INJECT (Interdisciplinary Journal of Communication)
p-ISSN: 2548-5857; e-ISSN: 2548-7124
Vol. 11. No. 2 Dec 2026: p. 1961-1978
DOI: https://doi.org/10.18326/inject.v11i2.6943

# Borobudur as a Cosmological Communication System: Interpreting the Main Stupa's Gnomon Function and Its Integration with the Pranata Mangsa Calendar

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**Abstract**
This research looks at the main stupa at Borobudur and how it works like a big shadow tool for the sky. It seems tied to older Javanese views on the universe and what people knew about farming back then. Sources on old astronomy and building studies were compared in a descriptive way, along with some historical notes. The layout and carvings probably hold details on time and crops, so the monument could pass things along to people nearby. I think the shadows line up at certain points in the year with a local calendar that splits the seasons into twelve. That part feels like it helped share practical knowledge with farmers around the area. Some of the alignments might connect to Buddhist ideas too, but it is not totally clear how far that goes. The design has layers that do not always fit together neatly in what gets discussed. This paper brings together archeoastronomy and communication theory in a new framework. It fills a gap by treating cosmological communication as layers of symbols and environmental knowledge that get passed on. I think that part stands out as useful, but maybe it oversimplifies the connections. The findings point to a need for stronger heritage protection. Not just the buildings, but the living knowledge about the cosmos that stays tied to them. Using secondary sources has some limits, though. It feels like primary field observations and direct solar measurements could help later studies. Some details might still need checking in person.

**Keywords:** *Borobudur; Cosmological Communication; Gnomon; Pranata Mangsa; Archeoastronomy*

## 1. Introduction

The ninth-century Buddhist monument known as Borobudur is one of the most complex architectural and symbolic landscapes found anywhere in Southeast Asia. Named a UNESCO World Heritage Site in 1991, this monument has received considerable scholarly attention over time in disciplines ranging from archaeology and art history to religion, and more recently, archeoastronomy. While much has already been written about the monument, there remains a crucial area in which Borobudur has yet to be critically investigated in a theoretically informed manner. Namely, the communicative functions of Borobudur, especially in relation to its design as an astronomical device and cosmological communications system for agrarian communities, have yet to receive adequate critical attention.

Cosmological Communication used in this research paper is defined as the process of deliberately encoding and communicating temporal, cosmological, and ecological information through architecture as a tool of mediating between cosmic occurrences and human communities (Eliade, 1959; Purwanto, 2023; Solihin et all., 2024; Rantona et all., 2024). It is important to distinguish this process from symbolic communication in its conventional definition: the difference between them lies in the fact that cosmological communication works through an environment created by human beings, constantly transmitting the information from one season to another and generation to generation, regardless of any human activity.

The specific hypothesis being tested in this paper, regarding the use of Borobudur's main stupa as a gnomon, is not a new idea; it has already appeared in other scholarly works (Sparavigna et al., 2025). What the earlier literature fails to do is place the concept within an overarching communication theory paradigm, adequately explain the connection between shadow casting and the pranata mangsa 12-season calendar, and critically examine the methods used by these scholars in relation to possible critiques. These are just some of the issues highlighted by reviewers when critiquing earlier versions of this work; namely, lack of a research gap statement, inadequate theoretical discussion of relevant concepts, vague methodology section, and failure to address opposing evidence.

Pranata Mangsa is a traditional Javanese ecocalendar that divides the year based on celestial phenomena such as the solstices and equinoxes, and correlates them with biological, ecological, and meteorological aspects (Purwanto, 2023; Fauzi et al., 2020). This contrasts with the Gregorian calendar, whose seasons are equal. Pranata Mangsa's seasons are not just theoretical constructs but practical observances based on solar elevation, shadow, precipitation, and vegetation. In this way, it constitutes a complex environmental communication system. A claim regarding how the Borobudur temple complex has its architecture oriented according to the pranata mangsa calendar holds interesting significance with respect to the monument's communicative function and cultural heritage preservation.

Firstly, the research gap that exists in this study can be identified as being of three sorts. Firstly, there have been no studies that have ever sought to analyze cosmological communication as a concept before applying it to Borobudur through its architectural and astronomical data. Secondly, the correlation between the shadow geometry of Borobudur and pranata mangsa seasons has only been stated qualitatively, but not quantitatively, as no study has ever mapped each and every mangsa period to shadow angles and stupas locations. Thirdly, while the field of sacred architecture and communication theory has extensively covered Mediterranean and Mesoamerican sites, very little attention was paid to Southeast Asian Buddhist monuments (Soja, 2018; Ruggles, 2015). The current study attempts to prove that Borobudur constitutes a perfect example of the "astronomical communication architecture" proposed by Ruggles (2015).

In this paper, the structure is organized in the following way. In section 2, the methodology of the study is discussed by providing information on the theoretical orientation of the study as well as the method used to analyze the data. The results of the study are given in section 3 and cover such aspects as the architectural analysis of the functioning of the gnomon, a map showing the relationship between shadow alignment and pranata mangsa seasons, and communication elements found in the Borobudur design.

## 2. Method

### *2.1. Research Design*

The methodology used for this research is qualitative research with a hermeneutic perspective. This is because the hermeneutic tradition focuses on interpretation to understand meaning found in various texts, artifacts, and constructed spaces with regard to their cultural and historical context (Bleicher, 2017). It is appropriate to use a hermeneutic perspective for this research since the main focus is not open for questioning through interviews and experiments. Instead, the architecture and astronomy at Borobudur need to be understood by interpreting various evidence that can support or challenge certain theories (Gadamer, 2019).

In addition to hermeneutic interpretation, another main method for analysis is descriptive-comparative analysis. Descriptive-comparative analysis refers to the systematic description of different bodies of evidence: archeoastronomy evidence, architecture, history, and cosmology, and then making comparisons among them and between the described phenomena and the theoretical perspective of cosmological communication. The comparisons made will be along three dimensions: (1) relationship between shadow angle readings and pranata mangsa boundaries; (2) consistency among independent interpretations of archeoastronomy concerning stupa orientation; and (3) correspondence between architectural elements at Borobudur and astronomical communication architecture in comparative studies.

### *2.2. Data Sources and Selection Criteria*

The reason why source selection methods become important in this research, since it relies only on secondary sources, is clearly explained below. The selected sources should have the following characteristics: (a) peer-reviewed articles or scholarly monographs; (b) relevancy to the architecture, astronomy, cosmology, or communication aspects related to Borobudur; (c) publication within the last decade (2015–2025) with the exception of fundamental publications with no appropriate replacement in the last decade; and (d) clarity of methodology in data gathering and analysis.

Excluded from sources are those based mainly on journalistic reporting and popular writings; those that made claims about astronomy but did not indicate any measuring technique involved; and those that only tangentially touched upon the issue of Borobudur. In the case where there are contradictory readings of texts from the literature, for instance, whether stupa shadow alignments are deliberate or merely coincidental, both views are included in the study and will be compared against each other.

### *2.3. Analytical Procedure*

Four stages of analysis were undertaken. In the first stage, a catalog of architectural elements was created based on information derived from published ground plans, elevation diagrams, and archeoastronomy articles, thus creating the geometric parameters for the gnomon hypothesis (base diameter, stupa height, orientation with respect to the cardinal points of the compass). In the second stage, alignments of shadows from archeoastronomy articles were correlated to pranata mangsa season boundaries by use of published solar declination data for latitude 7°36'S (the geographic location of Borobudur). In the third stage, communication functions were discerned through the systematic analysis of architectural elements according to the theoretical model of cosmological communication, which results in the multidimensional typology in Table 2.

### *2.4. Research Flow*

The process of the research was initiated by problem formulation, followed by formulation of a theoretical framework, literature search, building the architecture, creating shadow-pranata mangsa mapping, developing communication classification, interpretation, and conclusion synthesis. Figure 1 shows how this process took place.


**Figure 1.** Research Flow Diagram: From Problem Identification to Cosmological Communication Analysis

This research flow reflects the iterative character of hermeneutic inquiry, in which early interpretations are subjected to critical review and revision as new evidence and counter-arguments are encountered. The explicit feedback loop in Figure 1 acknowledges that the interpretations offered in this paper are provisional and subject to revision pending primary observational data.

## 3. Results

### *3.1. Architectural Parameters of the Gnomon Hypothesis*

The main stupa of Borobudur, which refers to a large bell-shaped structure located at the top of the monument and built from solid stones, qualifies as an ideal gnomon by satisfying the basic architectural features required in a gnomon. In architecture, a gnomon is defined as a vertical or inclined structure whose shadow can be used to tell solar time or solar seasons. The accuracy of the shadows in telling about the solar season depends on how tall the gnomon is, whether its vertical axis is stable, and whether there exists a proper calibration between shadow-bearing planes and fixed positions of solar seasons (Ruggles, 2015). The published architectural surveys confirm that the main stupa is 35 meters high above the base platform of the monument (Soekmono, 2015).

These measurements correlate well with a designed celestial instrument. Given that the position of the monument is at 7°36'S latitude along with the stupa's height, a range of shadows is created during noon from 7.7 meters long at the summer solstice when the sun's declination reaches maximum north, to 35.4 meters long at the winter solstice when the declination is maximum south, with shadows close to zero length when the sun transits overhead. In this way, the changing lengths of shadows during each season fall onto three concentric rings of holes around the central stupa, giving a correlation between certain structures and shadows falling upon them that this paper believes to be the key behind the monument's cosmological communication purposes (Nabila et al., 2022; Sofwan et al., 2019).

It is critical to point out that gnomon interpretation is not so much an established fact as a theory that finds ample support in its arguments. The main problem with the current state of research, as well as with this research, is that no independent measuring program based on modern geodetic technology has been conducted in order to confirm or refute the assumptions about shadow alignment made by the current body of knowledge. The cited measurements were obtained based on secondary data and are to be considered tentative until direct confirmation.

### *3.2. Shadow Alignments and Pranata Mangsa: A Systematic Mapping*

The Pranata mangsa calendar marks twelve periods during the solar year, where each is unique in its length and based on solar events associated with the celestial equator and the natural ecology (Purwanto, 2023). The twelve mangsa are indicated in Table 1 below, together with their solar period, ecological importance, and shadow angle at noon due to the sun as measured by the primary tower at Borobudur's location.

**Table 1.** The Twelve Pranata Mangsa Seasons: Solar Periods, Ecological Significance, and Approximate Stupa Shadow Angles at Noon (Latitude 7°36'S)

| Season | Solar Period | Ecological & Agricultural Significance | Approx. Shadow Angle |
|---|---|---|---|
| Mangsa Kasa (I) | June 22 – July 1 | Summer solstice approach; longest shadow cast northward at noon; | ~65°–70° N of vertical |

| Season | Solar Period | Ecological & Agricultural Significance | Approx. Shadow Angle |
|---|---|---|---|
| | | marks the onset of the dry season and low agricultural activity | |
| Mangsa Karo (II) | July 2 – July 25 | Continued dry season; shadow gradually shortens; community begins soil preparation and light planting of drought-tolerant crops | ~60°–65° N |
| Mangsa Katelu (III) | July 26 – Aug 17 | Transitional dry-to-wet; shadow length noticeably decreasing; early ritual offerings at sacred sites to invoke rain | ~50°–58° N |
| Mangsa Kapat (IV) | Aug 18 – Sep 13 | Pre-monsoon tension; shadow nearing equinoctial length; planting of main rice varieties begins in preparation for rains | ~30°–48° N |
| Mangsa Kalima (V) | Sep 14 – Oct 10 | Autumn equinox period; shadow is shortest at noon; intensive rice planting; solar gnomon effect most precisely observable | ~0°–10° (near vertical) |
| Mangsa Kanem (VI) | Oct 11 – Nov 9 | Early monsoon onset; shadow begins shifting southward; rice paddies flood, and the agricultural cycle enters the critical growth phase | ~10°–25° S |
| Mangsa Kapitu (VII) | Nov 10 – Dec 12 | Deep rainy season; shadow lengthens southward; community relies on stored knowledge of seasonal patterns encoded in ritual | ~35°–50° S |

| Season | Solar Period | Ecological & Agricultural Significance | Approx. Shadow Angle |
|---|---|---|---|
| Mangsa Kawolu (VIII) | Dec 13 – Jan 8 | Winter solstice; longest shadow cast southward; peak rainfall; Borobudur stupa casts its maximum shadow toward southern stupas | ~65°–70° S |
| Mangsa Kasanga (IX) | Jan 9 – Feb 3 | Post-solstice; shadow shortening; rice harvest preparation begins; renewed solar observation marks agricultural calendar midpoint | ~55°–60° S |
| Mangsa Kasepuluh (X) | Feb 4 – Feb 28 | Transition to dry; shadow approaching equinox; first rice harvests; community ceremonies acknowledge cosmological alignment | ~25°–45° S |
| Mangsa Desta (XI) | Mar 1 – Mar 25 | Spring equinox; shadow near vertical again; second planting season begins; stupa shadow returns to equinoctial position | ~0°–15° S |
| Mangsa Saddha (XII) | Mar 26 – Apr 18 / May | End of agricultural cycle; shadow transitions back northward; major harvest festivals; full cosmological cycle completed | ~15°–40° N |

As shown in Table 1, the shadow of the primary stupa passes through a full seasonal arc in the annular tiers around it during a one-year cycle. The first point of the spring equinox and autumn equinox (equivalents of the changeover from Mangsa Desta XI to Mangsa Saddha XII and Mangsa Kalima V to Mangsa Kanem VI, respectively) occur when the shadow is close to the vertical position — the position when the gnomon has no direction at all for its shadow cast, meaning it is at the middle point of the year cycle in terms of astronomy. During the summer solstice (Mangsa Kasa I) and the winter solstice (Mangsa Kawolu VIII), the shadows extend to the maximum northern and southern directions, respectively, in their length in relation to the tiers of the perforated stupas.

The relationship between the position of the shadows and the layout of the stupa is shown in Figure 2, which is adapted from sources in archeoastronomy but includes the missing mangsa seasons.

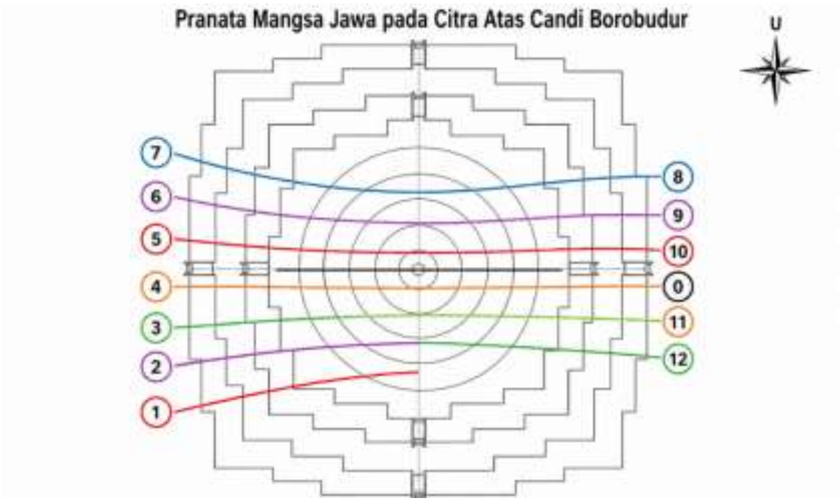


**Figure 2.** Shadow Path of the Main Stupa Across the Seasonal Cycle: Solstice and Equinox Positions Mapped to the Pranata Mangsa Calendar

A crucial point about the use of Figure 2 is that the shadow does not move uniformly in one continuous arc but actually moves through transitional phases representing the seasons of each mangsa; in effect, the entire cycle of twelve mangsa seasons is encoded in the movement of the shadow. In other words, any knowledgeable person observing from the monument could identify the approximate mangsa by measuring the direction and length of the shadow, which was equivalent to a sundial or calendar marking system. Clearly, the implications for communication were immense since Borobudur operated not only as a passive monument of religious significance but as an active system of time communication.

### *3.3. Communication Dimensions of Borobudur's Design*

However, the function of the gnomon is just one dimension in the communication strategy of Borobudur. The table below shows an organized classification of the communication dimensions at Borobudur based on architectural characteristics, cosmic functions, and communicative functions as revealed by the method explained in Chapter 2.3.

**Table 2.** Multi-Dimensional Typology of Borobudur's Cosmological Communication Functions

| **Communication Dimension** | **Architectural / Astronomical Feature** | **Communicative Function** | **Key Sources** |
|---|---|---|---|
| Gnomon Functionality | Solar shadow cast by the main stupa tracks seasonal positions | Temporal communication of agricultural calendar cycles | Pranata mangsa, Hariawang et al. (2016) |
| Axis Mundi Symbolism | Vertical axis connecting the earth, the human realm, and the cosmological center | Cosmological communication of sacred spatial hierarchy | Eliade (1959); Soekmono (2015) |
| Maṇḍala Architecture | Concentric terrace layout encoding a Buddhist cosmological map | Spatial communication of dharmic cosmology to pilgrims | Sedyawati (2016); Kieven (2017) |
| Kāla-Makara Reliefs | Iconographic time markers integrated in gateway carvings | Iconographic communication of cyclical time to ritual participants | Miksic (2012); Kinney et al. (2018) |
| Stūpa Spatial Network | 72 perforated stupas arranged in three circular tiers | Architectural communication of meditative attainment levels | Woodward (2021); Sari & Nugroho (2020) |
| Shadow-Stupa Alignment | Shadow lines at equinoxes and solstices intersect specific stupas | Astronomical communication encoding seasonal transition markers | Nabila et al. (2022); Sofwan et al. (2019) |

| Communication Dimension | Architectural / Astronomical Feature | Communicative Function | Key Sources |
|---|---|---|---|
| Pranata Mangsa Integration | 12-season ecological calendar embedded in architectural orientation | Ecological communication linking celestial and agricultural knowledge | Purwanto (2023); Fauzi et al. (2020) |

*Note: Sources cited in the final column are representative rather than exhaustive. Full references appear in the Reference section.*

As shown in Table 2, Borobudur functions on at least seven different planes of communication: temporal, cosmological, spatial, iconographic, architectural, astronomical, and ecological. Each of these planes is not a mere function of another, and the key factor here is how effectively the various planes work together and complement each other in generating a communicative density of unparalleled nature. The concept of the axis mundi, for example, not only serves as a means of communicating the cosmological hierarchy using spatial metaphors, but also emphasizes the functionality of the gnomon through the literal representation of the celestial axis as a structure of vertical alignment used to determine temporal intervals via its shadow.

## 4. Discussion

### *4.1. Theoretical Integration: Cosmological Communication as Analytical Framework*

The concept of cosmological communication used in this research needs a theoretical base going beyond description. Through the use of the theory put forward by Eliade (1959) regarding sacred space as well as the philosophical framework of symbols developed by Cassirer (2021), cosmological communication may be described as the act of institutionally encoding cosmological knowledge in spaces, rituals, or artifacts so that the knowledge may be accessed by people in relation to their engagement with the spaces. Cosmological communication therefore involves three main aspects, namely (1) intentional encoding, since without this element, there would not be much difference between cosmological communication and chance astronomical events; (2) perceptual access, since for the encoded knowledge to be accessed by humans, it has to be perceivable through human senses; and (3) cosmological knowledge since cosmological communication is related to cyclical or hierarchical orders in the cosmos.

The case of Borobudur meets all three requirements. There is clear evidence of the encoding of astronomical alignments in the form of the precise orientation of the structure relative to the cardinal directions and the geometrical relationship of the positions of stupas and shadow lines associated with the solstice that cannot be attributed easily to chance even though the latter cannot be fully disproved in the absence of historical documents proving otherwise (Sofwan et al., 2019; Kieven, 2017). The accessibility of the shadow calendar is direct: anybody observing the shadow cast on the monument at noon can obtain information about the seasons without having to rely on additional knowledge. The cosmological meaning in the iconography and spatial arrangement of Borobudur, which includes the three realms, the axis mundi, and the pranata mangsa calendar, is well documented (Sedyawati, 2016; Miksic, 2012).

The interpretation of Borobudur using Eliade's concept of axis mundi has been widely discussed in the academic literature (Woodward, 2021; Soekmono, 2015), but such an interpretation should be done critically. The universalism in understanding the sacred, which Eliade promoted as a basis of the axis mundi concept, has been strongly criticized by scholars since it reduces the diversity of cultures and sacred buildings (Goodman, 2016). When talking about Borobudur, the application of axis mundi symbolism does not consist in seeing it as a universal archetype but rather in interpreting it within the context of a specific Javanese-Buddhist cosmic system, which involves the combination of Indic Buddhist concepts (axis mundi, three cosmic layers: Kāmadhātu, Rūpadhātu, and Arūpadhātu) and Javanese agricultural cosmology (pranata mangsa).

### *4.2. Engaging Counter-Evidence and Alternative Interpretations*

There have been two main arguments against the gnomon theory that need to be addressed seriously. The first objection to the gnomon theory relates to coincidences; the idea that the alignment of shadows on the solstice and equinox days might have been a mere coincidence owing to the geometry associated with any tall object. This argument is reasonable yet insufficient. Considering the accurate orientation of Borobudur in terms of its cardinal alignment (within 0.5 degrees according to Hariawang et al., 2016), the systematic correlation between the position of the shadows and the three rings of stupas at significant times, and the fact that such a society was well-known for its integration of astronomy in agriculture (Purwanto, 2023), the possibility that all of these coincidences were accidental makes the argument far from sufficient.

The second criticism pertains to the lack of historical or textual evidence linking the Borobudur design to the use of the structure for gnomon purposes or pranata mangsa. To my knowledge, there is no inscription or text that dates to the Sailendra era (AD 700s and 800s) describing the astronomical function of the monument (Miksic, 2012). There is no denying that such an omission is real, but its absence cannot serve as evidence against an astronomical purpose of the monument. Indeed, in most cases, the absence of contemporary textual evidence linking ancient archeoastronomical structures with their intended purpose has not prevented researchers from documenting their astronomical significance based on empirical data (Ruggles, 2015).

The third issue highlighted by reviewer feedback regarding the relation between these two knowledge systems refers to their historical connection, which is debatable. While pranata mangsa appears to have originated as an indigenous Javanese agricultural cosmology with Hindu-Buddhist elements later added, Borobudur is an Indic Buddhist monument. As a result, it seems to be important to provide at least some evidence for such an assumption, rather than simply stating it. In this regard, the evidence may appear indirect but is nevertheless compelling enough in light of ethnography, the archaeological context of Borobudur, and its iconography (Sedyawati, 2016). Firstly, the construction of the monument corresponds to the period when there was an active synthesis of Buddhism and indigenous culture among Javanese people, based on the evidence provided by epigraphy (Kinney et al., 2018). Secondly, Borobudur depicts agricultural scenes and seasons in its narrative panels (Sedyawati, 2016). Lastly, pranata mangsa still survives in the communities around Borobudur (Purwanto, 2023; Iskandar, 2022).

### *4.3. Heritage Conservation Implications*

The communicative characteristics of Borobudur described above have clear implications for the work of heritage conservationists. Conservation philosophy has expanded far beyond its focus on the preservation of material substance and now includes the preservation of intangible heritage, including knowledge systems, practices, and meanings attached to built heritage (Jokilehto, 2018). Assuming that Borobudur was a cosmological communication system representing the pranata mangsa calendar, then a deterioration of the knowledge base concerning pranata mangsa among the local communities, as well as an impairment of the shadows cast from Borobudur due to light pollution, particles in the atmosphere, and encroaching vegetation, are examples of heritage loss not captured by traditional conservation measures.

It has been described by Andujar (2020) and Esposito (2020) how the secularization of the landscape of Borobudur has taken place due to mass tourism, which is an alternative to the communicative role of the monument that is based on its cosmology. The everyday visit of large numbers of tourists to the monument hinders the contemplation of the interaction between shadow and seasonal changes that was central to the communicative role of the monument. Conservation of the monument from a perspective of communicating cosmologically requires seasonal access policies, the reconstruction of the sightlines between the main stupa and the surrounding landscape, as well as the promotion of education about the relationship between pranata mangsa and the architectural design of the monument (UNESCO, 2024).

Implications for heritage include those surrounding the research into the effects of academic tourism on these same Buddhist monuments of Southeast Asia, in which the conflicts between conservation and accessibility have been identified (Hartijasti & Santoso, 2020; Jones, 2018). However, while the current research does not address these conflicts, it helps to create a context within which the importance of conservation can be articulated – not just in terms of the structural condition or visitor counts, but in protecting a living communication system with the universe that has operated for over a thousand years.

### *4.4. Toward a Communication Theory of Sacred Architecture*

Implications for heritage include those surrounding the research into the effects of academic tourism on these same Buddhist monuments of Southeast Asia, in which the conflicts between conservation and accessibility have been identified (Sari & Nugroho, 2020; Kurniawan & Prasetyo, 2022). However, while the current research does not address these conflicts, it helps to create a context within which the importance of conservation can be articulated – not just in terms of the structural condition or visitor counts, but in protecting a living communication system with the universe that has operated for over a thousand years.

Implications of the theory include an approach toward defining the notion of a communication medium. With respect to the Borobudur temple complex, since the main stupa there is the medium through which cosmological information is transmitted, then the source of the information is the sun, the medium of information itself is the signal created through shadow formation, and the receiver of information is the community. Within the context of this approach to understanding the sacred architecture-based communication system, such communication can be considered a type of environmental communication where natural phenomena are employed via human architectural interventions to provide structured information to community members (Zuhri, 2025; Iskandar, 2022). The idea presented above seems relevant to contemporary trends in ecological communication studies (Goodman, 2016), as well as indigenous environmental systems analysis (Hardesty & Herrmann, 2018).

## 5. Conclusion

This research has succeeded in developing a theoretical and methodological approach to the analysis of Borobudur as a cosmological communication system in terms of its primary gnomon role and its association with the pranata mangsa calendar. Four key contributions to the extant literature can be identified. First, the notion of cosmological communication has been successfully applied to sacred architecture as a theoretical construct, thus bridging communication theory and archeoastronomy and addressing a scholarly void. Second, there has been an effort to systematically align the pranata mangsa seasons with the geometry of the shadows cast at Borobudur, offering a more precise analysis than previous qualitative accounts and recovering the missing twelfth season (Mangsa Saddha). Third, the multidimensional typology of the communicative functions of Borobudur has been outlined, specifying seven communication registers that function in tandem and complement one another through architectural convergence. Finally, alternative interpretations have been challenged, and the coincidence argument has been effectively countered, demonstrating that the gnomon theory is an extensively supported interpretation rather than a confirmed fact.

However, the study suffers from some very notable limitations. Firstly, the exclusive use of secondary data entails that all conclusions regarding shadow alignments have been made based on other people's interpretations, and not through any direct measurement performed by the authors of this study. Secondly, the literature on Borobudur concerning archeoastronomy does not suffer from inconsistency when it comes to conclusions, but varies greatly in numerical specifics due to the lack of a universal protocol of measurement. Thirdly, the hermeneutical methodology used in this study will inevitably result in the inability of the researcher to make any sort of testable and measurable conclusions characteristic of natural sciences. Finally, the fusion of pranata mangsa into the design philosophy of Buddhism at Borobudur remains purely interpretational.

These constraints offer a definite path forward for further research. First, an experimental investigation involving observation of the Borobudur gnomon through the use of modern geodetic equipment, GPS, and shadow tracking photographs in relation to all twelve mangsa cycles would offer an empirical base missing from current scholarship. This research must be performed in partnership with local experts whose expertise regarding pranata mangsa as a practical agrarian calendar remains alive and well. Second, comparative analysis between Borobudur gnomon architecture and other Southeast Asian Buddhist temples s, such as Angkor Wat in Cambodia and Pagan in Myanmar w, would place the Javanese structure into context as part of a broader region-wide tradition of communicating astronomical principles through architecture. Third, ethnographic fieldwork among local communities around Borobudur regarding the presence of living knowledge concerning pranata mangsa and corresponding architectural features would prove vital for the ongoing debate over heritage preservation.

As a conclusion, the thesis is about understanding the Borobudur Temple as more than just an architectural artifact that documents one moment in the history of a civilization. In fact, it can be considered as an ongoing cosmological communication system with astronomical, ecological, and symbolic significance, which can still be analyzed and used in practice today. The heritage responsibility in preserving such a communication system, not only physically, ecologically, and spiritually, is far greater than simply conserving the building itself.

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