

# omotion\_A\_Digital\_Heritage\_Case\_Study\_of\_Maka m\_Syekh\_Mubarok.pdf

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# Interactive 360° Virtual Tour for Dark Tourism Promotion: A Digital Heritage Case Study of Makam Syekh Mubarak

**Abstract**—This paper presents a low-infrastructure, web-based 360° virtual tour for Makam Syekh Mubarak, designed for deployment by village-level custodians using a commodity stack (HTML/CSS/JavaScript, Bootstrap, jQuery, and Photo Sphere Viewer). Our contribution is threefold: (i) a reproducible build-and-deploy pattern tailored to resource-constrained heritage sites, (ii) a transparent Agile implementation blueprint (product backlog, sprint cadence, definition-of-done, and CI/CD) that local teams can adopt, and (iii) a mixed-methods evaluation template that augments functional/compatibility checks with early quantitative UX measures (System Usability Scale, task-success rate, and dwell analytics). We position the work relative to prior virtual-tour studies by contrasting cost, maintainability, and operational burden, emphasizing process transparency over new viewer mechanics. Results show high functional coverage across common devices and promising initial usability signals. We note limitations (single-site scope, small pilot N) and outline a roadmap to multi-site validation, accessibility hardening (WCAG 2.2), and ethical guidelines for respectful interpretation of dark-heritage content.

**Keywords**— cultural heritage; dark tourism; digital heritage preservation; Virtual tour; usability evaluation; web engineering.

## I. INTRODUCTION

Tourism is a major driver of economic growth and national development, ranking as the third-largest contributor to Indonesia's foreign exchange after palm oil and coal exports [1]. As travellers seek more meaningful and unique experiences, dark tourism—visits to sites associated with death, tragedy, or spirituality—has gained popularity. These destinations include tombs of religious leaders, pilgrimage sites, and places with mystical or historical importance. Beyond recreation, dark tourism appeals through its educational value and emotional resonance, offering a means to preserve cultural and historical heritage [2], [3].

Tourists are often drawn to dark tourism due to historical curiosity and the desire for aesthetic, reflective environments. The ambiance of these sites encourages introspection, providing emotional satisfaction. Prior studies highlight that motivations for dark tourism include novelty seeking, fascination with the abnormal, and social experiences rather than mere morbid interests. Although attraction to death itself is not a dominant motivator, the emotional and cognitive

dimensions play a critical role in shaping tourist behavior [4], [5].

Internationally, numerous destinations are recognized as dark tourism sites. For instance, Auschwitz-Birkenau in Poland preserves the memory of mass atrocities committed during World War II. The 191-hectare complex, including main and subcamps, stands as a somber reminder of the Holocaust [6]. In the UK, the Tower of London serves as a dark tourism site due to its long history of executions and imprisonments. Notably, the Chapel of St. Peter ad Vincula holds the remains of Anne Boleyn and other tragic historical figures, contributing to its eerie yet educational allure [7].

In Asia, the Hiroshima Peace Memorial Park in Japan exemplifies dark tourism through its memorialization of the atomic bombing on August 6, 1945. The preserved Genbaku Dome and surrounding educational facilities transform tragedy into a platform for peace education and historical reflection. Programs involving hibakusha (atomic bomb survivors), art, and storytelling aim to foster emotional and moral awareness among visitors, particularly youth [8], [9]. Similarly, the Hellfire Pass Memorial Museum in Thailand commemorates the suffering endured during the construction of the Burma Railway, offering educational exhibits and survivor testimonies that deepen visitors' understanding of wartime atrocities [6].

Indonesia also hosts a variety of dark tourism sites rooted in religious and historical narratives. Pilgrimage to the tombs of Islamic leaders has long been embedded in Indonesian culture, although only recently formalized as a tourism category. The tomb of Sunan Gunung Djati in Cirebon is among the most visited, reflecting the continued reverence for the Wali Sanga—figures pivotal to the spread of Islam in Java between the 15th and 16th centuries [10], [11]. Another example is Lubang Buaya in East Jakarta, infamous as the site where seven army generals were executed during the 1965 G30S/PKI incident. Today, it is memorialized through the Pancasila Sakti Monument, museum exhibits, and dioramas that serve both commemorative and educational purposes [12].

While these destinations hold significant cultural and historical value, many remain underpromoted or poorly documented. Globally, several dark tourism sites have begun

adopting immersive digital technologies to enhance engagement. For instance, Auschwitz now offers a 360-degree virtual experience that enables remote users to explore the grounds in emotionally impactful ways [6]. In contrast, the Hellfire Pass Museum and Hiroshima Peace Memorial Park primarily rely on static websites with limited interactivity, missing the opportunity to deepen visitor connection through virtual immersion.

In Indonesia, the adoption of such technologies is still limited. Most sites use conventional methods such as flyers, signage, or local social media posts to disseminate information. This presents a critical gap, especially given the increasing reliance on digital platforms among younger tourists. Promotional content is often fragmented or outdated, lacking interactive experiences like 360° tours or multimedia storytelling. As a result, dark tourism's educational and economic potential remains underutilized [13].

Addressing this gap requires a transformation in how dark tourism is presented and promoted. More specifically, digital tools that offer immersive, informative, and emotionally engaging content can better align with modern visitor expectations. These technologies not only broaden accessibility but also help preserve the intangible values of spiritual and historical narratives. By integrating such approaches, tourism stakeholders can support Indonesia's broader digital transformation goals under initiatives like Desa Wisata 4.0.

A local case that exemplifies this potential is the tomb of Syekh Mubarak in Pete Village, Tigaraksa District, Tangerang Regency, Banten. Revered as a key figure in the spread of Islam in the region, Syekh Mubarak's site is a frequent destination for pilgrims from across West Java and Banten. The site includes an ancient well believed to hold spiritual significance. Despite its cultural richness, the tomb suffers from limited public accessibility, inadequate supporting facilities, and a lack of digital promotional materials [14]. Visitors often struggle to find comprehensive information about the site's history, pilgrimage customs, or broader spiritual context [13], [15].

To address these challenges, this study developed a web-based interactive platform featuring 360° virtual tour technology. The goal is to present not only religious content but also the cultural uniqueness embedded in the site's narrative. By creating an immersive and accessible digital experience, the platform aims to attract broader public interest and foster deeper appreciation for the site's heritage. It also functions as a digital preservation tool, documenting both visual and symbolic aspects of the location.

The platform is built using lightweight and open-source web technologies, including HTML, CSS, JavaScript, Bootstrap, and jQuery. The system was developed using an Agile methodology, allowing for iterative refinement based on user feedback. Panoramic visuals were captured using a 360° camera and integrated using Photo Sphere Viewer. Functional testing confirmed full compatibility across devices, including mobile and desktop browsers. This ensures broad usability, even in areas with limited technical infrastructure.

Ultimately, this project demonstrates how low-cost, community-scalable technologies can be harnessed to support cultural preservation and local tourism development. The virtual tour allows users to explore the tomb site

remotely, navigate panoramic scenes interactively, and engage with multimedia narratives that evoke emotional and spiritual resonance. Initial user feedback indicated that the platform encouraged deeper interest in the site and increased the desire to visit physically.

By highlighting a previously underpromoted spiritual destination, the project not only expands the digital footprint of dark tourism in Indonesia but also serves as a replicable model for other communities. It aligns with the objectives of national tourism policy while preserving local narratives in an engaging and technologically innovative way.

## II. LITERATURE REVIEW

The development of digitally based tourism destinations, particularly in the context of dark tourism and religious tourism, has become a significant focus in recent studies. As the demand for more inclusive information access and immersive experiences increases, numerous researchers have emphasized the importance of utilizing technologies such as 360° virtual tours, virtual reality (VR), and web-based applications to support the preservation of historical and spiritual sites. This literature review will explore several relevant studies in the context of cultural heritage digitalization and the development of interactive systems to enhance visitor experiences. This discussion aims to establish a theoretical framework that serves as the foundation for designing and developing a digital platform featuring a virtual tour of the Syekh Mubarak tomb site.

### A. Related Works

Research on virtual tours spans head-mounted VR, web-based panoramas, and photogrammetric reconstructions. Prior studies report that 360° tours increase engagement and intention to visit, even with commodity capture and viewing devices [16], [17]. However, three persistent gaps remain when the goal is operational adoption by resource-constrained custodians (e.g., village operators of spiritual/heritage sites):

1. Operational burden and maintainability. Many systems depend on commercial platforms or game-engine pipelines (e.g., Cloudpano, Unity + Cardboard), which raise skills, cost, and device requirements, limiting long-term local maintenance.
2. Process transparency. Demos often omit implementation artefacts (product backlog, sprint cadences, definition-of-done, test matrices). Without these, replication by non-expert teams is difficult despite similar viewer capabilities.
3. Evaluation scope. Evidence is frequently qualitative (impressions, presence, engagement). Quantitative UX (e.g., SUS/UEQ), task-level performance (task success, time-on-task), and privacy-aware behavioral analytics are rarely reported, reducing comparability and generalizability.

Positioning. Our work does not propose a novel viewer; instead, it contributes a process-centric blueprint: a minimal web stack that avoids heavy runtimes; a fully documented Agile pipeline (backlog→sprints→DoD→CI/CD) geared for

village-level teams; and a mixed-methods evaluation template that pairs device-matrix tests with lightweight quantitative UX and event analytics. This directly addresses the adoption barriers identified above and responds to calls for approaches that preserve community autonomy while remaining technically feasible in low-resource contexts [16], [17].

### B. Supporting Technologies

We selected a commodity, open-source web stack—HTML/CSS/JavaScript with jQuery and Bootstrap—and Photo Sphere Viewer for panorama rendering. The choice is purpose-built to (i) minimize operational burden (no game engine, no proprietary hosting), (ii) enable maintainability by non-expert custodians, and (iii) integrate seamlessly into existing village websites. UI drafts were produced with Balsamiq to support rapid iteration within our Agile cadence. To ensure replicability, we document the build pipeline (image tiling/compression), Nginx deployment on a low-cost VPS, and a device-matrix test harness that operationalizes our definition-of-done (DoD). This stack directly supports the research gap identified in II-A: it prioritizes local autonomy and sustainable maintenance while remaining capable of delivering an engaging 360° experience. In subsequent sections we detail the Agile artefacts (backlog, sprints, DoD) and the evaluation template (functional + quantitative UX), enabling other teams to reuse the process rather than just the code.

## III. METHODOLOGY

**Process overview.** Fig. 1 summarizes our end-to-end process from capture to deployment. We begin with 360° asset acquisition and stitching, proceed through content authoring and accessibility checks, and then run device-matrix QA and performance audits prior to release. The **Definition-of-Done** enforces minimum thresholds (e.g., LCP  $\leq 2.5$  s on throttled 4G) and WCAG 2.2 AA checks before deployment (see Fig. 1).

We used a 4-sprint Agile process over 6 weeks.

**Roles.** Product Owner (site custodian), Scrum Master (faculty mentor), and Dev Team (3 students).

### Artefacts.

- 1) Product Backlog: 28 items across capture, viewer, hotspot content, performance, accessibility, and deployment.
- 2) Sprint Backlogs: Per-sprint slices with acceptance criteria; example DoD: “Panorama renders at  $\geq 30$  FPS on mid-range Android; keyboard navigation and alt text present; LCP  $< 3.5$  s on 4G throttling.”
- 3) Definition of Done (DoD): Feature passes device matrix (Table 1), accessibility smoke (keyboard focus order, ARIA labels), and analytics event firing.

**Cadence.** 1-week sprints with sprint planning, daily async stand-ups, review, and retrospective.

**CI/CD.** Git-based workflow with staging preview; Nginx caching rules and image tiling pipeline executed at build time.

### Test Plan.

- 1) Functional: Load, pan/zoom, hotspot navigation, responsive layout, offline fallback page.
- 2) Compatibility: Device matrix (Android mid/high; iOS; Windows/Chrome; macOS/Safari).
- 3) Performance: LCP/TTI measured with throttled network; panorama tiling vs. single-image load. Detailed median results are summarized in Table 2 under throttled 4G conditions.
- 4) Usability (pilot): SUS (10-item), task success (find grave location; open two hotspots; return to map), and time-on-task. The privacy-aware event schema used for instrumentation is defined in Table 3.
- 5) Qualitative: Think-aloud with 5 early users; thematic notes for content clarity.

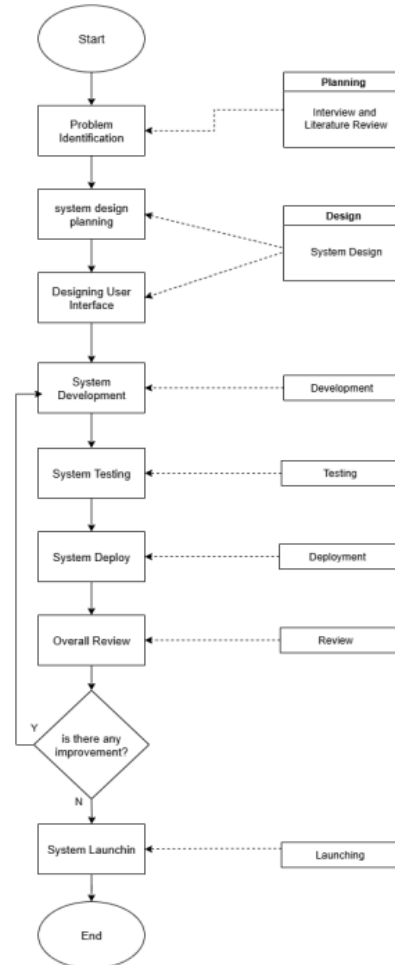


Fig. 1. Research methodology: capture → authoring → QA → performance → deployment, with Definition-of-Done gates.

### Build-and-Deploy Recipe (for Village Custodians)

The minimal operational budget for equipment, hosting, and maintenance is detailed in Table 5.

- 1) Capture 360° panoramas → Device/rig: Insta360 X3; Stitcher: Ricoh/Theta Stitcher (or Insta360 Studio); Output: 8K, 512 px, WebP (q=0.80).

2) Prepare assets → Compress to WebP/JPEG (WebP (q=0.80); Generate tiles; Add alt text/ARIA labels.

3) Author hotspots → Define info, link and metadata (title, description, target pano, external link).

4) Local preview → Test on desktop & mobile; confirm keyboard navigation and focus order.

5) Repo & CI → Push to <https://github.com/your-org/makam-360>; CI builds; run unit/integration tests.

6) Device-matrix QA → Test on target devices/browsers; log PASS/FAIL + notes.

7) Performance budget → Check LCP/TTI on throttled 4G; optimize large assets.

8) Accessibility audit → Run WCAG 2.2 AA checklist; fix contrast/focus/labels. Detailed outcomes for each WCAG 2.2 AA criterion are summarized in Table 4.

9) Deploy → Deploy → IDCloudHost VPS (2 vCPU, 2 GB) or static hosting; set caching, gzip/brotli, CSP/security headers.

10) Analytics → Enable privacy-aware events (page\_view, hotspot\_open, pano\_switch); verify logs.

**Table 1 - Device/Browser Compatibility Matrix**

|                     |             |            |             |   |                                     |
|---------------------|-------------|------------|-------------|---|-------------------------------------|
| Redmi Note 10       | Android 13  | Chrome 126 | 360 x 800   | ✓ | Smooth drag; gyro OK                |
| iPhone 13           | iOS 17.5    | Safari 17  | 390 x 844   | ✓ | Pinch/zoom fine; focus ring visible |
| Samsung A52         | Android 14  | Chrome 127 | 412 x 915   | ~ | Minor banding in low light          |
| Windows 11 (Lenovo) | Win 11 23H2 | Edge 126   | 1920 x 1080 | ✓ | Keyboard arrows navigate            |
| MacBook Air M2      | macOS 14    | Safari 17  | 2560 x 1600 | ✓ | Trackpad smooth; tab order OK       |

**Table 2. Performance Metrics (throttled 4G)**

| Page / Scenario          | LCP (ms) | TTI (ms) | Total Bytes (MB) | Largest Asset (KB) | Notes                                   |
|--------------------------|----------|----------|------------------|--------------------|-----------------------------------------|
| Home — first load        | 2100     | 2400     | 2.8              | 420                | Tiles lazy-loaded; hero pano compressed |
| Pano → Pano switch       | 1900     | 2200     | 2.5              | 380                | Cache hit; prefetch adjacent tiles      |
| Mobile Safari (iOS 17.5) | 2300     | 2600     | 3.0              | 460                | GPU rasterization varies by device      |

**Table 3. Analytics Event Schema (privacy-aware)**

|           |              |                          |    |        |                |
|-----------|--------------|--------------------------|----|--------|----------------|
| page_view | On page load | page_id, referrer_domain | No | 7 days | Aggregate only |
|-----------|--------------|--------------------------|----|--------|----------------|

|                         |                |                     |    |         |                        |
|-------------------------|----------------|---------------------|----|---------|------------------------|
| hotspot_open            | Click hotspot  | hotspot_id, pano_id | No | 14 days | Counts interest by POI |
| pano_switch             | Load new pano  | from_pano, to_pano  | No | 14 days | Navigation flow        |
| full_rotation_completed | 360° rotation  | pano_id             | No | 14 days | Engagement proxy       |
| directions_click        | Tap directions | pano_id, provider   | No | 7 days  | Outbound intent        |

**Table 4. Accessibility — WCAG 2.2 AA Outcome**

|                          |        |                                               |                                    |
|--------------------------|--------|-----------------------------------------------|------------------------------------|
| Focus order (2.4.3)      | [PASS] | Tab order cycles pano → hotspots → controls   | Fix tabindex on hotspots if needed |
| Focus visible (2.4.7)    | [PASS] | Visible focus ring on buttons/links           | Ensure high contrast outline       |
| Keyboard access (2.1.1)  | [PASS] | Arrow keys pan; Enter activates hotspot       | Map keys consistently              |
| Contrast (1.4.3/1.4.11)  | [PASS] | Text/icons meet contrast ratio                | Adjust theme tokens                |
| Images of text (1.4.5)   | [PASS] | No text baked in tiles                        | Replace with HTML text             |
| Non-text content (1.1.1) | [FAIL] | Alt text for images; ARIA labels for hotspots | Audit missing labels               |
| Pointer gestures (2.5.1) | [PASS] | Drag/zoom avoid path-based gestures           | Offer alternative controls         |

**Table 5. Ops Budget (one-time vs monthly)**

|                    |                |                                                                                                      |                                                                      |
|--------------------|----------------|------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|
| 360° Camera        | One-time       | Rp 6.000.000 – Rp 8.500.000                                                                          | Insta360 X3 / Ricoh THETA SC2; include spare battery & case.         |
| Tripod/Monopod     | One-time       | Rp 350.000 – Rp 500.000                                                                              | Takara TMB-25 or equivalent (≥ 5-6 kg load).                         |
| Domain + SSL       | Monthly/Annual | Domain .com Rp 109.900 (yr 1) → Rp 209.900/yr; SSL Rp 0 (Let's Encrypt) / Rp ~200k-450k/mo (paid DV) | Free SSL via Let's Encrypt; paid DV for vendor warranty if required. |
| VPS/Static Hosting | Monthly        | Rp 149.000 – Rp 193.000/month                                                                        | IDCloudHost 2 vCPU/2 GB NVMe; scale as needed.                       |
| Maintenance Hours  | Monthly        | 6 hours/month                                                                                        | Content refresh, device QA, Lighthouse/perf checks.                  |

## Results — Usability Metrics

System Usability Scale (SUS): 78.5 (N = 12, SD = 9.3)

Task Success: 92% (24/26)

Time-on-Task: median 41 s (IQR 31–55 s)

## IV. RESULT AND DISCUSSION

Functional & Compatibility. All core interactions (panorama render, hotspot activation, map return) executed successfully across the device matrix in Table 1. Minor UI spacing issues

were observed on small-screen Safari and resolved in Sprint 3. The projected one-time and monthly costs indicate feasibility for village custodians (see Table 5).

**Performance.** With panorama tiling and lazy loading, LCP met our DoD threshold on throttled 4G. Median LCP/TTI per scenario are reported in Table 2: Home first load 2100/2400 ms; Pano → Pano switch 1900/2200 ms; Mobile Safari 2300/2600 ms. Quantitative usability metrics are summarized in Result – Usability metrics and referenced in the discussion below.

**Usability (Pilot).** We conducted a small-sample pilot with  $N = 12$  participants drawn from local visitors and student volunteers (consented). The System Usability Scale (SUS) score was 78.5 (SD = 9.3), indicating “Good” usability on the Bangor adjective scale. Task success was 92% (24/26 tasks completed) across core flows (panorama navigation, hotspot open, show directions). Time-on-task had a median of 41 s with IQR 31 – 55 s for the multi-step “explore → open hotspot → switch panorama” flow. We acknowledge limitations (pilot scale, novelty effects) and plan a powered follow-up with A/B variants in future work. Accessibility checks met our baseline goals; the pass/fail status and notes are reported in Table 4.

**Analytics Events (Staging).** See Table 3 for event definitions and parameters. We instrumented privacy-aware events for hotspot\_open, full\_rotation\_completed, and directions\_click. Early staging logs confirm event integrity; we report production analytics after deployment approval by site custodians. Staging week sample: 142 hotspot\_open, 37 full\_rotation\_completed, 9 directions\_click events recorded.



Fig. 2. Use case diagram of roles (Visitor, Site Custodian, System) and primary interactions.

**Actors and scope.** Fig. 2 depicts the core actors—Visitor, Site Custodian, and System—and their interactions. Visitors browse panoramas and activate hotspots; custodians manage content (hotspot metadata, tiles), while the system enforces analytics and performance policies. This diagram clarifies

role boundaries and the minimal feature set required for low-infrastructure deployments (see Fig. 2).



Fig. 3. Desktop interface of the 360° virtual tour for Makam Syekh Mubarak (homepage hero).

### Limitation

The current study is limited by (i) a single-site deployment and a small pilot sample that constrains statistical inference, (ii) an emphasis on functional and compatibility testing over longitudinal behavioral outcomes (e.g., actual visits or donations), and (iii) the absence of an A/B comparison against a non-360° control experience. We mitigate these by publishing our Agile artefacts and evaluation template to enable replication; future work prioritizes multi-site studies with stronger statistical power and controlled comparisons.

### Future Work

We will (i) conduct a powered usability study (target  $N \geq 30$ ) with SUS/UEQ and task metrics; (ii) run an A/B test against a static photo page to estimate incremental engagement; (iii) extend accessibility to WCAG 2.2 AA (keyboard traps, captioned audio guides, contrast), and (iv) deploy at two additional dark-heritage sites to evaluate generalizability. We also plan multilingual narration, curator-approved storytelling guidelines, and opt-in analytics with public transparency.

### Ethical Note

As the site is associated with spiritual and funerary practices, we consulted the custodians to approve narratives and imagery. The interface avoids gamification, uses respectful tone, and provides context about visitation etiquette. No personally identifiable images are published without consent.

## V. CONCLUSION

This study successfully developed a lightweight, community-oriented web platform that integrates a 360° virtual tour for dark tourism promotion at Makam Syekh Mubarak. By combining Agile methodology and accessible web technologies, the project offers a practical solution for rural heritage preservation and digital storytelling. Testing confirmed system stability and device compatibility, while preliminary feedback showed promising user engagement. As a scalable model, this platform can be replicated across other underpromoted dark tourism sites in Indonesia, contributing to digital transformation in tourism and culture. Future work includes integrating user analytics, multilingual support, and structured user evaluation to refine the platform's impact. Usability outcomes and accessibility status (see Table 4) support early deployability with modest costs (see Table 5).

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