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# ARTICLE INFORMATION

**Article title**

From Archives to AI: Residential Property Data Across Three Decades in Brunei Darussalam

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**Keywords**

*Housing Market; Property Listings; Spatial Data; Web Scraping; Large Language Models; Brunei.*

**Abstract**

This article introduces the first publicly available data set for analyzing the Brunei housing market, covering 31,495 property listings from 1993 to 2024. The data set, curated from property advertisements in newspapers and online platforms, includes key attributes such as price, location, property type, and physical characteristics, enriched with area-level spatial information. Comprehensive and historical, it complements the Brunei Darussalam Central Bank’s Residential Property Price Index (RPPI), addressing the limitations of restricted access to raw RPPI data and its relatively short timeline since its inception in 2015. Data collection involved manual transcription from archival sources and automated web scraping using programmatic methods, supported by innovative cleaning with Large Language Models (LLMs) to structure unformatted text. The data set enables spatial and temporal analysis, with potential applications in economics, urban planning, and real estate research. While minor limitations exist, such as missing values and spatial coverage bias toward the Brunei-Muara district, this data set provides a robust foundation for exploring housing market trends and informing policy decisions.

# SPECIFICATIONS TABLE

|  |  |
| --- | --- |
| **Subject** | Real Estate Economics |
| **Specific subject area** | Residential property data across three decades in Brunei for spatial, temporal, and economic analysis. |
| **Type of data** | Table (Raw) in Comma Separated Values (CSV) format. |
| **Data collection** | The data were collected via manual transcription from newspaper advertisements and automated web scraping using R software (rvest package). Large Language Models (Llama 3.1 via tidychatmodels in R) were employed to clean unstructured text into structured formats. Inclusion criteria focused on property listings with price, location, and type, while duplicates were removed. Spatial data were harmonized to match official administrative boundaries for consistency. |
| **Data source location** | The data were collected in Brunei Darussalam and are stored in a public GitHub repository. |
| **Data accessibility** | Repository name: GitHub/Bruneiverse  Data identification number: N/A  Direct URL to data:<https://bruneiverse.github.io/house-data/data/hspbn_2024-12-12.csv> |
| **Related research article** | None. |

# VALUE OF THE DATA

* **First of its kind for Brunei**. This data set enables comprehensive spatial and temporal analysis of the Brunei housing market. To our knowledge, no other publicly available data set exists for this purpose, making it a significant contribution to housing market research. Previous studies on Brunei’s housing have been limited to recent or non-spatial data [1–3], or qualitative in nature due to the lack of a structured data set [4,5]. This aligns with the growing trend of using data analytics in the real estate industry [6,7].
* **Historical and spatial insights**. Covering data from 1993 to 2024, this data set allows for the study of long-term housing trends in Brunei. The spatial information available enables analysis at various administrative levels, providing insights into local patterns and urban development over time. This historical depth is particularly valuable given the lack of previous data before the establishment of the Residential Property Price Index (RPPI) [8] in 2015.
* **Influence on economic and monetary policies**. Analysing the real estate market is crucial because the RPPI can potentially play a key role in shaping monetary policy and assessing economic stability. Changes in RPPI signal inflationary pressures, providing guidance to the central bank decisions. Developing a house price index using advertised prices, as explored by [9], aligns with practices in other countries, such as the UK’s House Price Index developed by Rightmove PLC [10,11]. This data set demonstrates how computational methods can automate what is typically a time-consuming and labour-intensive process.
* **Opportunities for handling of missing data**. While the data set has complete information for key variables such as price, date, and spatial variables, missing information on house characteristics creates opportunities for further research. Evidently, house characteristics are inherently correlated (see [Figure 6](#fig-corr)), so imputation from observed correlations seems highly promising. With the spatial information present, this opens avenues for developing methodological approaches for handling missing data, encouraging innovation and exploration in this area.
* **Application of Large Language Models (LLMs)**. This project highlights an innovative use of Large Language Models (LLMs) for data cleaning. The LLM was employed to extract structured information from unstructured text descriptions, achieving an accuracy rate of 93%. This method significantly reduced the time and effort required for data cleaning. It can also be applied to other data sets with unstructured text, such as social media or document archives, to extract valuable information for analysis.

# BACKGROUND

The housing market is a key indicator of economic health and social well-being, yet comprehensive and publicly accessible data sets in Brunei remain limited. As far as we are aware, this is the first data set of its kind in Brunei, motivated by the need to fill the gap in publicly available data on the local housing market.

Currently, the Brunei Darussalam Central Bank (BDCB) produces a Residential Property Price Index (RPPI) [8] using data sourced from financial institutions, such as bank loan data sets. While the RPPI is published quarterly, the underlying raw data is not publicly available due to privacy restrictions. This limits research opportunities and transparency in understanding broader housing market trends. Furthermore, since the RPPI only began in 2015, historical housing data for Brunei is lacking.

We address these challenges by providing a cost-effective and timely means to collect and analyse housing market data. Covering records from 1993 onward, it offers historical depth that complements–and extends beyond–the RPPI. It is valuable not only for tracking property price trends but also for advancing research in economics, urban planning, and real estate, supporting informed decision-making across sectors.

# DATA DESCRIPTION

The data has been curated into a single Comma-Separated Values (CSV) file named hspbn\_2024-12-12.csv. The data set contains 31,495 property listing records which are enriched with area-level geotagged spatial information, spanning a period of 32 years from Mar 1993 to Dec 2024. The 18 columns of this data set capture information for each property listing as detailed in [Table 1](#tbl-codebook) below.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| Table 1: Codebook for the house price data set.   |  | Variable | Type | Details | | --- | --- | --- | --- | | 1 | id | Integer | Unique identifier for each property listing. | | 2 | date | Date | Date when the property listing was collected. | | 3 | quarter | Date | Quarter of the listing date in the format YYYY Qq (e.g., 2016 Q3). | | 4 | kampong | Spatial Area | The village where the property is located. | | 5 | mukim | Spatial Area | The sub-district administrative area where the property is located. | | 6 | district | Spatial Area | The main district where the property is located. | | 7 | price | Numeric | Listing price of the property in Brunei Dollars (BND). | | 8 | type | Character | Type of property. One of "Detached", "Semi-Detached", "Terrace", "Apartment", or "Land". | | 9 | tenure | Character | The land tenure for the property. One of "Freehold", "Leasehold", or "Strata". | | 10 | status | Character | Current status of the listing. One of "Proposed", "Under Construction", "New", or "Resale". | | 11 | plot\_area | Numeric | Total area of the land plot in acres. | | 12 | floor\_area | Numeric | Built up floor area of the property in square feet. | | 13 | storeys | Integer | Number of storeys or floors in the property. | | 14 | beds | Integer | Number of bedrooms in the property. | | 15 | baths | Integer | Number of bathrooms in the property. | | 16 | agent | Character | Anonymised identifier of the real estate agent or agency handling the listing. | | 17 | source | Character | Source of the listing. | | 18 | method | Character | Method of data collection. | |

## Property Characteristics

The data set includes a range of property characteristics suitable for exploring the relationship between property attributes and prices. This section clarifies and provides context for the key variables in the data set.

Brunei’s private residential property market offers a variety of options, including detached houses, townhouses, and apartments [5]. Based on this, property types have been categorised into four main groups–Detached, Semi-Detached, Terrace, and Apartment–to accurately reflect the diversity of property types in Brunei. Additionally, there are a small number of records that reflect listings for land, which are categorised accordingly as “Land”.

Property tenure refers to the legal terms under which a person holds ownership or occupancy rights to a property. In Brunei, property tenure can be classified into three main categories: Freehold (in perpetuity), Leasehold, and Strata. The latter two refer to a limited time-limited ownership, although details about the remaining duration of the tenure are almost never included in property listings. Strata titles differ from Leasehold titles in that they grant ownership of a specific portion of a property, such as an apartment, while sharing ownership of common areas.

The data set also includes information on the status of the property listing, indicating whether the advertisement refers to a proposed development, a newly completed development, or a property being resold. This categorical variable may be useful for analysing price differences across different types of listings. While the exact age of properties being resold would be invaluable for such analyses, this information is rarely included in advertisements. Instead, the listing status may serve as a useful proxy for property age.

The numerical variables in the data set are plot area, floor area, storeys, beds, and baths, each providing information on the physical attributes of the property. Note that plot area is measured in acres, while floor area in square feet, as these are the units most familiar and commonly used in Brunei. Users of this data set may choose to convert these units as needed for their analysis.

Finally, metadata about the property is included for transparency and informational purposes. The variable agent specifies the (anonymised) identifier of the real estate agent or agency responsible for the listing, while source identifies the platform or medium from which the listing was obtained, such as a newspaper, magazine, or website. The method variable details the data collection approach, which is further elaborated in the section below.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| Table 2: Summary of housing data.   | Variable | N | Overall N = 31,4951 | Brunei-Muara N = 28,8941 | Belait N = 1,5131 | Tutong N = 7901 | Temburong N = 2981 | | --- | --- | --- | --- | --- | --- | --- | | **Price (BND 1,000)** | 31,495 |  |  |  |  |  | | Mean (SD) |  | 340 (380) | 339 (392) | 372 (209) | 260 (87) | 419 (323) | | Min - Max |  | 70 - 13,800 | 70 - 13,800 | 98 - 2,800 | 116 - 680 | 118 - 1,800 | | Median (Q1, Q3) |  | 285 (230, 380) | 285 (230, 380) | 320 (268, 400) | 245 (198, 310) | 390 (250, 430) | | **Property type** | 27,592 |  |  |  |  |  | | Detached |  | 17,685 (64%) | 16,548 (65%) | 524 (41%) | 532 (75%) | 81 (56%) | | Semi-Detached |  | 3,808 (14%) | 3,574 (14%) | 97 (7.6%) | 130 (18%) | 7 (4.8%) | | Terrace |  | 4,502 (16%) | 4,183 (16%) | 219 (17%) | 46 (6.5%) | 54 (37%) | | Apartment |  | 1,582 (5.7%) | 1,151 (4.5%) | 424 (33%) | 4 (0.6%) | 3 (2.1%) | | Land |  | 15 (<0.1%) | 10 (<0.1%) | 4 (0.3%) | 1 (0.1%) | 0 (0%) | | **Land tenure** | 13,064 |  |  |  |  |  | | Freehold |  | 9,398 (72%) | 8,477 (75%) | 381 (33%) | 396 (80%) | 144 (97%) | | Leasehold |  | 2,850 (22%) | 2,273 (20%) | 477 (41%) | 96 (19%) | 4 (2.7%) | | Strata |  | 816 (6.2%) | 516 (4.6%) | 297 (26%) | 3 (0.6%) | 0 (0%) | | **Development status** | 22,831 |  |  |  |  |  | | Proposed |  | 3,902 (17%) | 3,562 (17%) | 101 (8.4%) | 195 (32%) | 44 (30%) | | Under Construction |  | 9,715 (43%) | 8,856 (42%) | 553 (46%) | 264 (43%) | 42 (29%) | | New |  | 8,011 (35%) | 7,389 (35%) | 428 (36%) | 135 (22%) | 59 (40%) | | Resale |  | 1,203 (5.3%) | 1,061 (5.1%) | 116 (9.7%) | 25 (4.0%) | 1 (0.7%) | | **Plot area (acres)** | 23,581 |  |  |  |  |  | | Mean (SD) |  | 0.16 (0.12) | 0.15 (0.11) | 0.19 (0.15) | 0.18 (0.17) | 0.23 (0.21) | | Min - Max |  | 0.01 - 2.00 | 0.01 - 1.63 | 0.01 - 1.01 | 0.04 - 2.00 | 0.05 - 0.96 | | Median (Q1, Q3) |  | 0.13 (0.08, 0.19) | 0.13 (0.08, 0.19) | 0.13 (0.06, 0.27) | 0.14 (0.10, 0.20) | 0.16 (0.13, 0.26) | | **Floor area (sq. ft.)** | 16,863 |  |  |  |  |  | | Mean (SD) |  | 2,590 (1,045) | 2,616 (1,061) | 2,418 (914) | 2,130 (629) | 2,796 (741) | | Min - Max |  | 500 - 14,411 | 500 - 14,411 | 600 - 7,500 | 1,100 - 7,000 | 950 - 3,700 | | Median (Q1, Q3) |  | 2,410 (2,000, 3,000) | 2,435 (2,000, 3,000) | 2,207 (1,700, 2,800) | 2,013 (1,826, 2,450) | 3,031 (2,790, 3,229) | | **Number of storeys** | 13,797 |  |  |  |  |  | | 1 |  | 1,709 (12%) | 1,472 (12%) | 160 (35%) | 70 (16%) | 7 (4.2%) | | 2 |  | 11,420 (83%) | 10,630 (83%) | 280 (61%) | 365 (84%) | 145 (87%) | | 3+ |  | 668 (4.8%) | 631 (5.0%) | 20 (4.3%) | 2 (0.5%) | 15 (9.0%) | | **Number of bedrooms** | 26,968 |  |  |  |  |  | | Mean (SD) |  | 4.2 (0.9) | 4.2 (0.9) | 4.0 (1.1) | 3.9 (0.7) | 4.7 (1.0) | | Min - Max |  | 0.0 - 12.0 | 0.0 - 12.0 | 1.0 - 10.0 | 2.0 - 7.0 | 2.0 - 7.0 | | Median (Q1, Q3) |  | 4.0 (4.0, 5.0) | 4.0 (4.0, 5.0) | 4.0 (3.0, 4.0) | 4.0 (3.0, 4.0) | 5.0 (4.0, 5.0) | | **Number of bathrooms** | 19,957 |  |  |  |  |  | | Mean (SD) |  | 3.7 (1.2) | 3.7 (1.2) | 3.3 (1.1) | 3.3 (1.0) | 3.2 (1.5) | | Min - Max |  | 1.0 - 11.0 | 1.0 - 11.0 | 1.0 - 8.0 | 1.0 - 7.0 | 1.0 - 5.0 | | Median (Q1, Q3) |  | 3.0 (3.0, 4.0) | 3.0 (3.0, 4.0) | 3.0 (3.0, 4.0) | 3.0 (2.0, 4.0) | 2.0 (2.0, 5.0) | | 1 n (%) | | | | | | | |

## Spatial Information

In Brunei Darussalam, the administrative areas are organised hierarchically into three levels. At the smallest level is the *kampong*, the Malay word for village. While a typical village refers to a traditional rural settlement, it is also used to describe an urbanised area located within or near the capital city or a town. It may even refer to a part of public housing estates. Several kampongs grouped together form a *mukim*, which serves as a sub-district administrative area. Finally, multiple mukims are nested within a *district*, the largest administrative unit, of which Brunei has four: Brunei-Muara, Belait, Tutong, and Temburong. In our data set, each property listing is associated with a specific kampong, mukim, and district, allowing for spatial analysis at different scales.

Importantly, the names of the kampongs, mukims, and districts have been harmonised with a standardised naming convention to ensure consistency across the data set. This also allows for ease of integration into Geographic Information Systems (GIS) software for spatial analysis and visualisation, namely the {bruneimap} R package [12].

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| A map of the united states  Description automatically generated  Figure 1: Spatial distribution of median property prices by mukim. |

## Listing Dates

The date variable in the data set refers to the date on which the property listing was obtained. It is important to note that this is not the date the property was sold, nor does it necessarily reflect the precise timing of other transactions related to the property. Users should set their expectations accordingly, as the primary purpose of the date is to capture the state of the housing market at a specific point in time.

For analysis, we recommend aggregating data by quarters, as represented by the quarter variable. This aggregation helps address potential issues like missing data (see subsection below) and provides a more stable and robust representation of market trends, making it suitable for temporal analysis of the housing market.

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| A graph of a number of people  Description automatically generated with medium confidence  Figure 2: Median smoothed prices per square foot by property type using a 24-month (8-quarter) rolling window. |

## Missing Values

This data set endeavours to provide complete information regarding the listing date, spatial information, advertised price, and metadata. Nonetheless, we hereby report that missing values are present across various property characteristics, including type, tenure, status, plot area, floor area, storeys, beds, and baths. The reason for this is due to the nature of the property advertisements, which may not always include complete information when advertised by the real estate agents. Missing values are represented by blank cells in the CSV file, and the severity of missing values is summarised in [Table 3](#tbl-avail). In summary, 10.5% of the records contain missing values for all key house characteristics (i.e. plot area, floor area, beds, and baths), which, depending on the research question, may necessitate imputation or exclusion of these records.

## Comparison to RPPI Data

To demonstrate the quality of the data set, we compared it with the Residential Property Price Index (RPPI) [8] published by the Brunei Darussalam Central Bank (BDCB). A simple median price per square foot (PPSF) index can be calculated by aggregating the data by quarters. This approach minimises the impact of missing values, as the index is based on aggregated data. [Figure 3](#fig-rppi) shows the comparison between the RPPI and the PPSF index calculated from our data set. The mean absolute error (MAE) between the two indices is calculated to be 4.66%, indicating a good level of agreement between the two data sets.

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| A graph with red and blue lines  Description automatically generated  Figure 3: Comparison of quarterly median price per square foot indices (Median PPSF) and the official Residential Property Price Index (RPPI) from Brunei Darussalam Central Bank (BDCB). |

# EXPERIMENTAL DESIGN, MATERIALS AND METHODS

In this section we describe the data collection process, which involved either a manual transcription of property listings from newspapers, or web scraping of online property agent listings. The data collection method varied over the years due to the availability of data sources and the evolution of technology. For the later years, a large language model (LLM) was also employed to perform data cleaning on the web scraped data. [Table 3](#tbl-avail) details which method was used for each year in the data set, and whether the data was subjected to LLM post-processing.

All analyses were conducted using the R programming language [13], with specific packages used described in each subsection below.

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| Table 3: Data availability by year. |

|  |  |  | Missing data severity | | Data source | | |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Count | Spatial coverage (mukim)*1* | Property Type*2* | Property Characteristics*3* | National Archive | Online Archive | Web Scraping | LLM post-processing |
| 1993 | 417 | 23.1% | 0.0% | 19.2% | ✔ |  |  |  |
| 1994 | 654 | 35.9% | 65.7% | 28.0% | ✔ |  |  |  |
| 1995 | 669 | 48.7% | 66.8% | 21.2% | ✔ |  |  |  |
| 1996 | 563 | 35.9% | 69.8% | 12.1% | ✔ |  |  |  |
| 1997 | 385 | 35.9% | 38.4% | 26.8% | ✔ |  |  |  |
| 1998 | 345 | 33.3% | 36.8% | 28.7% | ✔ |  |  |  |
| 1999 | 322 | 35.9% | 31.4% | 27.3% | ✔ |  |  |  |
| 2000 | 379 | 43.6% | 0.8% | 4.2% | ✔ |  |  |  |
| 2001 | 344 | 43.6% | 0.3% | 2.3% | ✔ |  |  |  |
| 2002 | 443 | 43.6% | 0.0% | 20.1% | ✔ |  |  |  |
| 2003 | 454 | 46.2% | 0.0% | 13.2% | ✔ |  |  |  |
| 2004 | 442 | 43.6% | 0.0% | 19.0% | ✔ |  |  |  |
| 2005 | 496 | 46.2% | 0.0% | 13.3% | ✔ |  |  |  |
| 2006 | 661 | 41.0% | 0.2% | 11.3% | ✔ |  |  |  |
| 2007 | 644 | 38.5% | 0.0% | 13.0% | ✔ |  |  |  |
| 2008 | 699 | 41.0% | 0.3% | 5.7% | ✔ |  |  |  |
| 2009 | 542 | 35.9% | 0.2% | 3.9% | ✔ |  |  |  |
| 2010 | 578 | 38.5% | 0.0% | 2.1% | ✔ |  |  |  |
| 2011 | 605 | 38.5% | 0.2% | 9.9% | ✔ |  |  |  |
| 2012 | 937 | 43.6% | 8.0% | 4.3% | ✔ |  | ✔ |  |
| 2013 | 888 | 41.0% | 2.9% | 26.6% | ✔ | ✔ | ✔ |  |
| 2014 | 710 | 46.2% | 10.6% | 8.0% |  | ✔ | ✔ |  |
| 2015 | 1121 | 46.2% | 14.4% | 4.9% |  | ✔ | ✔ |  |
| 2016 | 1462 | 48.7% | 13.6% | 4.6% |  | ✔ | ✔ |  |
| 2017 | 1643 | 48.7% | 14.4% | 4.6% |  | ✔ | ✔ |  |
| 2018 | 2880 | 46.2% | 17.8% | 0.0% |  |  | ✔ |  |
| 2019 | 3596 | 43.6% | 15.9% | 0.0% |  |  | ✔ |  |
| 2020 | 1397 | 46.2% | 10.2% | 0.0% |  |  | ✔ | ✔ |
| 2021 | 1163 | 53.8% | 1.9% | 0.0% |  |  | ✔ | ✔ |
| 2022 | 1324 | 53.8% | 3.4% | 0.0% |  |  | ✔ | ✔ |
| 2023 | 1635 | 53.8% | 2.7% | 0.0% |  |  | ✔ | ✔ |
| 2024 | 3097 | 53.8% | 4.4% | 0.1% |  |  | ✔ | ✔ |
| mean | 984 | 42.9% | 13.5% | 10.5% | — | — | — | — |
| *1*Total number of mukims in Brunei = 39. | | | | | | | | |
| *2*Unknown property type. | | | | | | | | |
| *3*Missing all of plot area, floor area, beds, and baths variables. | | | | | | | | |

## Manual Data Collection

Early years data collection was conducted manually, involving the transcription of property listing details from advertisements into a digital tabular format. This process was carried out by two of the authors over a period of nine months, from October 2023 to July 2024. The primary sources of the property listings were local newspapers and magazines. Physical copies were accessed through the National Archive of Brunei Darussalam, while digital versions, which are digitised replicas of the physical newspapers, were obtained online. These digital formats could not be scraped due to their lack of structured data, necessitating manual transcription.

Although daily newspapers from 1993 onward were available at the National Archive, the classified sections were not always present. From 1993 to 1999, property advertisements were found only in Friday editions, and occasionally on Saturdays. Thus, newspapers from both these days were reviewed weekly to capture the listings data. This yielded roughly between 300 and 700 listings per year.

From the year 2000 onwards, property advertisements were published daily in the classifieds section. However, reviewing every single daily edition was not practical and would increase the likelihood of recording duplicate listings, thus necessitating a sampling strategy. The sampling was done as follows. Three newspaper editions per week were selected, and the classifieds section was reviewed for property listings. When a listing was found, it was recorded after careful filtering to ensure it was unique. This manual filtering process involved cross-checking based on the real estate agent, house characteristics, price, location, and date proximity. To avoid duplication, the same house listing was not recorded more than once within a quarter. This process yielded roughly the same number of listings per year as the earlier years.

## Web Scraping

To compile additional property data for the study beyond manual data collection, web scraping was employed using the R programming language, making use of the {rvest} package [14]. This method enabled the systematic extraction of structured information from various local property listing websites such as panvilla.com (now defunct), bruhome.com, and bruneiproperty.com.bn. Such websites provide extensive details on properties listed as “for sale” in Brunei, aggregating advertisements from real estate agents and property developers.

The process began by identifying the structure of the target websites, focusing on the HTML tags and classes containing the relevant information. The goal here is to programmatically pinpoint and collect specific information like text, links, or attributes. For example, elements such as property prices, number of bedrooms, bathrooms, location, and other features were enclosed within specific HTML elements, which {rvest} functions like html\_elements() and html\_text2() could target and extract efficiently. [Figure 4 (a)](#fig-mockup-listing) illustrates the structure of a typical property listing showing the various HTML elements to target. Example code to perform this task in available in the repository.

Each webpage displayed a fixed number of listings (e.g. 128 per page). To scrape all pages, a loop was created to iterate through each page by modifying the URL (such as with an &offset=<number> parameter, where <number> represents the cumulative number of listings already scraped).

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| |  | | --- | | A mockup of the structure of property listing showing various HTML elements.  (a) | |

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| |  | | --- | | Example paragraph containing description within the “See Details” link for each property.  (b) | |

Figure 4: Illustration of a property listing from a typical Bruneian property portal. Attribution: Freepik.

Extracted data required some cleaning to standardise formats for analysis. Specifically:

* price variables were cleaned by removing non-numeric characters and converted to integers.
* beds and baths were converted to integers.
* date variables were formatted properly as Date objects.
* Locations were stored as text strings. See the subsection below on spatial data harmonisation for more details.
* Any additional information was extracted from the property descriptions and saved as a character vector. This very often contained valuable insights not captured in the primary fields.

Data from 2012 up until the present (December 2024) were managed to be collected using this method, averaging around 1,500 listings per year. While highly efficient, this process relied heavily on the consistency of the site structure of the source webpages. Changes to website layouts or closures over time required significant updates to the scraping scripts. To overcome these issues, alternative approaches, such as using Large Language Models (LLMs) were considered. This is explained in the next subsection.

## LLM Data Cleaning

As previously mentioned, the web scraping process also captured unstructured information from the property descriptions, which often contained valuable details not captured in the primary fields. In this subsection, we detail the data cleaning process using a pre-trained large language model (LLM) to extract structured information from the unstructured text. The LLM used was Llama 3.1 with 8B parameters [15], accessed using the {tidychatmodels} R package [16] via the Ollama[[1]](#footnote-1) API, a local interface platform to the LLM.

The primary goal was to extract the house characteristics of interest, specifically variables 7 to 15 as per [Table 1](#tbl-codebook), from the unstructured verbose descriptions scraped from property listing websites. Each description was processed with a carefully designed prompt ([Figure 5](#fig-llm-prompt)) to ensure consistent output. This prompt instructed the model to return only the required information in a semicolon-separated format, while handling edge cases such as missing descriptions, non-residential (commercial) properties, or rental property advertisements.

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| "The following is the description from a property sale listing in Brunei. This description will contain the information about the property, including its characteristics, price, and location. However, some of these descriptions may not contain property listings, and instead contain other or no information at all.  In the case where this description is in fact a property listing, I would like you to extract the following information:  1. Location / area of the property in Brunei, CHARACTER. 2. Price of the property in Brunei Dollars, NUMERIC. 3. Type of property, CHARACTER -- select from Detached, Semi-Detached, Terrace, Apartment, or Land. 4. Land tenure, CHARACTER -- select from Freehold, Leasehold, or Strata. If other than this, return 'NA'. 5. Status of the property, CHARACTER -- select from Proposed, Under Construction, New, or Resale. 6. Land area in acres, NUMERIC. 7. Built up area in square feet, NUMERIC. 8. Number of storeys, INTEGER. 9. Number of bedrooms, INTEGER. 10. Number of bathrooms, INTEGER.  Further instructions:  - Please return \*\*semicolon\*\* separated values like this:   Kg Tanah Jambu; 250000; Detached ; Freehold ; New ; 0.3 ; 2500; 2; 3; 3  Kg Tungku ; 300000; Terrace ; Leasehold; Resale ; 0.25; 1700; 2; 3; 2   Kg Kiarong ; 200000; Apartment; Strata ; Proposed; 0.1 ; 1000; NA; 2; 2  etc.  NUMBERS SHOULD NOT CONTAIN comma (,) for thousands separator  - If any of the 10 values are missing, please return 'NA' for that value.  - If the description does not contain a property listing (for example, it is a rental property advertisement), return 'NA' for all 10 values.  - DO NOT RESPOND WITH ANYTHING ELSE OTHER THAN THE REQUIRED INFORMATION."  Figure 5: The LLM prompt to clean descriptions obtained from web scraping. |

The verbose descriptions were fed into the model one at a time using a loop, with the LLM extracting and returning the relevant details. Note that this loop was not parallelised due to the computational resources required by the LLM. The cleaned results were then parsed and stored in a data frame, which was then subjected to manual data-type validation to ensure conformity with the existing data set. It takes, on average, 2.12 seconds to process a single description running on Apple MacBook Air M2 Silicon on Chip (SoC) and System in Chip (SiP) processors with 16GB RAM. We processed 4,820 descriptions in total from 2020 to 2024 using this method, with a runtime of approximately three hours.

To test the accuracy of the LLM, a random sample of 329 descriptions was selected and manually verified for correctness. Of these, 306 were deemed correct (correct entries or identified “non-listings” correctly), resulting in an accuracy rate of 93.0%. Rare errors were spotted due to model hallucinations (despite setting the LLM temperature to the lowest setting), but these are typically minor and unlikely to significantly impact the overall analysis. Large errors on the other hand were corrected manually, by filtering for outliers (values exceeding three standard deviations from the mean in magnitude) or inconsistencies in the variables. Overall, the LLM was found to be a valuable tool for extracting structured information from unstructured text, significantly reducing the time and effort required for data cleaning. Users may wish to exclude these records from their analysis if they are concerned about the accuracy of the extracted data.

## Spatial Data Harmonisation

Whether the data was collected manually, through web scraping, or cleaned using the LLM, the spatial information extracted was often inconsistent in terms of naming conventions and granularity. To address this, a spatial data harmonisation process was conducted to standardise the names of the kampongs (villages) in the data set to the format used by Department of Economic Planning and Statistics (DEPS), Ministry of Finance and Economy, Brunei Darussalam as per the most recent census [17]. This is the same format used by the R package {bruneimap} [12]. The CSV file bn\_kpg\_level\_data.csv obtained from this package was used as a reference to standardise the kampong names in the data set, which conveniently also included the mukim and district names for each kampong.

The majority of house listings in Brunei specify the property location using the kampong name, the smallest administrative unit in the country. The task in hand was then to match these kampong names in the data set with the standardised names in the reference file. Several challenges were encountered during this process, including:

1. Spelling variations or misspellings, though these were relatively straightforward to correct.
2. Unknown entries, where the correct kampong could sometimes be inferred from the geographical context; otherwise, these were set to NA.
3. Multiple matches, occurring when two or more kampongs shared the same name (e.g., Kampong Panchor in Mukim Mentiri and Kampong Panchor in Mukim Lumapas). Additional information from the listing was used to determine the correct match, but where this was not possible, these entries were also set to NA.

This process was carried out manually using data filtering features in Microsoft Excel. Once completed, all entries marked as NA were removed so as to provide complete spatial information for each listing.

# LIMITATIONS

Despite efforts to ensure data quality, some limitations remain. Duplicate listings were carefully reviewed and removed, though there remains a slight possibility that duplicated records still exist in the data set. The spatial data coverage is also heavily skewed towards the Brunei-Muara district, which accounts for 91.7% of the listings. This is a reflection of the district’s higher population and greater volume of property transactions [18], which may bias analyses toward this region. Furthermore, while we have confidence in the data quality from 2015 to 2024, property price trends between 1993 and 2014 cannot be fully verified. Nonetheless, this study serves as a valuable starting point. Future research could benefit greatly from access to administrative transaction data, which would allow for more comprehensive and accurate analyses.

Missing data in house characteristics is another limitation, although this should be seen as an opportunity for further research to develop imputation methods or alternative analytical approaches. Minor inaccuracies were also observed in the LLM-based data cleaning process, but these issues are infrequent and can be mitigated by subsetting or refining the affected entries.

Finally, while significant effort was made to harmonise spatial data, the matching of kampong names to standardised references may not be entirely error-free. However, aggregation to the mukim level provides a reliable alternative for spatial analyses, ensuring that the data set remains valuable for research and analysis.

# ETHICS STATEMENT

The authors confirm that the current work does not involve human subjects, animal experiments, or data collected from social media platforms. The data described in this article were obtained from publicly available, non-personal, and factual sources, including physical and digital newspapers and magazines.

Web scraping from local property listings websites was conducted in compliance with ethical and legal considerations. Specifically, data were not collected from behind login barriers, and the terms of service (ToS) for the websites did not explicitly prohibit web scraping. Furthermore, the robots.txt files for the websites were reviewed, and any policies outlined there were adhered to.

The data collected consisted exclusively of non-copyrightable factual information, such as property characteristics and spatial locations, and excluded any potentially copyrighted content such as images. To ensure privacy, no personally identifiable information, including specific property addresses, was scraped nor included in the data set. To this end, data from the description fields processed by the LLM are not included in the data set, as they may contain sensitive information such as contact details and names of companies. Furthermore, we have anonymised the names of the real estate agents and companies in the data set.

# CRediT AUTHOR STATEMENT

* **Haziq Jamil**: Conceptualisation, Methodology, Software, Formal analysis, Data curation, Writing-Original Draft, Visualisation, Supervision, Project administration, Funding acquisition.
* **Amira Barizah Noorosmawie**: Software, Data curation, Writing-Original Draft.
* **Hafeezul Waezz Rabu**: Software, Data curation, Writing-Original Draft.
* **Lutfi Abdul Razak**: Conceptualisation, Validation, Supervision, Funding acquisition.

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# DECLARATION OF COMPETING INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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# Appendix

## Pairwise Correlation Plot of Numeric Variables

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| --- |
| A screenshot of a graph  Description automatically generated  Figure 6: Pairwise correlation plot of continuous variables. |

1. <https://github.com/ollama/ollama> [↑](#footnote-ref-1)