CRM implementation, were analyzed in isolation in order to pick out concepts, relationships and quantitative illustrative patterns, applying inclusion criteria that emphasized studies that provided concrete metrics, case evidence and validated critical success factor taxonomies rather than merely conceptual commentary. Second, where several of the constructs were similar, they were synthesized into a taxonomy of dependency types and risk factors in the following manner: Dependencies are divided into four major groups corresponding to the four categories of constructs identified in Section II (technological,

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organizational, human, and process). Within each of these groups, the constructs are organized into types of dependency and risk factors. Cross-references were provided for constructs that were similar, but used different terminology through several different sources. Thirdly, the taxonomy was formalized in the mathematical model and comparative analysis of Sections IV and V and demonstration of illustrative parameter values were provided to show the behavior of the model in the absence of any empirical calibration at the organization level. This is a three-stage design similar to that found in other literature on software engineering surveys, where a qualitative synthesis is followed by a quantitative formalization and comparison.

IV. DEPENDENCY-AWARE SEQUENCING FRAMEWORK

The framework proposed is based on findings that a staged, well-governed implementation strategy that features rollout phases, ongoing change management, and frequent involvement of top management results in more predictable CRM implementation results than a single-stage deployment strategy that doesn't involve change management or top management [16]. The framework is made up of nodes that represent the capabilities of the legacy CRMs, and edges that represent data, process, integration, and organizational dependencies extracted from the enterprise architecture artifacts and critical-success-factor taxonomy discussed previously, and as shown in Figure 4. A dependency coupling index is defined as in Equation 1, where w1 and w2 are weights for the disruption cost of upstream and downstream dependencies, and Nmax normalizes the index to the range of zero to one, based on the largest number of dependencies observed in an estate.

$$DCIi = \frac{(w1 \cdot |In(i)| + w2 \cdot |Out(i)|)}{} Nmax(1)$$

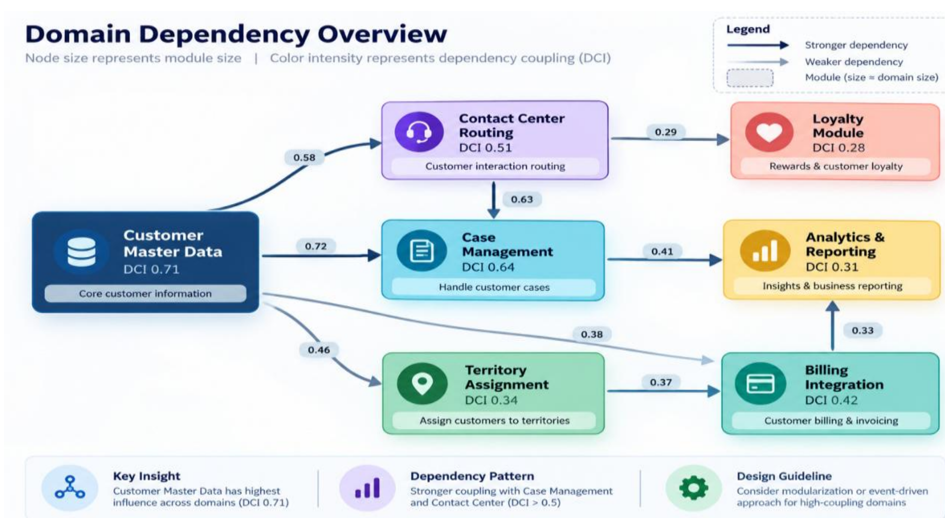

Fig. 3. Illustrative dependency graph for a legacy CRM capability estate, with node size reflecting coupling density.

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The technical debt is modeled as the compounded interest of the technical debt of a capability's independent components, as a function of how many dependent components there are and how long the delay until the components are remediated, using the same compounding interest formulation as that used by other debt models, as shown in Equation 2: where Pi is the principle of the design or implementation shortcut to the capability's cost, ri is the interest rate for a capability, based on the dependency coupling index and observed defect propensity, and t is the number of remaining transformation phases before the capability is remediated. An empirical survey of technical debt in the software industry showed that components with high structural coupling and low documentation are over-represented among those with high remediation costs, and among the most commonly cited causes of schedule overrun: about 40% of the software industry's claims of debt-induced schedule overruns to date have been for low-documentation, high-structural-coupling components. It can be inferred from this evidence, summarized in Figure 7 and Table 7 below, that dependency coupling can be used as a driving force for the interest-rate parameter, ri. The coupling index, along with the debt interest function, provides a score for sequencing priority using the risk-adjusted equation: Equation 3: Risk-adjusted sequencing priority score (RP). The ordering then focuses on capabilities that have high structural dependencies along with high business value, like customer master data and case management, and pushes to later phases anything with low coupling and low business value, like analytics reporting and loyalty modules—as shown in Table 4 and Figure 5.

$$TDi(t) = Pi \cdot (1 + ri)t(2)$$

$$SPSi = \alpha \cdot DCIi + \beta \cdot BVi - \gamma \cdot TDi(t) \,/\, TDmax(3)$$

TABLE 4. ILLUSTRATIVE DEPENDENCY COUPLING AND SEQUENCING PRIORITY SCORES FOR SAMPLE CRM CAPABILITIES

Capability	In-Dep.	Out-Dep.	DCI	Bus. Value	SPS	Phase
Customer Master Data	0	4	0.71	0.93	0.86	1
Case Management	2	3	0.64	0.80	0.74	1
Contact Center Routing	1	2	0.51	0.72	0.69	2
Territory Assignment	1	1	0.34	0.58	0.52	2
Billing Integration	2	1	0.42	0.49	0.47	3
Loyalty Module	1	1	0.28	0.33	0.31	4
Analytics & Reporting	2	0	0.31	0.27	0.24	4

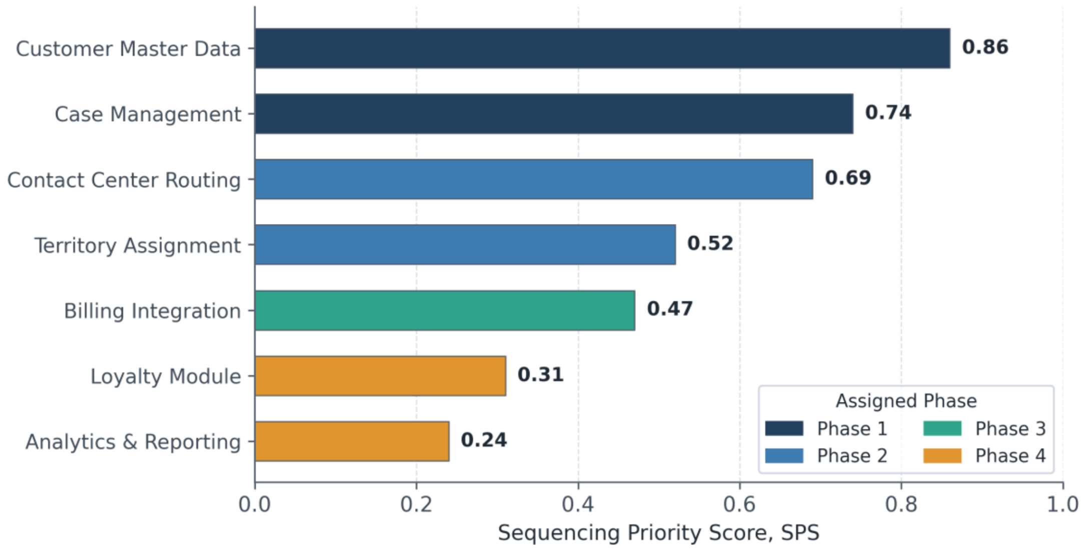

Fig. 4. Ranked sequencing priority scores for sample legacy CRM capabilities.

V. COMPARATIVE ANALYSIS OF SEQUENCING STRATEGIES

Based on evidence that quality information technology investment decisions are related to the strength of enterprise architecture practice, three approaches to implementing the sequencing strategy were compared: a big-bang approach, which replaces all the legacy capabilities at once, an undifferentiated phased approach, which phases in capabilities, but does not explicitly analyze the dependences between them, and the proposed dependency-aware approach. Three approaches to implementing the sequencing strategy were compared based on illustrative estimates that have been synthesized from the reviewed literature, a big-bang approach, in which the entire set of legacy capabilities are phased in simultaneously, an undifferentiated phased approach, in which the capabilities are phased in by functional area, but are not explicitly analyzed for dependency, and the proposed dependency-aware approach. As outlined in Table 5 and illustrated in Figure 6, the dependency-aware strategy has significantly lower projected downtime and lower post-migration defect density than the big-bang strategy and a lower cost overrun than the undifferentiated phased strategy, showing that the extra analysis effort demanded to build the dependency graph pays off in terms of reduced disruption when migrating.

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TABLE 5. COMPARATIVE OUTCOMES OF SEQUENCING STRATEGIES

Strategy	Avg. Downtime (indexed hrs)	Defect Density (per 1,000 txns)	Cost Overrun (%)	Satisfaction Impact (Δ points)
Big-Bang	46	38	34	−4.1
Undifferentiated Phased	29	24	22	−1.6
Dependency-Aware	14	11	9	+1.2

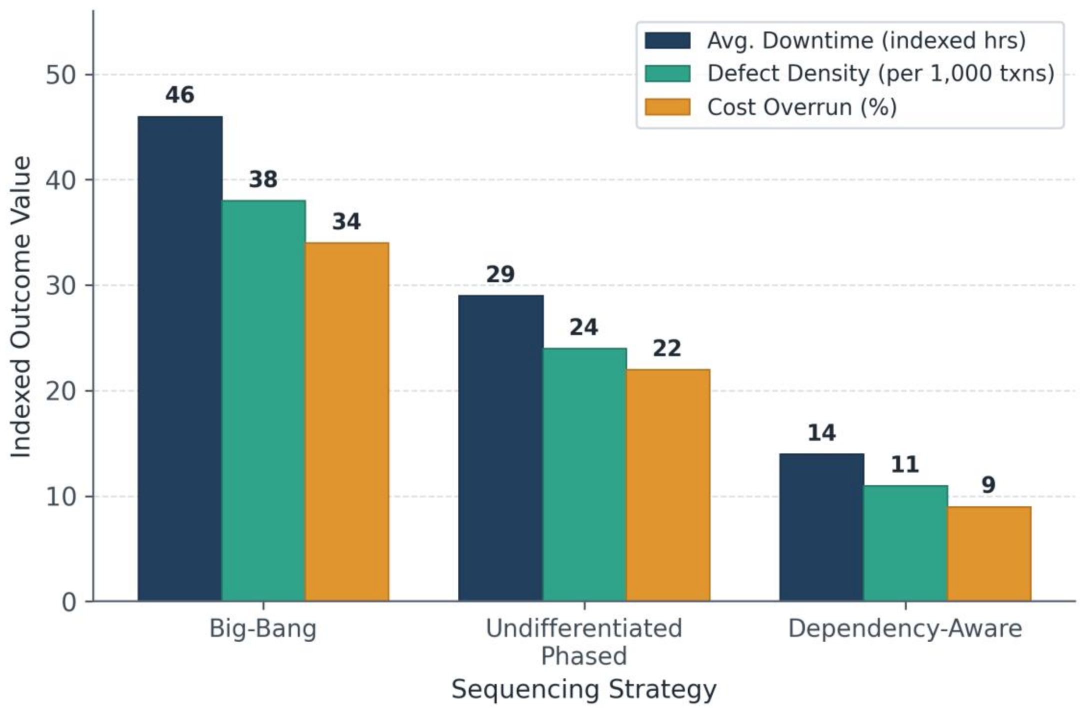

Fig. 5. Comparative downtime, defect density, and cost overrun across three sequencing strategies.

VI. FINDINGS, IMPLICATIONS, AND FUTURE DIRECTIONS

The results align with the current digital transformation literature and call for research agendas that link strategic intent of digital transformation with the process of technological change over time, its sequence and its governance [19]. The synthesis gives rise to three implications. First, the granularity of enterprise architecture artifacts should be big enough to enable the creation of the dependency graph so as to include all the necessary information needed for calculating the coupling index shown in Table 6 and Figure 7. Second, when considering the phases for treatment, governance bodies should take technical debt interest into account when making

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funding decisions, not assuming functional groupings are the only consideration; the sensitivity analysis in Table 7 shows that this can make a significant difference in the number of capabilities that are considered for early-phase treatment. Third, as previously discussed in this paper, employee resistance to the change is dependent upon the rate of change and the predictability of the change. Therefore, the sequencing decisions should be communicated as an explicit, criteria-based schedule and not as an emergent project outcome. A fourth practical implication is with regards to data governance – if the organizations do not have an up-to-date and granular capability inventory, then they should consider inventory remediation as a prerequisite step instead of building a dependency graph with incomplete or outdated documentation. The framework is dependent upon the quality of underlying dependency documentation, and the weights do not lend themselves to empirical validation, both of which warrant further research on the empirical testing of the framework that builds upon the literature summarized here.

TABLE 6. TECHNICAL DEBT PREVALENCE AND COMMON CAUSES ACROSS REVIEWED EVIDENCE

Cause Category	Reported Prevalence (%)	Typical Downstream Effect
High structural coupling	39	Schedule overrun, cascading defects
Undocumented business rules	27	Requirements rework
Time-pressured shortcuts	22	Rising remediation interest
Insufficient test coverage	12	Delayed defect detection

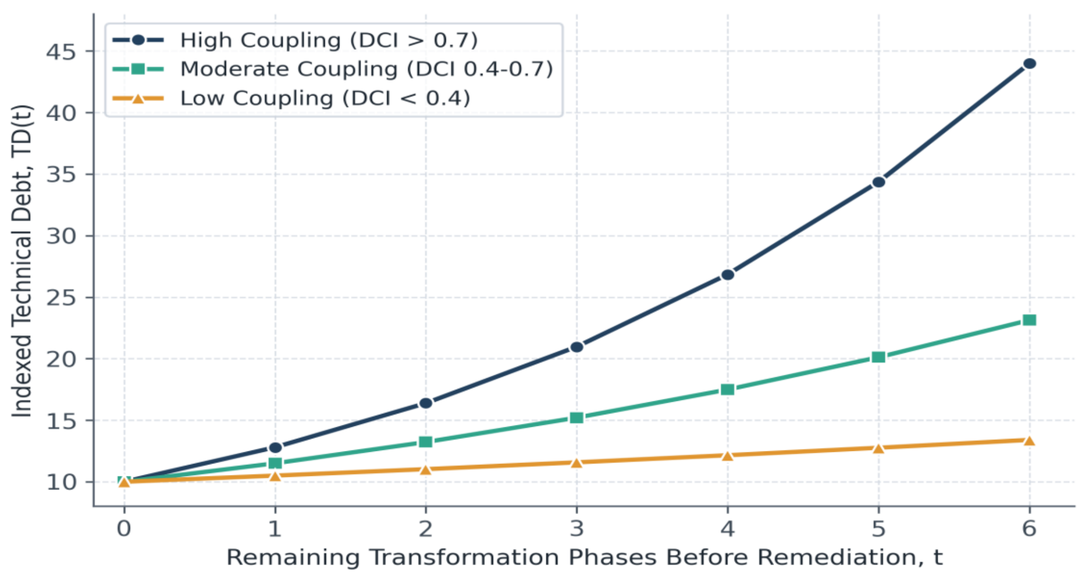

Fig. 6. Projected technical debt interest accrual across transformation phases, by dependency coupling tier.

TABLE 7. WEIGHTING PARAMETER SENSITIVITY FOR SEQUENCING PRIORITY SCORE

Scenario	α (Coupling)	β (Business Value)	γ (Debt Interest)	Phase-1 Capability Count
Coupling-dominant	0.6	0.3	0.1	2
Balanced (baseline)	0.4	0.4	0.2	2
Value-dominant	0.2	0.6	0.2	3
Debt-averse	0.35	0.25	0.4	1

VII. CONCLUSION

Based on the literature, this paper has synthesized the concepts and ideas of legacy systems, architectural technical debt, enterprise architecture, digital transformation, BPM and CRM critical success factors and created a framework that enables sequencing of the capability modernization for legacy CRM systems in a dependency aware manner. Its main contribution to the framework is to formalize dependency coupling, technical debt interest and risk-adjusted sequencing priority into a meaningful, manageable, and governable model for making decisions which can be integrated into existing enterprise architecture and CRM implementation practice. The comparative analysis indicates that there are measurable benefits of dependency-aware sequencing over big-bang and undifferentiated phased approaches when considering outcomes of downtime, defect, and cost-overrun, and the sensitivity analysis presented as part of the framework shows that the sequencing recommendations remain directionally consistent across a reasonable range of governance-determined weighting choices. The framework can be leveraged by enterprise architects, CRM program managers, and digital transformation practitioners to organize the modernization roadmaps, while honoring the interdependencies between various organizational and technical components described in the literature. For future work, the proposed weighting parameters should be experimentally proven on a variety of organizational settings and the model should be applied to other legacy enterprise applications than CRM.

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