



Semantic Bridging as Contextual Interoperability Infrastructure for GLAM Discovery: A Design-Based Research Study

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Purpose

This study theorises information repackaging as a semantic bridging strategy for contextual interoperability in Galleries, Libraries, Archives, and Museums (GLAM) discovery systems, addressing persistent fragmentation of access to conceptually interrelated resources across libraries, archives, galleries, and museums

Method

Adopting a first-cycle design-based research orientation, the study integrates problem analysis with conceptual artefact development. MARC21, DACS/EAD, VRA Core, CIDOC CRM, and Dublin Core are examined through crosswalk modelling, relationship typology construction, and design rationale articulation to formulate an intermediary semantic bridging framework for cross-domain discovery.

Results/findings

GLAM interoperability emerges as not merely technical but contextual and epistemological, since each standard inscribes heritage meaning through divergent descriptive logics. The framework recasts information repackaging as a relational transformation mechanism, operationalised through identification, form selection, reprocessing, organisation, and dissemination. The resulting intermediary layer establishes shared semantic anchors, explicit relationship assertions, and explanation-driven recommendations, enabling cross-collection discovery without schema replacement or wholesale migration

Conclusion

The model substantiates information repackaging as viable contextual interoperability infrastructure, reconciling institutional metadata traditions with cross-collection discoverability, pending validation through expert appraisal, prototyping, and user evaluation in subsequent design-based research cycles.

Keywords

information repackaging, semantic bridging, GLAM discovery, metadata interoperability, design-based research

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Abstrak

Tujuan

Studi ini mengonseptualisasikan penyusunan kembali informasi (information repackaging) sebagai strategi jembatan semantik untuk mewujudkan interoperabilitas kontekstual pada sistem penemuan GLAM, dengan menyoroti persoalan fragmentasi akses terhadap sumber daya yang secara konseptual saling berkaitan di lingkungan perpustakaan, arsip, galeri, dan museum.

Metode

Penelitian ini menerapkan orientasi Design-Based Research siklus pertama, yang memadukan analisis masalah dengan pengembangan artefak konseptual. Standar MARC21, DACS/EAD, VRA Core, CIDOC CRM, dan Dublin Core dikaji melalui pemodelan crosswalk metadata, konstruksi tipologi relasi, serta artikulasi rasional desain guna merumuskan kerangka jembatan semantik sebagai lapisan perantara bagi penemuan lintas domain GLAM

Hasil/Temuan

Temuan menunjukkan bahwa interoperabilitas GLAM bukan sekadar persoalan teknis, melainkan juga persoalan kontekstual dan epistemologis, karena setiap standar metadata merepresentasikan makna warisan budaya melalui logika deskriptif yang berbeda. Kerangka yang diusulkan memposisikan penyusunan kembali informasi sebagai mekanisme transformasi relasional yang dioperasionalkan melalui tahap identifikasi, pemilihan bentuk, pemrosesan ulang, pengorganisasian, dan penyebaran. Lapisan perantara ini membentuk jangkar semantik bersama, pernyataan relasi yang eksplisit, serta rekomendasi berbasis penjelasan yang memungkinkan penemuan lintas koleksi tanpa memerlukan penggantian skema atau migrasi sistem secara menyeluruh.

Kesimpulan

Model ini membuktikan bahwa penyusunan kembali informasi dapat berfungsi sebagai infrastruktur interoperabilitas kontekstual yang menyelaraskan tradisi metadata institusional dengan keterlacakan lintas koleksi, meskipun validitasnya masih memerlukan pengujian lebih lanjut melalui tinjauan pakar, prototipe, dan evaluasi pengguna pada siklus *Design-Based Research* berikutnya.

Kata kunci

information repackaging, semantic bridging, GLAM discovery, metadata interoperability, design-based research.

المخلص

الهدف

تطرح هذه الدراسة نظرية إعادة تغليف المعلومات كاستراتيجية ربط دلالية لتحقيق التوافق السياقي في أنظمة اكتشاف المتاحف والمعارض والمكتبات ودور المحفوظات (GLAM)، وذلك لمعالجة التجزئة المستمرة للوصول إلى الموارد المترابطة مفاهيمياً عبر هذه المجالات.

الطريقة

تعتمد الدراسة، من خلال منهجية بحثية قائمة على التصميم في المرحلة الأولى، على دمج تحليل المشكلة مع تطوير النماذج المفاهيمية. ويتم فحص معايير MARC21 و DACS/EAD و VRA Core و CIDOC CRM و Dublin Core من خلال نمذجة الربط، وبناء تصنيف العلاقات، وتوضيح الأساس المنطقي للتصميم، وذلك لصياغة إطار عمل وسيط للربط الدلالي لاكتشاف المعلومات عبر المجالات المختلفة.

النتائج

يبرز التوافق بين أنظمة GLAM ليس فقط من الناحية التقنية، بل أيضاً من الناحية السياقية والمعرفية، حيث يُجسد كل معيار معنى التراث من خلال منطق وصفي متباين. يُعيد هذا الإطار صياغة إعادة تغليف المعلومات كآلية تحويل علائقية، تُفَعِّل من خلال تحديد المعلومات، واختيار شكلها، وإعادة معالجتها، وتنظيمها، ونشرها. وتُرسخ الطبقة الوسيطة الناتجة روابط دلالية مشتركة، وتأكيدات صريحة للعلاقات، وتوصيات قائمة على التفسير، مما يُتيح اكتشاف المعلومات عبر المجموعات دون الحاجة إلى استبدال المخططات أو نقلها بالكامل.

الخلاصة

يؤكد هذا النموذج على أن إعادة تغليف المعلومات تُشكِّل بنية تحتية فعّالة للتوافق السياقي، حيث يُوفِّق بين تقاليد البيانات الوصفية المؤسسية وإمكانية اكتشاف المعلومات عبر المجموعات، وذلك رهناً بالتحقق من صحتها من خلال تقييم الخبراء، وبناء النماذج الأولية، وتقييم المستخدمين في دورات بحثية لاحقة قائمة على التصميم.

الكلمات الرئيسية

إعادة تغليف المعلومات؛ الربط الدلالي؛ اكتشاف GLAM؛ توافق البيانات الوصفية؛ البحث القائم على التصميم

INTRODUCTION

When a researcher, student, or member of the public seeks to understand Mohammad Hatta (1902–1980, Indonesia's first Vice-President as proclamer of Indonesian independence, cooperative movement thinker, a member of the Minangkabau intellectual tradition, and actor in international diplomacy, no single discovery pathway makes that journey possible. Books and biographies are retrievable through library catalogues; letters and official documents are accessible only through archival finding aids; photographs are managed within visual documentation systems; and artefacts are described through museum records (Alkemade et al., 2025; Candela, 2023). Each institution within Hatta Heritage—a multi-institutional cultural heritage site in Bukittinggi, West Sumatra, Indonesia (Majidah et al., 2025) operates according to metadata standards that are professionally legitimate within their own traditions (Doerr et al., 2007; Zeng, 2019) yet no mechanism bridges these collections into a coherent interpretive pathway for the user (O'Neill & Stapleton, 2022a). This is not primarily a digitisation problem. Many GLAM institutions, including those comprising Hatta Heritage, have invested substantially in making their holdings digitally accessible (Candela, 2023). The more fundamental failure is one of contextualisation: the absence of infrastructure capable of explaining why a Hatta letter, a photograph, and a physical artefact are connected within the same historical episode (Baca, 2008; Hjørland, 2023; Zeng, 2019).

This problem is not unique to Hatta Heritage. GLAM institutions face the same structural challenge globally: the descriptive standards they employ differ not merely in technical format but in the epistemological assumptions they embody about what constitutes a cultural object and which relationships are worth recording (Hjørland, 2023). MARC21 is oriented toward bibliographic description; EAD encodes archival hierarchy; VRA Core addresses works of visual culture; and CIDOC-CRM models objects, events, actors, and places as ontological entities (Doerr et al., 2007; Liu et al., 2023). These differences render metadata format uniformity insufficient: users navigating across collections receive no relational explanation—only a list of records that stand independently, stripped of contextual connection (O'Neill & Stapleton, 2022a).

Several approaches have been developed to address this problem. Metadata harmonisation attempts to produce a unified index but risks compressing archival hierarchy, visual specificity, and museum event semantics into generic descriptive fields (Baca, 2008; Hillmann et al., 2004; Zeng, 2019). Federated search preserves institutional autonomy but returns combined result lists rather than meaningful interpretive pathways, with persistent challenges in result merging, ranking, and clustering (Garba & Wu, 2025; Walsh et al., 2017). Linked data and ontology-based aggregation can generate rich semantic relations but require infrastructure that remains unevenly available—persistent identifiers, RDF transformation, ontology governance, and technical capacity that most small and medium-sized GLAM institutions do not yet possess (Freire et al., 2017; Liu et al., 2023). As a result, many GLAM discovery initiatives remain technically integrated but contextually weak (Doerr et al., 2007).

Recent scholarship documents a significant shift in GLAM practice: from basic digitisation toward collections as data, semantic enrichment, and user-centred computational exploration (Alkemade et al., 2025; Candela, 2023). Candela (2023) demonstrates that GLAM Labs increasingly frame datasets as resources for semantic and computational exploration and argues that small and medium-sized GLAM institutions require practical documentation, licensing frameworks, and data structuring to publish collections as data; Alkemade et al., (2025) emphasise that responsible reuse of cultural heritage datasets requires transparent documentation of provenance, selection criteria, and digitisation pipelines. Zeng (2019) further argues that semantic enrichment supports deeper exploration of library, archive, and museum data. Together, these studies mark a paradigm shift from simple access provision toward interpretive connectivity (Hyvönen, 2019; Liu et al., 2023).

Nevertheless, these contributions leave three interrelated gaps unaddressed. First, research on information repackaging—classically understood as the selection, restructuring, and presentation of information for specific user contexts (Atmi et al., 2025; Hjørland, 2023) has not been developed as a theory of semantic integration infrastructure for GLAM discovery (Zeng, 2019). Second, studies on GLAM interoperability have concentrated primarily on data exchange, schema alignment, and ontology publication, giving insufficient attention to how cross-collection relationships can be communicated transparently to end users (Liu et al., 2023). Third, the concept of contextual interoperability—the capacity of a system to preserve, model, and communicate culturally meaningful relations among heterogeneous records—has not been operationalised as a design construct in regional heritage ecosystems that have not yet migrated fully to RDF-based environments (Baca, 2008; Candela, 2023; Zeng, 2019).

Although prior research has identified the limitations of metadata harmonisation and linked data aggregation for small and medium-sized GLAM ecosystems (Isaac et al., 2020; O'Neill & Stapleton, 2022), there remains a limited body of work that operationalises information repackaging as a semantic intermediary infrastructure specifically, a model capable of deploying a Dublin Core-based intermediary layer as a relational bridge across heterogeneous collections without compromising institutional autonomy or requiring full RDF maturity (Hjørland, 2023). This gap is particularly consequential for cases such as Hatta Heritage, where the value of discovery lies not in retrieving isolated items but in reconstructing the historical relations among persons, events, places, objects, texts, and collective memory (O'Neill & Stapleton, 2022a; Walsh et al., 2017).

This article proposes semantic bridging as an intermediary design mechanism that: (a) maps heterogeneous metadata into a minimal shared semantic layer based on Dublin Core; (b) models' multidimensional relationships among records across institutional boundaries; and (c) exposes these relationships through user-facing discovery functions, including transparent "see also" recommendations and graph-based exploration (Candela, 2023; Liu et al., 2023). The novelty of this article lies in a conceptual repositioning of information repackaging: from a content communication activity to a relational contextualisation infrastructure, and from format adaptation to meaning modelling (Atmi et al., 2025; Hjørland, 2023).

This study aims to design a first-cycle conceptual artefact using a design-based research orientation (Anderson & Shattuck, 2012; McKenney & Reeves, 2018), comprising a Dublin Core intermediary layer, a multidimensional semantic relationship typology, a cross-standard mapping model, and a user-facing recommendation logic (Doerr et al., 2007; Zeng, 2019). It is important to clarify the scope of this design at the outset: the object of design here is strictly a conceptual model rather than a deployable software system, and the study is deliberately confined to problem analysis and conceptual formulation, meaning that no actual software or digital tool has been built or implemented at this stage. Because the inquiry is restricted to a first-cycle design, critical evaluation metrics—specifically expert validation, prototype implementation, and real-world user testing—are intentionally absent from the present cycle and are explicitly deferred to a subsequent, empirically oriented research cycle. This staged positioning is consistent with design-based research traditions, in which conceptual artefact formulation precedes, rather than substitutes for, prototyping and evaluation (Barab & Squire, 2004; Sandoval, 2014). The theoretical contribution of this study extends the conceptual boundary of information repackaging into the domain of contextual interoperability. The methodological contribution demonstrates how design-based research can be applied to construct a conceptual artefact prior to empirical prototyping (Barab & Squire, 2004; Sandoval, 2014). The practical contribution offers a staged strategy for cultural heritage GLAM institutions that require contextual connectivity without immediate system migration or schema replacement (Candela, 2023; Zeng, 2019).

METHOD

This study employs a first-cycle Design-Based Research (DBR) orientation (Anderson & Shattuck, 2012; Kennan & Lymn, 2019), selected because the research problem is design-oriented: it requires constructing an artefact that simultaneously addresses a practical problem and advances theoretical understanding of contextual interoperability in GLAM discovery. While DBR shares with Design Science Research a commitment to artefact construction and utility (Hevner et al., 2004), DBR is more specifically oriented toward knowledge construction within complex institutional settings, fitting the multi-institutional ecology of Hatta Heritage.

The unit of analysis is the semantic relationship among metadata records representing different GLAM descriptive traditions. Hatta Heritage Bukittinggi is selected through theoretical purposiveness, constituting a multi-institutional ecosystem where cultural memory is distributed across four institutions under separate administrative authorities: the Bung Hatta Proclamator Library (National Library of Indonesia), the Bung Hatta Birthplace Museum (Bukittinggi Department of Culture and Tourism), archival holdings under the Bukittinggi City Library and Archives Service, and Istana Bung Hatta under the West Sumatra Provincial Government. This administrative and descriptive fragmentation makes Hatta Heritage a theoretically productive site for designing semantic bridging infrastructure.

The design procedure comprised four steps: identifying each schema's dominant descriptive logic (MARC21, DACS/EAD, VRA Core, CIDOC-CRM, Dublin Core); extracting common discovery anchors (title, creator, subject, date, type, coverage, provenance, relation); mapping these anchors into a Dublin Core-based intermediary layer via cross-walk analysis; and formulating a multidimensional semantic relationship typology grounded in GLAM interoperability literature (Baca, 2008; Doerr et al., 2007; Hillmann et al., 2004; Zeng, 2019).

Consistent with the scope of a first DBR cycle, the object of design is strictly a conceptual artefact rather than a deployable software system; no digital tool has been built or implemented. Accordingly, expert validation, prototype implementation, and user testing are entirely absent here and explicitly deferred to a subsequent empirical cycle (Easterday et al., 2016; Sandoval, 2014). Validity at this stage is therefore theoretical and procedural, established through explicit mapping logic and grounding in metadata interoperability literature (Alkemade et al., 2025; Hjørland, 2023; Kennan & Lymn, 2019).

RESULT/FINDING AND DISCUSSION

Landscape of Metadata and Interoperability

The first finding of the design analysis is that GLAM interoperability cannot be reduced to the technical conversion of fields. Each metadata standard structures heritage reality through a different descriptive epistemology (Pasciuto et al., 2025; Zeng, 2019). MARC21 privileges bibliographic control, authority, and publication description; DACS/EAD foregrounds archival hierarchy, context, and provenance; VRA Core foregrounds work-image distinctions and visual documentation; and CIDOC-CRM foregrounds entities, events, actors, places, and temporal relations (CIDOC CRM Special Interest Group, 2026; Doerr et al., 2007; Library of Congress., 2025; Library of Congress, 2026). If these differences are collapsed into a single flat schema, GLAM discovery may become more searchable but less meaningful. The challenge is to identify a bridge that is thin enough to be implementable and rich enough to preserve contextual meaning (Hillmann et al., 2004; O'Neill & Stapleton, 2022).

Table 1 operationalises this argument. It does not propose a total schema migration. Instead, it identifies a minimum mapping layer through which records can be connected for discovery purposes. The mapping is intentionally selective. Only elements required to support cross-collection discovery are drawn into the intermediary layer, while specialised descriptive detail remains in the source system. This approach reduces institutional

resistance because libraries, archives, galleries, and museums are not asked to abandon their standards. It also avoids the epistemic loss that occurs when archival hierarchy, visual context, or event-based museum semantics are flattened into a single catalogue record.

Table 1. Operational Mapping of GLAM Metadata Standards to Dublin Core and Bridging Functions

Source standard	Domain logic	Selected source elements	Dublin Core bridge	Operational bridging function
MARC21	Bibliographic description	100, 245, 260/264, 520, 650, 856	dcterms: creator, title, date, description, subject, identifier	Anchors books and articles through title, person, subject, date, and persistent link.
DACS/EAD	Hierarchical archival description	unittitle, unitdate, origination, controlaccess, scopecontent	dcterms: title, date, creator, subject, description, provenance	Connects letters, files, and archival units through context, creator, date, and archival provenance.
VRA Core	Work-image visual description	title, agent, date, location, worktype, culturalContext	dcterms: title, creator, date, spatial, type, subject	Links photographs and visual documentation through depicted person, place, period, and visual type.
CIDOC-CRM	Event/object ontology	E22 object, E39 actor, E5 event, E53 place, E52 timespan	dcterms: type, creator/contributor, temporal, spatial, relation	Connects museum artefacts through object, actor, production/use event, place, and time.
Dublin Core/DCMI terms	Cross-domain intermediary	title, creator, subject, date, relation, spatial, temporal, provenance	Shared intermediary semantic layer	Provides minimum shared discovery anchors while preserving source metadata in native systems.

Dublin Core as an Intermediary Semantic Layer

The proposed intermediary layer is built on Dublin Core and DCMI terms because they offer a pragmatic vocabulary for identifying entities and relations across domains. DCMI terms include the fifteen classic Dublin Core elements and additional refinements that allow more precise description of agents, coverage, provenance, and relationships (DCMI Usage Board, 2020; Hillmann et al., 2004). This does not mean that Dublin Core should replace MARC21, DACS/EAD, VRA Core, or CIDOC-CRM. Rather, it functions as a discovery-oriented semantic layer through which heterogeneous records can be connected for exploration. This role is consistent with the broader literature on semantic interoperability, which emphasises shared vocabularies, lightweight crosswalks, and relationship modelling as mechanisms for preserving meaning across systems (Zeng, 2019).

The intermediary layer contains four components. The first is a normalised entity set for persons, places, periods, events, and object types. The second is a field mapping layer that translates source fields into Dublin Core and DCMI terms. The third is a relationship assertion layer that stores the type of relationship between records, such as same person, same place, same event, same period, same creator, or same material form. The fourth is a recommendation explanation layer that renders the relation in user-readable language. A user should not simply see another item; the interface should explain why the item matters. For example, a personal letter may be recommended because it shares the subject 'Mohammad Hatta', the provenance 'Hatta correspondence', and the temporal coverage 'Indonesian nationalist movement period'.

Figure 1 summarises this architecture. The source metadata remains in its native systems. The Dublin Core intermediary layer extracts only shared discovery anchors. The multidimensional relationship model produces semantic assertions, and these assertions feed a user-facing discovery interface. The central design principle is separation of concerns: source institutions maintain their professional standards, the bridge manages cross-domain relations, and the interface communicates context to the user.

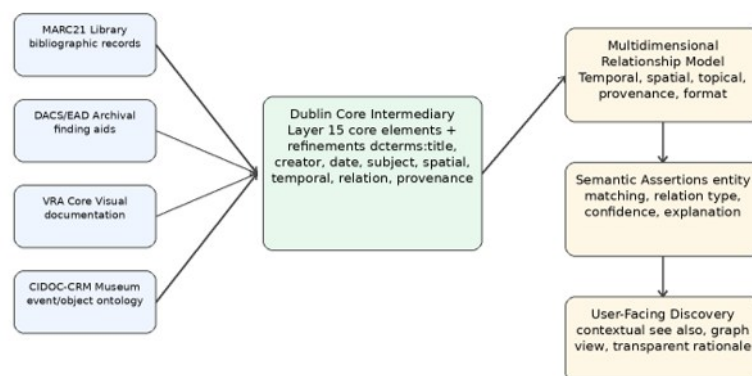


Figure 1. Dublin Core-Based Semantic Bridging Architecture for GLAM Metadata Interoperability

Multidimensional Semantic Relationship Typology

The second design finding is that a useful GLAM bridge must model more than one relation type. Many discovery systems rely heavily on keyword similarity or subject matching, but cultural heritage understanding is built through relations among persons, places, events, periods, materials, and institutional contexts (Hjørland, 2023; O'Neill & Stapleton, 2022). Recent studies on cultural heritage linked data and semantic discovery similarly show that explicit relationships and graph-oriented exploration can support richer interpretation than linear result lists (Candela, 2023; Hyvönen, n.d.; Moyano et al., 2023). Therefore, the proposed typology includes five dimensions: topical, temporal, spatial, provenance, and format or materiality.

Topical relations connect records that share persons, themes, concepts, or subject headings. Temporal relations connect records produced in the same period, referring to the same historical episode, or commemorating the same date. Spatial relations connect records associated with the same place, such as Bukittinggi, Fort de Kock, or a specific heritage site. Provenance and agency relations connect records through creator, sender, recipient, collector, owner, custodian, or institutional source. Format and materiality relations connect records through object type or medium, such as book, manuscript, photograph, audio, building, statue, or personal object.

Table 2 translates these dimensions into operational indicators. The most important feature of this typology is explainability. The system should not hide the logic of recommendation. If a photograph appears beside a book record, the interface should state whether the connection is topical, temporal, spatial, provenance-based, or format-based. This design principle responds to the wider concern that semantic enrichment can improve discovery but may also introduce opaque, erroneous, or weakly documented associations if not curated carefully (Alkemade et al., 2025; Candela, 2023). In this sense, semantic bridging is not merely a technical relation layer; it is also a communicative device for making metadata relations intelligible to users.

Conceptual Implementation in Hatta Heritage

Hatta Heritage provides a strong illustrative case because its materials are distributed across multiple institutional and object traditions. A library record may describe a biography of Mohammad Hatta, an archival record may describe personal correspondence, a visual record may describe a photograph of Hatta in a public event, and a museum record

may describe an artefact associated with his life. In conventional systems, these materials are usually retrieved through separate catalogues and professional metadata traditions. Yet cultural heritage discovery requires users to move across these traditions to reconstruct historical context (Candela, 2023; O'Neill & Stapleton, 2022a; Walsh et al., 2017). The proposed bridge therefore seeks to connect the records not by replacing institutional metadata but by creating shared semantic anchors and explicit relationship assertions.

Table 2. Multidimensional Semantic Relationship Typology for GLAM Discovery

Relationship Dimension	Operational indicator	Example in Hatta Heritage	User-facing Explanation
Topical	Shared person, theme, concept, subject heading, or keyword	Biography, letter, and photograph all refer to Mohammad Hatta	Related because both records concern Mohammad Hatta.
Temporal	Same date, period, historical episode, commemoration, or sequence	Records linked to the nationalist movement or early Republic period	Related because both records refer to the same historical period.
Spatial	Same place, region, site, building, or geographic coverage	Bukittinggi, West Sumatra, or Hatta Birthplace Museum	Related because both records are associated with Bukittinggi.
Provenance or agency	Same creator, sender, recipient, owner, custodian, collector, or institutional source	A personal letter and archival file associated with Hatta correspondence	Related because both records share provenance or actor context.
Format or materiality	Same or complementary object type, medium, genre, or material form	Book, manuscript, photograph, artefact, room display, or documentation image	Related because the records represent complementary material forms.

Table 3 shows an illustrative mapping scenario. The scenario begins with a user opening a bibliographic record for a biography of Mohammad Hatta. In a conventional catalogue, discovery would likely end with similar books, subject headings, or author searches. In the proposed model, the record generates semantic anchors: person equals Mohammad Hatta, place equals Bukittinggi or West Sumatra, period equals the nationalist movement and early Republic, and topic equals biography, leadership, nationalism, or Minangkabau intellectual history. The bridge then searches other mapped records that share one or more anchors. A personal letter can be recommended through a topical and provenance relation, a photograph through a person and temporal relation, and a museum artefact through a place and material relation.

Table 3. Illustrative Hatta Heritage Cross-Collection Mapping Scenario

Seed record	Native Standard	DCMI anchors	Recommended item	Relationship basis
Biography of Mohammad Hatta	MARC21	title, creator, subject: Mohammad Hatta; spatial: Bukittinggi; type: text	Personal letters of Mohammad Hatta	Topical + provenance relation
Personal letters of Mohammad Hatta	DACS/EAD	creator/recipient, unitdate, scopecontent, provenance	Photograph of Hatta in Bukittinggi	Person + temporal + spatial relation
Photograph of Hatta in Bukittinggi	VRA Core	agent, location, date, worktype, cultural-Context	Artefact displayed in Hatta Birthplace Museum	Spatial + historical context relation
Museum artefact associated with Hatta	CIDOC-CRM	object, actor, event, place, timespan	Biography and archival notes explaining the artefact	Object + event + explanatory relation

This scenario should not be read as an implemented production system. It is a conceptual implementation scenario intended to specify the design logic before prototyping. The distinction is important. A top-tier design article must avoid presenting a mock-up as if it

were empirical evidence. The present contribution is a design artefact: it defines the layers, mappings, relationship types, and interface logic needed for later implementation. In the next DBR cycle, this model should be transformed into a clickable prototype and evaluated by metadata experts, GLAM practitioners, and users seeking Hatta-related information.

The user-facing recommendation logic is specified as a transparent semantic explanation rather than as a generic related-item display. When a user opens a MARC21 record for a Hatta biography, the system may recommend an EAD archival letter because both share the entity Mohammad Hatta as subject or creator; a VRA photograph because it shares the same historical period or event; and a CIDOC-CRM museum artefact because it is associated with the same place, person, or provenance chain. This logic is consistent with semantic web approaches that make relationships explicit through structured assertions, but it is adapted to a lighter intermediary model that can be implemented incrementally in resource-constrained GLAM settings (Candela, 2023; Liu et al., 2023; Zeng, 2019).

Comparison with Existing Integration Approaches

The third finding concerns the position of semantic bridging among established GLAM integration strategies. Metadata harmonisation, federated search, and linked data aggregation should not be dismissed; each has a legitimate place in the GLAM interoperability ecosystem (Doerr et al., 2007; Gaitanou et al., 2024; Petras et al., 2017). However, the Hatta Heritage design problem requires an approach that can preserve native metadata, operate before full RDF maturity, and still provide user-facing contextual recommendations. This is where semantic bridging occupies a distinctive position between shallow aggregation and technically demanding linked data transformation (Candela, 2023; Liu et al., 2023; Zeng, 2019).

Table 4 positions semantic bridging as such an intermediate strategy. Its novelty does not lie in claiming to replace established methods but in combining selective mapping, multidimensional relationship modelling, and user-facing explanations. The source metadata is preserved; the intermediary layer provides minimal shared semantics; and the recommendation logic translates semantic assertions into discovery pathways. This makes the framework particularly relevant for heritage ecosystems where institutional autonomy, uneven technical capacity, and culturally rich context must be managed together.

Compared with harmonisation, semantic bridging reduces the risk of semantic flattening. Compared with federated search, it adds relationship modelling. Compared with linked data aggregation, it lowers the initial technical threshold while remaining compatible with later RDF or ontology development. The framework can therefore operate incrementally. A GLAM consortium could begin by mapping only title, creator, subject, date, place, type, and identifier. Later, it could add authority control, controlled vocabularies, persistent identifiers, RDF export, and machine-assisted entity reconciliation. This staged pathway is important because sustainability in GLAM interoperability is often limited not by conceptual ambition but by governance, staffing, funding, and maintenance capacity.

The framework also invites careful governance. Semantic bridging can only be reliable if relationship assertions are curated, documented, and periodically reviewed. Automated similarity may assist, but it should not replace expert judgement, especially in heritage contexts where relations are interpretive, culturally loaded, and historically consequential (Alkemade et al., 2023; Baca, 2016; Hjørland, 2023). This governance concern is also consistent with collections-as-data scholarship, which stresses the importance of provenance, documentation, licensing, versioning, and transparent data preparation for responsible reuse (Candela et al., 2023).

Table 4. Comparative Position of Semantic Bridging among GLAM Integration Approaches

Approach	Main strength	Main limitation	Position of semantic bridging
Metadata harmonisation	Produces a common index and simplifies cross-collection display.	May flatten domain nuance and requires sustained schema governance.	Uses selective mapping only for discovery anchors while source metadata remains intact.
Federated search	Preserves institutional systems and can be implemented relatively quickly.	Often returns merged lists without modelling why records are related. Requires technical infrastructure, persistent identifiers, and ontology governance.	Adds explicit semantic relation types and explanation logic.
Linked data aggregation	Supports rich RDF relations, URI-based identity, and ontology reasoning.		Provides an incremental route that can later evolve toward RDF and ontology alignment.
Semantic bridging	Balances institutional autonomy, contextual modelling, and user-facing explanation.	Requires curated relationship assertions and later empirical validation.	Proposed model for first-cycle contextual interoperability in regional GLAM ecosystems.

Theoretical Contribution: Contextual Interoperability

The central theoretical contribution of the article is the concept of contextual interoperability. Structural interoperability allows systems to exchange data; semantic interoperability allows systems to interpret shared meaning; contextual interoperability allows systems to preserve and communicate why culturally related items should be explored together (O'Neill & Stapleton, 2022b; Vogt, 2025; Zeng, 2019). This distinction matters because GLAM metadata often derives value from relations rather than from isolated fields. A letter, photograph, book, and artefact may have different metadata structures, but they become meaningful to users when connected through actor, event, place, period, provenance, or materiality (Doerr et al., 2007; Hjørland, 2023).

Contextual interoperability has four indicators. First, relation plurality: the system can represent more than one kind of relationship, including topical, temporal, spatial, provenance, and format relations. Second, domain preservation: source metadata remains available in its own descriptive logic. Third, explanation transparency: the interface communicates why recommended records are connected. Fourth, extensibility: the bridge can incorporate authority files, controlled vocabularies, linked data identifiers, or machine-learning suggestions in later stages without destroying the original design. These indicators make contextual interoperability measurable in the next research cycle.

This concept also sharpens the theoretical position of information repackaging. In classical library and information science, repackaging often addresses user need through format transformation or content presentation (Atmi et al., 2025). In GLAM discovery, the more urgent task is relationship transformation: converting dispersed metadata traces into intelligible contextual pathways. The proposed model therefore extends repackaging from a service function into an infrastructural and epistemic function. It repackages not merely information objects but the relations that allow users to understand them as part of cultural memory (Hjørland, 2023; O'Neill & Stapleton, 2022).

Practical Implications for GLAM Governance and Discovery Design

The practical implication for GLAM institutions is that interoperability should be treated as a governance project as much as a technical project. A semantic bridge requires agreement on shared entities, controlled vocabularies, mapping priorities, provenance documentation, and maintenance responsibilities (Alkemade et al., 2025; Candela, 2023; Zeng, 2019). For Hatta Heritage, this implies that institutions do not need to begin with a complex full-system merger. They can begin by identifying high-value entities, such as Mohammad Hatta, Rahmi Hatta, Bukittinggi, the Indonesian nationalist movement, and specific historical periods, and then mapping records around these anchors.

For metadata governance, the model recommends three staged actions. First, institutions should identify high-value entities, such as Mohammad Hatta, Rahmi Hatta,

Bukittinggi, the Indonesian nationalist movement, and key episodes in Hatta's public life. Second, each institution should map a small set of fields into Dublin Core and DCMI terms. Third, curators and librarians should validate relationship assertions before they are displayed to users. This staged approach recognises that GLAM institutions often have different systems, different staff capacity, and different professional vocabularies.

For discovery interface design, the model recommends that every 'see also' feature be explanatory. A recommendation that says only 'related item' is insufficient. A better design says: 'Related because both records concern Mohammad Hatta', 'Related because both refer to the same period', or 'Related because both originate from the same provenance context'. Such explanation-oriented design aligns semantic discovery with user sense-making and reduces the opacity often associated with algorithmic or automatically enriched recommendations (Candela, 2023; Walsh et al., 2017).

For policy and institutional collaboration, semantic bridging offers a low-threshold strategy for heritage integration. It can begin as a metadata governance agreement before becoming a full technical platform. This is particularly useful for regional GLAM ecosystems where institutions may lack advanced semantic web infrastructure. It also supports cultural autonomy: each institution can maintain its descriptive tradition while contributing to a shared discovery environment. In the long term, the same bridge can be expanded toward RDF, Wikidata alignment, CIDOC-CRM mapping, and API-based collection sharing.

Limitations and Next DBR Cycle

The main limitation of this study is that the artefact remains conceptual. The article does not claim to have implemented a production system, measured retrieval performance, or evaluated user satisfaction. The illustrative Hatta Heritage scenario demonstrates design plausibility rather than empirical effectiveness. This limitation is not a weakness if it is clearly positioned within DBR as a first-cycle design output. The next cycle must transform the model into a prototype, test the mapping with actual metadata records, evaluate recommendation relevance, and examine whether users understand the explanation logic (Anderson & Shattuck, 2012; Walsh et al., 2017).

Three validation pathways are recommended. First, metadata expert validation should assess whether the crosswalk preserves sufficient domain meaning and whether the relationship typology is adequate. Second, system prototyping should test whether semantic assertions can be stored, updated, and displayed efficiently. Third, user evaluation should measure exploratory search experience, perceived relevance, sensemaking support, and trust in recommendations. Only after these evaluations can stronger claims be made about effectiveness. Until then, the contribution should be framed as a theoretically grounded and practically oriented design artefact for contextual interoperability (Hevner et al., 2004; McKenney & Reeves, 2018).

Contextual Interoperability as The Core Design Contribution

The most important theoretical implication of the proposed artefact is the distinction between semantic interoperability and contextual interoperability. Semantic interoperability enables systems to interpret shared meanings across metadata elements. Contextual interoperability goes further by enabling systems to preserve and communicate why two cultural heritage records should be understood together. In the Hatta Heritage context, this means that the relationship between a biography, a personal letter, a photograph, and a museum artefact is not treated as a weak keyword similarity but as a culturally meaningful association grounded in person, place, time, agency, and material form (Doerr et al., 2007; Moyano et al., 2023).

This distinction is crucial because GLAM records often carry meaning through context rather than through isolated descriptive fields. An archival letter is meaningful not only because it has a title and date, but because it belongs to a correspondence network, an institutional provenance, and a historical episode. A museum object is meaningful not only

because it has a type or material, but because it is linked to an event, a place, a custodian, and a public memory practice. Contextual interoperability therefore requires more than shared vocabularies; it requires explicit relationship modelling and user-facing explanation (Farhah & Lawanda, 2023; Vogt, 2025).

The design artefact operationalises contextual interoperability through three indicators. The first is relation traceability: the system must be able to show which metadata anchors generated a recommendation. The second is relation typology: every recommendation must be categorised by a relationship type such as topical, temporal, spatial, provenance-based, or format-based. The third is relation explainability: the interface must translate machine-readable assertions into user-readable statements. These indicators make the concept testable in later DBR cycles and prevent contextual interoperability from remaining an abstract slogan (Sandoval, 2014; Vogt, 2025).

Design Principles for Semantic Bridging

From the mapping and comparison exercise, four design principles can be derived. The first is preservation before integration. Source metadata should remain in its native system because each GLAM domain has its own professional logic, institutional history, and descriptive granularity. A library catalogue, an archival finding aid, a museum object record, and a visual documentation record should not be forced into a single thick schema at the first stage. The bridge should extract only the minimum shared anchors required for discovery while allowing domain-specific description to remain available for specialist interpretation (Baca, 2008; Pasciuto et al., 2025).

The second principle is incremental semantic enrichment. Many regional GLAM institutions cannot immediately build RDF stores, persistent identifier infrastructures, or full ontology governance. A practical model must therefore allow institutions to begin with simple Dublin Core anchors and progressively add refinements, controlled vocabularies, authority files, entity reconciliation, and eventually RDF alignment. Semantic bridging is not designed as an alternative to linked data in the long term, but as a staged pathway toward it. It enables cultural heritage institutions to enter semantic interoperability without waiting for complete technological readiness (Candela, 2023; Gaitanou et al., 2024).

The third principle is multidimensional relation modelling. Cultural heritage discovery should not depend only on title, author, or subject similarity. In the Hatta Heritage case, users may need to explore relationships among a person, a birthplace, a correspondence file, a photograph, a public office, a commemorative event, and an artefact. The proposed model therefore treats relation types as plural and layered. A recommendation becomes stronger when several dimensions converge, for example when two records share the same person, the same place, and the same historical period. This principle can later be translated into weighting rules for recommendation ranking (Garba & Wu, 2025; Liu et al., 2023).

The fourth principle is transparent recommendation. GLAM discovery should avoid opaque algorithmic suggestions that merely state that an item is related. Users should be able to see the logic of the relation. A transparent interface can display a short explanation such as 'related by same historical actor', 'related by same place', or 'related by same provenance'. This is important not only for usability but also for information literacy. By explaining relations, the system teaches users how cultural heritage knowledge is organised and how different institutional collections speak to each other (Mayesti, 2023; Walsh et al., 2017).

Implications For Glam Metadata Governance

The proposed model has practical consequences for metadata governance. It implies that GLAM collaboration should not begin with the most difficult question of system merger. Instead, it can begin with a shared agreement on semantic anchors, relation categories, authority control, and explanation language. Institutions can maintain their catalogues and databases while participating in a common discovery layer. This approach

may reduce institutional resistance because the bridge does not remove ownership, alter internal workflows, or erase domain-specific standards. It asks institutions to contribute shared semantic points rather than surrender their descriptive systems (Kennan & Lymn, 2019; Zeng, 2019).

For Hatta Heritage, this governance model would require a small cross-institutional metadata working group involving library cataloguers, archivists, museum curators, historians, and information system designers. The group would identify priority entities such as Mohammad Hatta, Bukittinggi, the Indonesian independence movement, Minangkabau intellectual networks, and key historical periods. It would also define preferred labels, variant names, place terms, and relationship types. This institutional process is as important as the technical architecture because semantic bridging depends on shared curatorial judgement, not only software design (Majidah et al., 2025; Putra & Adam, 2026).

Metadata governance should also include provenance documentation. When the bridge asserts that two records are related, the system should preserve information about who created the assertion, which metadata fields support it, whether the assertion was generated manually or automatically, and when it was last reviewed. This is essential for trust, auditability, and long-term sustainability. Without provenance governance, semantic recommendations may become difficult to maintain and may introduce misleading associations. In heritage contexts, where interpretation carries cultural and historical weight, relationship assertions must be accountable (Alkemade et al., 2025; Hillmann et al., 2004).

Evaluation Agenda for The Next DBR Cycle

Because this article is deliberately positioned as a first-cycle conceptual design study, the next DBR cycle must move from conceptual plausibility to empirical testing. The first evaluation pathway should be metadata expert validation, involving librarians, archivists, museum professionals, and heritage scholars who assess whether the mapping preserves domain meaning and whether the proposed semantic relationship dimensions are sufficient (Kennan & Lymn, 2019; Sandoval, 2014). The second pathway should be prototyping testing with a bounded dataset of Hatta Heritage records. The third pathway should be user-based assessment through exploratory search tasks, measuring whether semantic recommendations improve contextual understanding, navigation, and discovery satisfaction (Candela, 2023; Walsh et al., 2017).

The second evaluation pathway should be prototyping testing. A limited prototype can be built using a small set of real records from a library catalogue, archival finding aid, visual documentation source, and museum record. The prototype should store source metadata, intermediary Dublin Core fields, semantic assertions, and recommendation explanations as separate but connected layers. Testing should examine whether new records can be added without redesigning the whole architecture, whether relationship assertions can be updated, and whether recommendations remain understandable when the number of records grows.

The third evaluation pathway should be user-based assessment. Users should be asked to complete exploratory tasks such as tracing the relationship between Mohammad Hatta, Bukittinggi, a historical period, a personal document, a visual object, and a museum artefact. Their behaviour can be analysed through task completion, path exploration, perceived usefulness, and qualitative feedback. This would allow the next DBR cycle to test whether semantic bridging improves contextual discovery rather than merely producing a theoretically elegant model (Kennan & Lymn, 2019; Sandoval, 2014; Walsh et al., 2017).

This evaluation agenda also protects the article from overclaiming. The present study does not assert that the model has already improved retrieval performance or user satisfaction. It argues that the model is theoretically coherent, methodologically defensible, and practically feasible as a design artefact. Stronger claims should be reserved for later cycles after expert review, prototype implementation, and user testing. This cautious positioning is important for top-tier publication because design research must distinguish clearly between proposed artefacts, implemented systems, and empirically validated out-

comes.

Limitations and Transferability

Several limitations must be acknowledged. First, Hatta Heritage is used as an illustrative case rather than as a fully implemented empirical case study. The article therefore does not present statistical generalisation or system performance data. Second, the mapping rules remain preliminary because they are derived from conceptual crosswalk analysis and illustrative metadata surrogates. Third, the recommendation logic has not yet been validated with users. These limitations do not invalidate the contribution, but they define its scope: the article offers a first-cycle design artefact and design principles, not a completed discovery platform (Anderson & Shattuck, 2012; Sandoval, 2014).

The transferability of the model depends on institutional and metadata conditions. It is most suitable for GLAM ecosystems where collections are culturally related but institutionally distributed, where metadata standards differ but share identifiable anchors, and where full system migration is impractical. Other heritage clusters could adapt the model by replacing the Hatta-specific entities with their own people, places, periods, objects, and events. The design is therefore not universal in content, but transferable in logic. Its core proposition is that cultural heritage discovery improves when systems connect not only records but contexts (Hyvönen, 2020; Petras et al., 2017).

Operationalisation for Metadata and Interface Design

At the metadata level, the operationalisation of semantic bridging requires a distinction between descriptive fields, semantic anchors, and relationship assertions. Descriptive fields are the original metadata elements maintained by each institution. Semantic anchors are selected terms or entities that can be reused across collections, such as a person name, place name, historical period, object type, or subject concept. Relationship assertions are statements that connect two records through a defined relation type. This distinction allows the model to preserve the richness of source records while producing a lighter discovery layer that is easier to manage and evaluate (DCMI Usage Board, 2020; Zeng, 2019).

A practical workflow can begin with entity normalisation (Baca, 2008; Library of Congress., 2025). Variant names such as 'Mohammad Hatta', 'Moh. Hatta', 'Bung Hatta', or local references to Hatta should be reconciled into a preferred entity while preserving variants as access points. The same logic applies to places such as Bukittinggi, Fort de Kock, West Sumatra, and specific heritage sites. Entity normalisation is not merely a technical act; it is a curatorial decision that must respect historical usage, local terminology, and multilingual access. Without this step, semantic recommendations may be weakened by inconsistent naming.

The second workflow is relation assertion (Doerr et al., 2007; Liu et al., 2023). Once entities are normalised, metadata records can be linked through rules such as same Person, same Place, same Period, same Provenance, same Event, same Object Type, or complementary Format. These assertions can initially be created manually by metadata experts and later supported by semi-automatic methods such as named-entity recognition or authority matching. However, automatic detection should not replace expert judgement in heritage contexts. It should function as a suggestion layer that requires review because historical relations can be interpretive, ambiguous, and culturally sensitive.

The third workflow is interface translation (Farhah & Lawanda, 2023; Walsh et al., 2017). Semantic assertions have little value for ordinary users if they remain hidden in backend metadata. Therefore, the interface must convert each assertion into an intelligible discovery statement. A record should not simply display an undifferentiated list of related items. It should group recommendations by relation type and provide short explanations. For example, a panel may display 'related by person', 'related by place', 'related by period', or 'related by provenance'. This enables users to choose exploratory routes according to their information need and cognitive strategy.

This operationalisation also clarifies how recommendation ranking could be developed in the prototype phase (Garba & Wu, 2025). A recommendation supported by multiple dimensions may be ranked higher than a recommendation supported by only one weak relation. For example, a photograph connected to a biography through the same person, same place, and same period may be more contextually relevant than an item connected only through a broad subject term. The model therefore allows future ranking logic without making premature claims about algorithmic performance in the present conceptual study.

Finally, the model should include a feedback mechanism in later implementation implementation (Walsh et al., 2017). Users, curators, and metadata specialists should be able to flag weak recommendations, confirm strong relations, or suggest missing connections. Such feedback would transform semantic bridging from a static crosswalk into a living knowledge infrastructure. In the Hatta Heritage context, this is especially important because cultural memory continues to be interpreted through scholarship, commemoration, institutional exhibitions, and community knowledge. A robust GLAM discovery system should therefore allow relations to be revised as historical understanding develops.

The operational model also requires documentation of uncertainty uncertainty (Alkemade et al., 2025; Hillmann et al., 2004). Not every semantic relation has the same evidential strength. Some relations are directly supported by explicit metadata fields, such as a shared creator or date. Others are inferred from contextual knowledge, such as an object associated with a commemorative event or a photograph associated with a historical episode. The prototype should therefore distinguish confirmed relations, curator-suggested relations, and machine-suggested relations. This distinction will make the system more transparent and protect users from if all recommendations carry equal authority.

In addition, semantic bridging should be designed as a reusable institutional protocol rather than a one-time technical project (Alkemade et al., 2025; Vogt, 2025). The protocol would define how records are selected, how anchors are normalised, how relationships are asserted, how disagreements are resolved, and how revisions are documented. For regional GLAM ecosystems, this protocol may be more important than the software itself because it creates shared rules for collaboration. In this sense, the proposed framework contributes not only to discovery interface design but also to the governance of public cultural memory.

These operational requirements show that semantic bridging is not a decorative layer added after cataloguing has been completed (Kennan & Lymn, 2019; Zeng, 2019).. It is a socio-technical arrangement that combines metadata policy, curatorial interpretation, interface design, and iterative evaluation. The framework therefore invites GLAM institutions to think of discovery not as a neutral search box but as a structured encounter between users and cultural relationships. This is the reason information repackaging becomes infrastructure: it packages not only information objects but also the contextual pathways through which those objects become meaningful. For that reason, the model should be read as a disciplined bridge between metadata scholarship and design practice: it translates theoretical claims about interoperability into concrete, reviewable, and revisable design decisions that GLAM institutions can negotiate collectively.

CONCLUSION

This study proposes semantic bridging as a contextual interoperability infrastructure for GLAM discovery. Using Hatta Heritage in Bukittinggi as an illustrative case, the article develops a first-cycle DBR design artefact comprising a Dublin Core-based intermediary layer, cross-standard mapping logic, a multidimensional relationship typology, and a user-facing "see also" recommendation mechanism. The framework responds to a persistent GLAM problem: cultural heritage records may be digitised and professionally described yet remain contextually disconnected across institutional systems. It must be emphasised that the proposed architecture remains entirely theoretical at this stage; it has not been built, coded, or implemented as a functioning system or

software application.

The article contributes to information science by extending information repackaging from content transformation toward the packaging of semantic relationships. It also advances interoperability theory by formalising contextual interoperability as the capacity to preserve, model, and communicate culturally meaningful relations among heterogeneous metadata records. Practically, the framework offers GLAM institutions a staged strategy for integrated discovery that avoids immediate schema replacement, system migration, or full linked data transformation.

The study is limited because the architecture has not been implemented as a functioning system and has not undergone real-world user testing. Consequently, no empirical data currently exist to demonstrate how intuitive or helpful the framework would be for researchers, students, or the general public engaging with such a discovery system. Future DBR cycles should therefore prioritise expert validation of mapping rules, prototype development, usability testing, and evaluation of recommendation relevance. For Hatta Heritage, the immediate next step is constructing a small pilot using authentic records drawn from library, archival, visual documentation, and museum collections. Such a pilot would enable the framework to progress from conceptual plausibility toward an empirically validated cultural heritage discovery infrastructure, directly addressing the current absence of implementation evidence and user-testing data highlighted in this evaluation.

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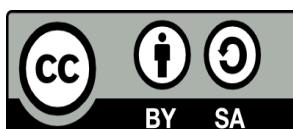
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