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## Digital Heritage as a Heritage Conservation Effort: Digital Modeling with Sequence Diagram of Karangsuwung Sugar Factory

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### ABSTRACT

*The Karangsuwung Sugar Factory, a colonial-era industrial site in Cirebon, holds significant historical and architectural value. However, over time, the building has experienced physical deterioration and lacks proper documentation, particularly in digital form. This research aims to address that gap by digitally documenting and modeling the factory as part of a cultural heritage conservation effort. The approach involves using sequence diagrams to reconstruct the geometric formation of the building, enabling a better understanding of its historical and architectural significance. Each architectural element is simplified into basic geometric forms, points and lines, then parameterized to retain the essential characteristics of the structure. The modeling process employs Rhino 3D software and the Grasshopper plugin, which are selected for their capacity to produce precise and flexible parametric geometries. Through Grasshopper's parametric system, the research generates a sequence-based representation of the factory's geometry, explaining the building's form, proportion, and structure based on historical records. To support the digital modeling process, a combination of literature study, field observation, and interviews was conducted. The literature review provides insight into the factory's historical and architectural context, while field observations document the current physical state, which informs the digital reconstruction. This study contributes to the advancement of digital heritage documentation in Indonesia. It not only helps preserve the legacy of the Karangsuwung Sugar Factory but also lays a methodological foundation for future research in the conservation and management of historic architectural sites.*

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## 1. INTRODUCTION

The sugar industry in Indonesia played a crucial role in the economy during this period. With policies such as the forced cultivation system (*Cultuurstelsel*) (1830-1870), the Dutch colonial government utilized indigenous labor to increase sugarcane production, the primary ingredient in sugar. This system was later abolished and replaced by the *Agrarische Wet* policy of 1870, which opened up investment opportunities in the plantation sector and accelerated the industrialization of sugar factories in Java. Along with technological advances, many sugar factories underwent modernization in the late 19th century, including the Karangsuwung Sugar Factory, which began using steam engines to increase production efficiency.

However, over time, many colonial sugar factories experienced declining production, leading to their closure. The Karangsuwung Sugar Factory experienced declines and ultimately closed in 2014 due to several factors, including limited land, a lack of competitiveness compared to modern factories, and changes in economic policy (Dharussalam & Assilmi, 2023). Furthermore, changes in consumer consumption patterns and increased sugar imports also contributed to the closure of these factories.

In the context of cultural heritage preservation, the Digital Heritage approach offers an innovative solution for digitally documenting and reconstructing historic buildings. Using digital modeling methods, buildings like the Karangsuwung Sugar Factory can be accurately documented and serve as references for conservation, restoration, and educational efforts.

### 1.1. Problem Identification

1. The physical condition of the Karangsuwung Sugar Factory is alarming, experiencing physical degradation, despite its status as a cultural heritage building.
2. There is a lack of digital technology implementation in architectural conservation efforts, particularly in documenting historic buildings.

### 1.2. Research Questions

1. How has the history and architecture of the Karangsuwung Sugar Factory developed as a colonial industrial heritage?
2. Are there architectural elements in the Karangsuwung Sugar Factory that require conservation as cultural heritage objects?
3. How is the digital documentation process for the Karangsuwung Sugar Factory to obtain three-dimensional model sequences for these elements, and are there sequences for forming these elements using a computational/parametric design approach?

### 1.3. Research Purposes

1. To examine the cultural heritage values of the Karangsuwung Sugar Factory.
2. To determine which elements are worthy of conservation as cultural heritage objects.
3. To digitally document factory building elements using a computational/parametric design approach to generate formation processes/sequences.

### 1.4. Research Benefits

This research is expected to enrich insights in the field of digital heritage, particularly in architectural documentation and preservation. The result is a simplified 3D model of the Karangsuwung Sugar Factory, which can serve as a reference for conservation and reconstruction efforts. In addition to serving as a reference for further studies, this documentation also contributes to raising awareness of the importance of cultural heritage preservation and supporting historical education and tourism programs.

## 2. LITERATURE REVIEW

### 2.1. Sugar Industry During the Colonial Period

During the Dutch colonial period, the sugar industry played a crucial role in the economy of the Dutch East Indies, particularly on the island of Java. Sugar production in Java began in the early 17th century, initially as an export commodity to China, India, and Persia. However, dominance in the European market was difficult due to competition from American sugar (Knight, 2014). The post-Java War financial crisis prompted the colonial government to implement the *Cultuurstelsel* (Cultivation System) in 1830, requiring indigenous farmers to grow sugar cane. This system greatly benefited the Dutch but caused hardship for the local population. After much criticism, this system was replaced by the Agrarian Law of 1870, which opened up private investment in the plantation industry, including the establishment of modern sugar factories. The sugar industry developed rapidly in the early 20th century, particularly after the establishment of the *Algemeen Syndicaat van Suikerfabrikanten in Nederlandsch-Indië* in 1908 (Knight, 2014). Java became one of the world's largest sugar producers. However, the global economic crisis of 1929–1930 and World War II caused the industry to decline sharply. After independence, the Indonesian government nationalized Dutch-owned sugar mills in 1958 (Dinas Komunikasi dan Informatika Kabupaten Cirebon, 2025).

In Cirebon, the development of sugar mills since the late 19th century has been influenced by soil fertility and water availability. The Karangsuwung Sugar Mill was one of the few mills that did not own its land, but instead leased community land due to restrictions on land ownership for foreigners under the Agrarian Law of 1870. This system allowed the company to operate long-term through a lease scheme. Sugar mills in Cirebon had a significant impact on the socio-economic life of the community. In addition to creating jobs, these mills also shaped the surrounding settlement patterns. However, colonial social structures remained evident, with native workers in labor positions and Dutch nationals in technical positions. Amid its economic role, the sugar industry also gave rise to cultural traditions such as the "*Kawin Tebu*" ritual, a symbolic ceremony expressing gratitude and hope for a good sugar cane harvest (Romdhon & Arief, 2023). This tradition reflects the acculturation of local culture and colonial influence.

### 2.2. Karangsuwung Sugar Factory

The Karangsuwung Sugar Factory is one of the oldest colonial sugar factories in Indonesia, located in Cirebon. Established in 1896 by the Dutch company *NV Maatschappij tot Exploitatie der Suiker Onderneming Karangsoewoeng*, the factory played a crucial role in the colonial sugar industry.



Figure 1: Karangsuwung Sugar Factory  
Source: LPPM UNPAR (2025)

The location was chosen due to Cirebon's fertile and strategic geography, supported by transportation access such as railways and ports. Following the nationalization of Dutch assets in 1958, the factory was managed by the government until it finally ceased operations in 2014 due to various industry challenges, including increasing sugar imports and production inefficiencies (Dharussalam & Assilmi, 2023).

Architecturally, the Karangsuwung Sugar Factory features a rectangular floor plan with overlapping gable roofs made of corrugated iron. Its open layout facilitates production efficiency, and it features a steam engine and chimneys that function as part of the operational system. The building's architecture reflects a colonial style with Art Deco influences, characterized by a massive structure, natural ventilation, and distinctive decorative elements such as moldings on the windows and doors. According to Handinoto (2012), colonial architecture in Indonesia developed through three periods: the Indische Empire, the Transitional, and the Modern Colonial. The Karangsuwung Sugar Factory reflects many colonial characteristics, such as a symmetrical facade, an open floor plan, and the principle of form follows function.

### **2.3. Conservation**

Conservation is the effort to preserve cultural heritage to prevent damage and ensure its longevity. Cultural heritage is important to conserve because it contains historical values that can serve as a source of learning for present and future generations. According to the Indonesian Dictionary or *Kamus Besar Bahasa Indonesia* (KBBI), conservation is the act of regularly maintaining and protecting it to prevent damage or destruction. In the context of architecture, conservation involves efforts to maintain, care for, and restore historic buildings so that they remain functional and do not lose their original value (Orbasli, 2008).

The values in architectural conservation encompass various aspects, including historical, architectural, cultural, artistic, and educational values. Other values, such as social, symbolic, technical, and urban planning, also play a role in strengthening the rationale for preservation. Cultural heritage buildings also contain values of rarity, local uniqueness, and political and economic values related to identity, function, and tourism potential.

In implementing conservation, various actions can be taken, such as adaptation, consolidation, preservation, protection, reconstruction, replication, and restoration. These actions are tailored to the physical condition of the building and the preservation needs to ensure it does not lose its authenticity and function. Preventive measures are also crucial to slowing the deterioration of age. Architectural conservation must adhere to strong principles such as integrity, authenticity, appropriateness to the environmental context, and appropriate use. It is also crucial to pay attention to the judicious use of technology, respect for traditions, and minimize interference with the building's original elements. Legality and sustainability are also fundamental to conservation, as preservation encompasses not only the physical preservation of the building but also its inherent cultural values.

### **2.4. Cultural Heritage Building**

Cultural heritage is a historical and cultural heritage that holds significant value for a nation's identity. According to UNESCO, cultural heritage includes physical heritage such as buildings and artifacts, as well as non-physical heritage such as traditions and cultural expressions that have historical, artistic, social, or archaeological value. In the national context (*UU No. 11 Tahun 2010 tentang Cagar Budaya*) (2010), defines cultural heritage as objects, buildings, structures, sites, or areas that hold significant historical and cultural value and must be preserved. The objectives of preservation include enhancing national dignity,

strengthening identity, improving people's welfare, and promoting Indonesian culture internationally.

Cultural heritage buildings are a physical form of cultural heritage that holds architectural, scientific, and social value. These buildings must meet criteria such as being at least 50 years old, representing a specific architectural style, and possessing historical, cultural, or educational value. According to the Ministerial Regulation of the Ministry of Public Works and Public Housing No. 13 of 2021 (*Permen PUPR No. 19 Tahun 2021 tentang Pedoman Teknis Penyelenggaraan Bangunan Gedung Cagar Budaya yang Dilestarikan*) (2021), and Government Regulation of the Republic of Indonesia on the National Register and Preservation of Cultural Heritage No. 1 of 2022 (*PP Republik Indonesia No. 1 Tahun 2022 tentang Register Nasional dan Pelestarian Cagar Budaya*) (2022), cultural heritage buildings must possess significant value (historical significance, philosophy, or social relevance) and physical attributes (design, materials, architectural components) that shape the building's character. These attributes are classified as primary, supporting, and non-supporting based on their contribution to the building's cultural value.

The preservation of cultural heritage buildings encompasses three main aspects: protection, development, and utilization. Protection aims to prevent damage and destruction; development focuses on enhancing cultural values and information; and utilization relates to the use of cultural heritage for the benefit of the community. In practice, preservation is divided into several approaches: preservation, restoration, reconstruction, revitalization, and protection.

## 2.5. Digital Heritage

Digital heritage is an approach that utilizes digital technology to document, conserve, and present cultural heritage. The methods used are diverse, ranging from digitizing physical objects and 3D modeling to interactive technologies. According to Chen et al. (2023) and Siliutina et al. (2024), these methods include digital documentation and digital modeling, each of which plays a crucial role in the preservation of cultural heritage.

Table 1. Types of Digital Heritage Methods and Their Explanations

| <b>Digital Documentation</b>                            |  |   |
|---|--|---|
| High-resolution Imaging                                 |  | The use of high-resolution cameras or image recording devices to document cultural heritage objects with a high level of detail.  |
| 3D Scanning   | Laser Scanning/LiDAR (Light Detection and Ranging) | Scanning objects using laser technology.  |
| Remote Sensing  | Photogrammetry                                     | Aerial scanning of objects/aerial photography. A remote scanning technique used to record, analyze, and represent objects or landscapes at various scales without direct contact. |
| <b>Digital Modeling</b>                                 |  |   |
| Building Information Modeling (BIM)                     |  | Modeling building objects with high accuracy and storing important information.   |
| Artificial Intelligence (AI) and Machine Learning Based |  | Used to analyze damage patterns and predict parts of buildings that require further intervention.   |

Source: Chen et al. (2023) and Siliutina et al. (2024)

In digital documentation, methods such as high-resolution imaging are used to record objects with a high level of detail. 3D scanning technologies include laser scanning/LiDAR (Light Detection and Ranging) and photogrammetry, while remote sensing allows for remote scanning of objects or landscapes without direct contact. For digital modeling, Building Information Modeling (BIM) is used to represent buildings with high accuracy, while Artificial Intelligence (AI) and machine learning can help analyze damage patterns and predict the need for conservation interventions.

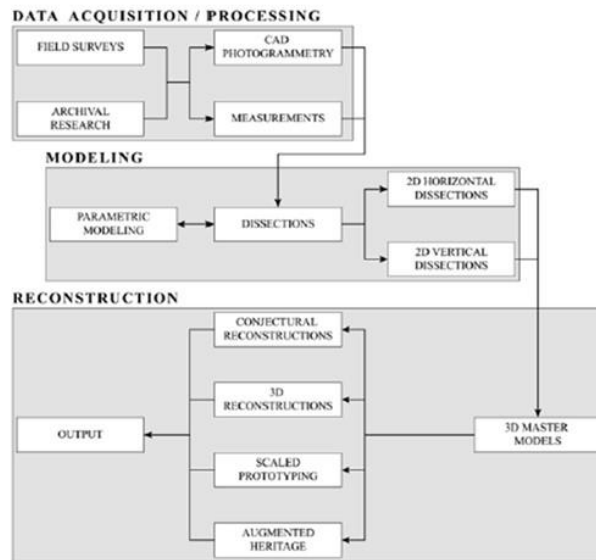


Figure 2: Data Acquisition/Processing, Modeling, and Reconstruction Flow in Digital Heritage  
Source: Datta & Beynon (2014)

## 2.6. Computational/Parametric Design in Digital Heritage

Computational design and parametric modeling approaches, such as those implemented through the Grasshopper plugin in Rhino 3D, offer significant potential in the preservation and restoration of cultural heritage buildings. By visually constructing geometric logic and linking design elements to specific parameters, shape changes can be automated and efficient. Unlike conventional modeling, parametric approaches allow building elements such as columns and beams to automatically adapt to parameter changes, supporting design efficiency, alternative exploration, and structural simulation. In the context of cultural heritage, this method enables the creation of accurate and flexible digital copies of historic buildings for documentation, analysis, and restoration planning (Datta & Beynon, 2014).

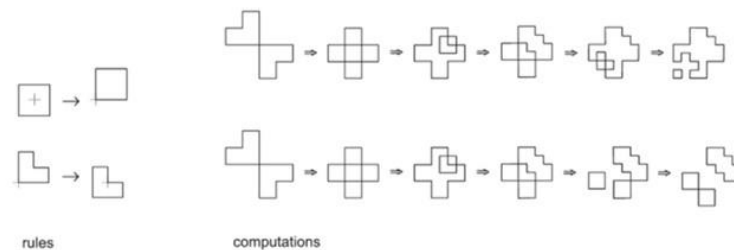


Figure 3: Diagram Rules for Form Creation in Computational Design  
Source: Knight & Stiny (2015)

## 2.7. Sequence Diagrams in Computational/Parametric Design

A sequence diagram is a visual representation that shows the logical sequence in the process of creating a geometry or design system based on specific parameters. This diagram illustrates the flow of information from inputs such as size and shape data, which is then processed step by step to produce the final design output. In parametric modeling using Grasshopper in Rhino 3D, a sequence diagram helps visualize process stages such as grid creation, column placement, beam installation, and roof formation. Each design element is dynamically connected through predetermined parameters.

This diagram also reflects the construction process chronologically using a coordinate system, starting from the origin (0,0) and progressing according to a logical spatial sequence. Typically, this process begins with the creation of a point matrix or grid as a reference for the position of main structures, such as columns, where the distance between points is

determined based on the building's dimensions. Sequence diagram visualizations can be presented in the form of plans, elevations, or sections to aid structural analysis and restoration planning (Yoas, 2023).

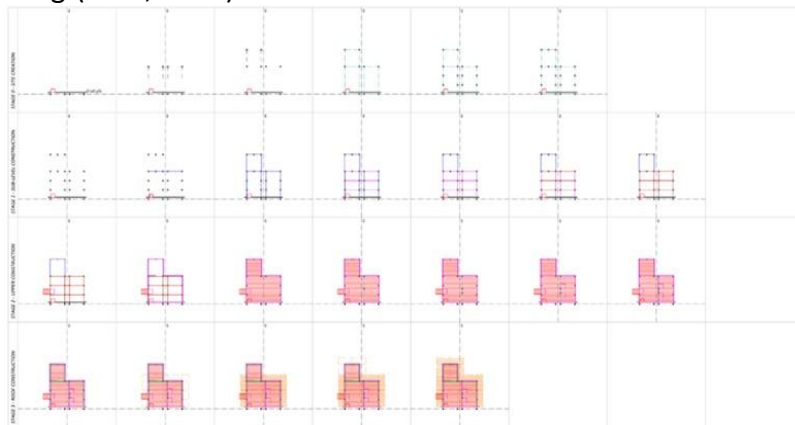


Figure 4: Example of a Sequence Diagram of a Traditional Batak House Construction  
Source: Yoas (2023)

### 3. RESEARCH METHODOLOGY

#### 3.1. Research Type

This research is a qualitative study with a descriptive approach. Descriptive qualitative research was chosen because it is appropriate for explaining, describing, and analyzing phenomena related to the study object in depth. In this context, the research focuses on exploring the historical and architectural value of the Karangsuwung Sugar Factory and documenting the physical condition of the factory building using digital methods created in simple geometric shapes consisting of points and lines using a parametric approach. The descriptive approach is used to describe the actual condition of the building and the factory's surrounding environment, including architectural elements and existing physical conditions.



Figure 5: Location of the Study Object  
Source: Personal Document (2025)

#### 3.2. Research Location and Time

The research was conducted at the Karangsuwung Sugar Factory in Cirebon Regency. The study lasted for three months, from March to May 2025. Research activities included literature review, historical data collection, field observations, interviews with key informants, and building documentation.

#### 3.3. Data Collection Techniques

1. **Literature Study:** A literature study was conducted to obtain a theoretical basis and initial information regarding the history of the Karangsuwung Sugar Factory, the concept of

cultural heritage, and the use of digital technology in the preservation of historic buildings.

2. **Field Observation:** Field observation was the primary method for understanding the actual condition of the Karangsuwung Sugar Factory. During this process, researchers recorded the physical condition of the building, remaining architectural elements, the building's structural system, and any remaining industrial machinery on site.
3. **Interviews:** Semi-structured interviews were conducted with informants with in-depth knowledge of the Karangsuwung Sugar Factory.

### 3.4. Data Analysis

Data analysis in this study was conducted using a qualitative approach. Data obtained from literature study, field observations, and interviews aimed to identify the relationship between the history, architecture, technology, and preservation value of the Karangsuwung Sugar Factory. The analysis stage involved several steps:

1. Reviewing the historical development of the Karangsuwung Sugar Factory based on written sources and interviews.
2. Analyzing building elements that contain architectural and industrial technological value.
3. Evaluating the results of digital modeling as a form of technology-based preservation.
4. Validation of the factory's status as a cultural heritage object based on the cultural heritage criteria in UU No. 11 of 2010.

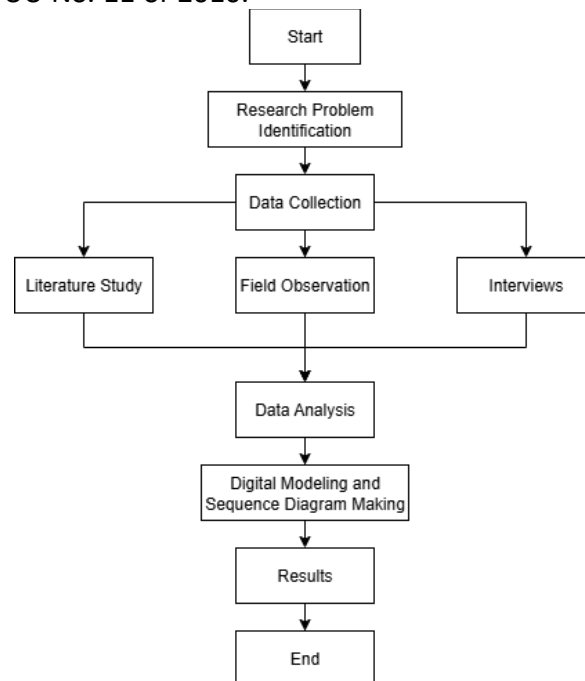


Figure 6: Research Methodology Diagram  
Source: Personal Document (2025)

## 4. RESULTS AND DISCUSSION

The Karangsuwung Sugar Factory initially used traditional production methods before undergoing modernization with steam engines in the late 19th century. This modernization significantly increased production capacity and made the factory a major sugar producer, exporting its products internationally. Supporting facilities, such as a rail network, were also built to expedite the distribution of raw materials, which also encouraged the growth of worker settlements around the factory area. After Indonesian independence, the Karangsuwung Sugar Factory was nationalized in 1958 and became part of the national sugar

industry. However, over time, economic challenges, limited land, and the influx of imported sugar led to a decline in production at many factories, including Karangsuwung, until it finally ceased operations in 2014 (Dharussalam & Assilmi, 2023).

The Karangsuwung Sugar Factory holds significant historical value as it was part of the colonial industrial network that served as the backbone of the Dutch East Indies economy through commodity exports. The factory also reflects the socio-economic dynamics of the local community, where many residents depend on it for their livelihood as plantation laborers or factory workers. This industrial heritage is not only important economically, but also as a testament to technological developments and changes in social structures. The remaining buildings, historical archives, and the community's collective memory are tangible evidence of its enduring historical value. The factory represents the influence of the global economy on local industry, as well as the colonial legacy that continues to shape Indonesia's social and economic landscape today.

#### 4.1. Architectural Value of the Karangsuwung Sugar Factory

The Karangsuwung Sugar Factory was first architecturally studied through 1901 photographic documentation from the Amsterdam World Museum (see figure 7). The original facade exhibited a transitional colonial style with a symmetrical composition, consisting of a large central main door, six symmetrical windows, and circular vents above each window. The tall, brick chimney reflected its important function as an exhaust gas duct during the era of fossil fuels such as coal. This style reflects transitional architecture, as described by Handinoto (2012), characterized by a symmetrical facade and the absence of classical ornamentation.

In 1927, the building underwent an expansion. The number of windows on the facade increased to eight, and the number of columns to ten, as the building was widened to accommodate the installation of new machinery. This modernization coincided with the development of increasingly efficient sugar industry technology. Since these changes, the factory's main elements remained relatively stable until its closure. From 2006 to 2014, documentation from Albert Gieseler shows the factory in operational condition with a white and light green exterior. Following the post-1958 nationalization, new elements emerged, such as Arabic script on the windows and a change in the text on the arch from "S.F. Karangsoewoeng" to "Anno 1896" (see figure 7). However, after its closure in 2014, the factory underwent physical degradation. Many parts of the building were decaying, paint was peeling, and wild vegetation grew unchecked. In the post-closure period (2015–present), the factory was in a state of neglect. Although the main structure appears sturdy, the interior shows signs of damage and decay. Structural analysis shows that the building uses red brick with 40 cm thick walls and 70 cm columns. The main roof columns use H-shaped steel supporting a lightweight steel roof frame. Original machinery from the 19th century is still stored inside the factory, testifying to its authenticity and historical value.

Table 2. Architectural Comparison of the Karangsuwung Sugar Factory Each Decade Period

| Aspects             | Period 1901   | Period 1927  | Period 2006-2014   | Periode 2015-present  |
|---------------------|---|--|--|---|
| Architectural Style | Transitional Colonial Style   |  | Some buildings are in disrepair or undergoing renovation. Modernization is possible. |   |
| Facade              | Symmetrical, with 6 large windows, and a large main door with an arch inscribed with "S.F. Karangsoewoeng." | The number of windows increased to 8, resulting in changes and | The color combination was white and light green, then changed to white and red. The  | The color has faded, the paint has peeled, and the red brick has been exposed due to degradation. |

| Aspects            | Period 1901  | Period 1927                                     | Period 2006-2014                          | Periode 2015-present  |
|--------------------|--|---|---|---|
| Windows            | Circular holes above the windows provide air circulation.  | Additional ventilation holes have been removed. | Iron bars have been added to the windows. | Many vents are damaged, some blocked by weeds.  |
| Building Structure | 40 cm thick red brick, 70 cm brick columns, and a lightweight steel roof structure. Reinforced with additional H-shaped steel columns supporting the roof structure.   |   |   | The main structure still stands, but has experienced weathering and some sections have collapsed. |
| Roof Construction  | A steel truss frame with zinc covering. Some sections have been replaced due to age.   |   |   | Several sections of the roof have holes, but the steel frame remains intact.                      |
| Chimney            | The chimney has remained standing strong since its inception. This chimney is a distinctive element of the colonial-era sugar factory, becoming a distinctive feature. |   |   |   |

The Karangsuwung Sugar Factory holds high architectural value as an example of industrial colonial architecture in Indonesia. Its original design reflects a functional transitional colonial aesthetic, with a symmetrical composition and natural ventilation structures. These elements support the factory's role not only as industrial infrastructure but also as a cultural heritage reflecting Indonesia's historical, technological, and socioeconomic development.



Figure 7: Comparison of the Karangsuwung Sugar Factory Facade from Year to Year  
 Source: Personal Document (2025)

#### 4.2. Socio-Cultural Values of the Karangsuwung Sugar Factory

Since its inception, the Karangsuwung Sugar Factory has been a center of economic activity that has helped shape the social structure of the local community. The factory employs residents, both as direct laborers and as sugarcane farmers who supply raw materials. The close relationship between the community and the factory has created communities with lifestyles that revolve around the sugar production cycle. One unique tradition born from this relationship is the "*Kawin Tebu*" (Sugarcane Marriage), a symbolic ritual marking the start of the milling season. In this tradition, a pair of sugarcane stalks, symbolizing the bride and groom, are decorated and paraded from the plantation to the factory as a form of thanksgiving. This tradition enriches local culture with spiritual values and community togetherness.



Figure 8: Sugarcane Farmers Hold a "*Kawin Tebu*" Ritual in 2023

Source: [www.kompas.com](http://www.kompas.com)

The Karangsuwung Sugar Factory holds significant socio-cultural value as part of Cirebon's industrial history and the lives of the people. Socially, the factory has formed a worker community and created a unique social system, involving various groups, from local workers to foreign workers during the colonial era. Culturally, the factory's existence has helped preserve local traditions, such as the *Kawin Tebu* ritual, which reflects spiritual values and local wisdom. This tradition demonstrates that the sugar industry plays a role not only in the economic aspect but also in shaping and preserving the cultural identity of the surrounding community.

#### 4.3. Scientific Value of the Karangsuwung Sugar Factory

Sugar processing in the Indonesian archipelago has been practiced since the time of the Ancient Mataram Kingdom, with the Javanese people already familiar with fermentation and crystallization techniques to produce brown sugar. This local knowledge formed the initial foundation of an agro-industrial system that was later adopted and developed by the Dutch colonialists, particularly during the cultivation system (*Cultuurstelsel*). The arrival of the Dutch colonialists had a significant impact on the sugar industrialization of Java (Knight, 2014). The Karangsuwung Sugar Factory represents the integration of European technologies such as steam engines, vacuum devices, and crystallization systems with local agricultural practices. After independence, the nationalization of the factory gave it a new role as a technical training center and knowledge transfer center for Indonesian workers, making it a center for informal industrial engineering learning. The Karangsuwung Sugar Factory is a concrete example of 19th-century technological heritage that can still be physically observed, particularly in the production machinery left behind by the Dutch. These artifacts serve as valuable sources for studies of the history of technology, industrial archaeology, and mechanical engineering within the colonial context, as well as their interaction with local agricultural systems.

#### 4.4. Assessment of the Criteria for the Karangsuwung Sugar Factory as a Cultural Heritage

The Karangsuwung Sugar Factory is a colonial industrial heritage with significant historical value, testifying to the economic and technological developments of the Dutch colonial era. Its 129-year-old history demonstrates its strong historical significance and reflects the influence of the Industrial Revolution on the development of sugar technology in Indonesia. Furthermore, the factory illustrates the changes in the local social structure brought about by industrialization.

Architecturally, the Karangsuwung Sugar Factory represents the colonial architectural style, with distinctive features such as a symmetrical facade, thick brick walls, a roof with steel trusses, and a chimney, a symbol of industrial factories during the Dutch East Indies era. The uniqueness and rarity of this factory's design, particularly the preservation of most of its original architectural elements, make it one of the rare surviving examples of a colonial sugar factory in West Java. The factory's cultural value is also significant, having played a role in the formation of a local worker community and given rise to traditions such as "*Kawin Tebu*", which have become part of the local cultural heritage. Scientifically, the factory serves as a significant example of the development of industrial technology in Indonesia, particularly the transition from human labor to the use of industrial machinery.

Based on the criteria in UU No. 11 of 2010, especially on Chapter VI, Articles 42 and 44 on the National Register of Cultural Heritage, Karangsuwung Sugar Factory is worthy of being designated as a cultural heritage site, both at the national and provincial levels. The factory has extensive conservation significance, representing a sugar industry that plays a significant role in the economy of West Java and Indonesia. The factory's rarity and physical integrity further strengthen the conservation case, making it a valuable asset that illustrates the development of civilization and industrial technology in the past.

Table 3. Analysis of Each Cultural Heritage Value at the Karangsuwung Sugar Factory

| Value Aspect         | Analysis   |
|----------------------|--|
| Historical Value     | It bears witness to the historical development of the sugar industry during the Dutch colonial era, related to the Cultuurstelsel system and global sugar exports.   |
| Architectural Value  | It features a colonial architectural style with elements such as high gabled roofs, distinctive ornaments, and symmetrical facades.  |
| Socio-Cultural Value | It was involved in the formation of a local worker community and gave birth to traditions such as " <i>Kawin Tebu</i> ," which are still known in the local culture.                                       |
| Scientific Value     | This factory is an important piece of evidence in the history of industrial technology development in Indonesia. Its existence marked the transition from a human-powered industry to a machine-based one. |

#### 4.5. Digital Modeling and Sequence Diagrams

The digital modeling of the Karangsuwung Sugar Factory was performed using Rhino 3D software combined with the Grasshopper plugin. This approach allows for the parameterization of building elements, resulting in a flexible representation of the Karangsuwung Sugar Factory building model.

##### Karangsuwung Sugar Factory Construction Sequence Diagram

###### Main Building

The first section describes the modeling sequence diagram for the Karangsuwung Sugar Factory building. The building section selected for this modeling is the sugarcane milling building located at the front of the factory complex. This section of the factory has been designated a cultural heritage building by the Cirebon Regency Culture and Tourism Office,

making it crucial to document it through digital modeling. This section of the building was also chosen because it best represents the facade, proportions, and architectural elements of the entire Karangsuwung Sugar Factory building.

1. **Sequence 1:** Describes the creation of a rectangle as a reference for the area of the Karangsuwung Sugar Factory building.
2. **Sequence 2:** Explains the placement of the axis points of the brick columns on the horizontal sections of the Karangsuwung Sugar Factory building.
3. **Sequence 3:** Explains the placement of the brick column pivot points on the vertical section of the Karangsuwung Sugar Factory building.
4. **Sequence 4:** Explains the process of duplicating the brick column pivot points, which are moved to the Y-axis as the pivot points for the steel columns.
5. **Sequence 5:** Explains the removal of the pivot points for the brick and steel columns, which could cause the two columns to collide, necessitating the removal of one of the pivot points.
6. **Sequence 6:** Explains the process of duplicating the steel column pivot points, which are moved to the Y-axis according to the width of the Karangsuwung Sugar Factory building.
7. **Sequence 7:** Explains the process of thickening the walls of the Karangsuwung Sugar Factory building, referring to the geometry in Sequence 1.
8. **Sequence 8:** Explains the process of creating the height of the brick columns in the Karangsuwung Sugar Factory building.
9. **Sequence 9:** Explains the process of creating the height of the steel columns in the Karangsuwung Sugar Factory building.
10. **Sequence 10:** Describes the process of creating the wall height of the Karangsuwung Sugar Factory building using Extrude along the Z-axis.
11. **Sequence 11:** Describes the process of creating the beams of the Karangsuwung Sugar Factory building, similar to Sequence 9.
12. **Sequence 12:** Describes the creation of the roof of the Karangsuwung Sugar Factory building.
13. **Sequence 13:** Similar to Sequence 16, but with several changes, such as the overlapping roof dimensions from the Sequence 9 geometry, which are then raised along the Z-axis.
14. **Sequence 14:** Describes the creation of the steel roof frame of the Karangsuwung Sugar Factory building.
15. **Sequence 15:** Describes the process of duplicating the steel roof frame of the Karangsuwung Sugar Factory building.
16. **Sequence 16:** Describes the creation of the purlin frame by dividing the sloping roof plane into several horizontal lines.
17. **Sequence 17:** Describes the creation of window placement points obtained from Sequence 2.
18. **Sequence 18:** Describes the removal of points that would collide with brick columns. In this case, the free points are even-numbered columns (2, 4, 6, etc.).
19. **Sequence 19:** Explains the deletion of door placement points, both for entrance doors and lorry doors.

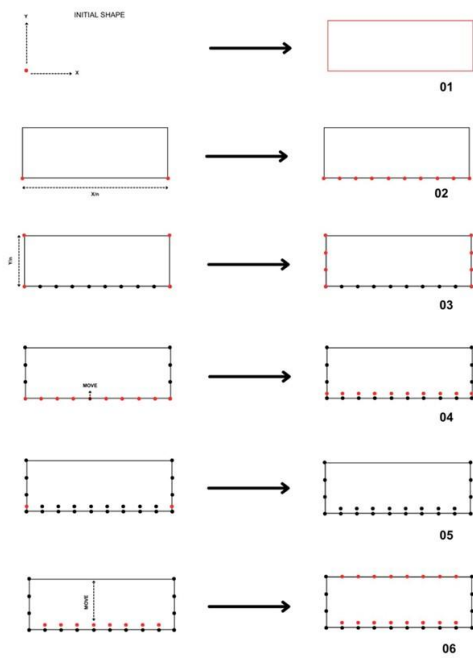


Figure 9: Sequence 1 to 6 Explaining the Process of Forming a Square Plan and Placing Brick and Steel Column Points  
Source: Personal Documentation (2025)

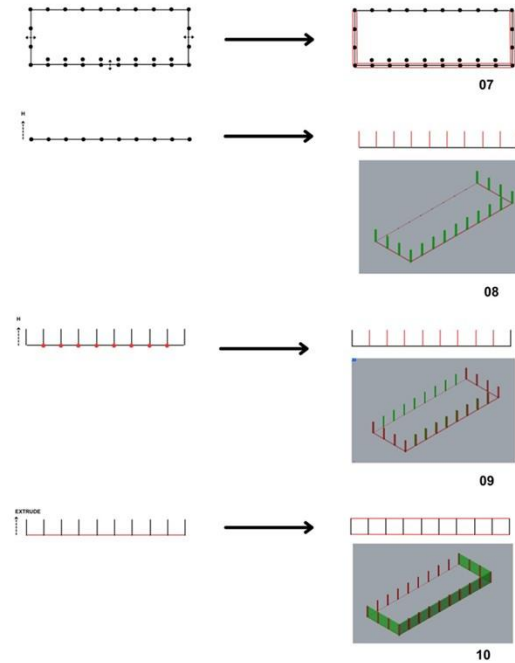


Figure 10: Sequence 7 to 10 Explaining Wall Formation Process, and Height of Brick and Steel Columns  
Source: Personal Documentation (2025)

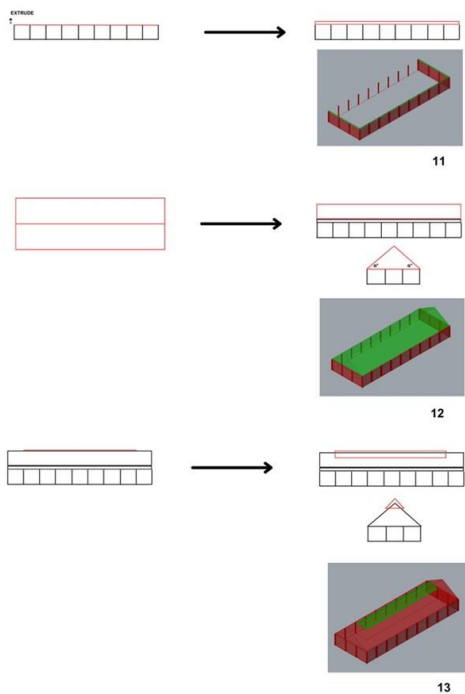


Figure 11: Sequence 11 to 13 Explaining the Process of Forming Beams and Roofs  
Source: Personal Documentation (2025)

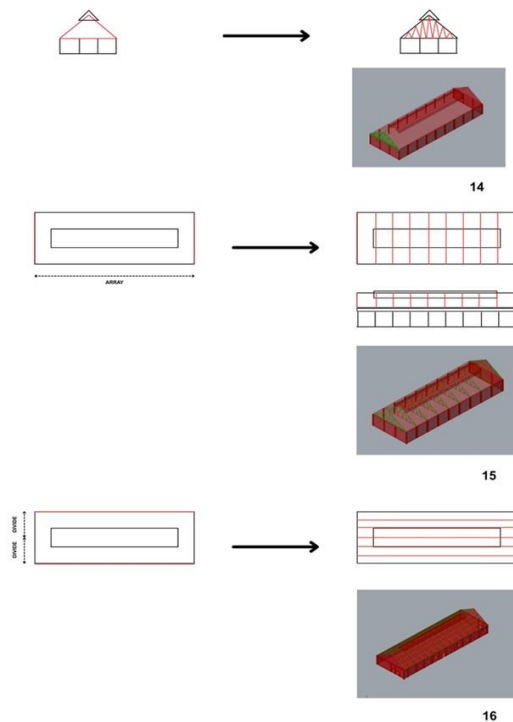


Figure 12: Sequence 14 to 15 Explaining the Roof Truss Formation Process  
Source: Personal Documentation (2025)

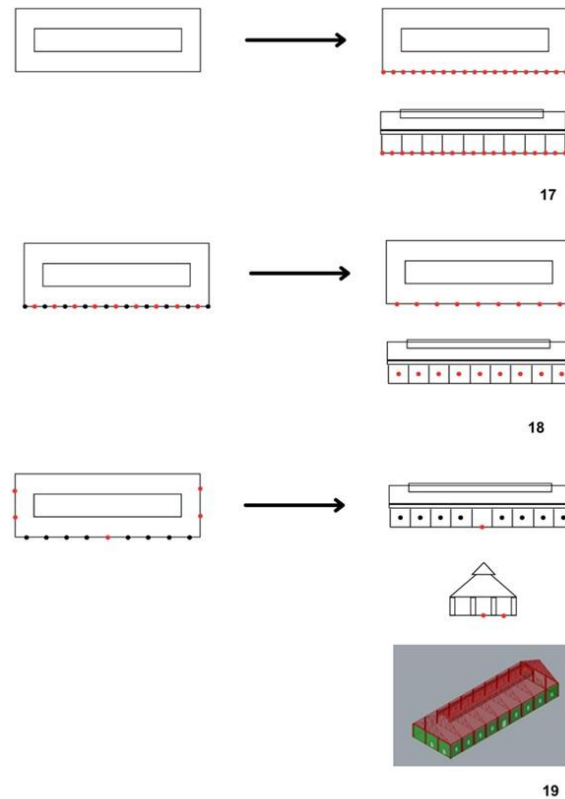


Figure 13: Sequence 16 to 18 Explaining the Process of Forming Window and Door Openings  
Source: Personal Documentation (2025)

### Chimney

The next section is the chimney, an interesting feature of the Karangsuwung Sugar Factory building complex. This chimney is an important feature in the sugar factory industry, as it serves as a place to exhaust smoke from the combustion process.

1. **Sequence 1:** Describes the creation of a rectangle as the base of the chimney.
2. **Sequence 2:** Describes the creation of the chimney's base height.
3. **Sequence 3:** Describes the creation of a circle as a reference for creating the chimney pillars for the lower section.
4. **Sequence 4:** Describes the creation of a circle for the top of the chimney to create the roof pillar shape.
5. **Sequence 5:** Describes the lofting of the two circles.
6. **Sequence 6:** Describes the creation of a new circle for the top of the chimney.
7. **Sequence 7:** Describes the creation of the next circle above it.
8. **Sequence 8:** Describes the lofting of the two circles and their combination with the results of the previous lofting.

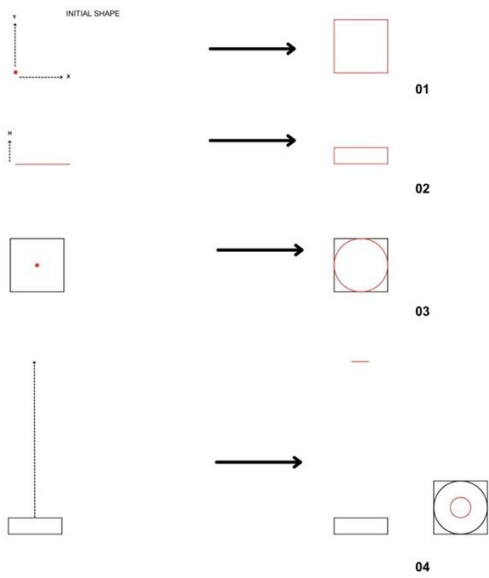


Figure 14: Sequence 1 to 4 Explaining the Process of Forming the Base and Columns of the Chimney  
Source: Personal Documentation (2025)

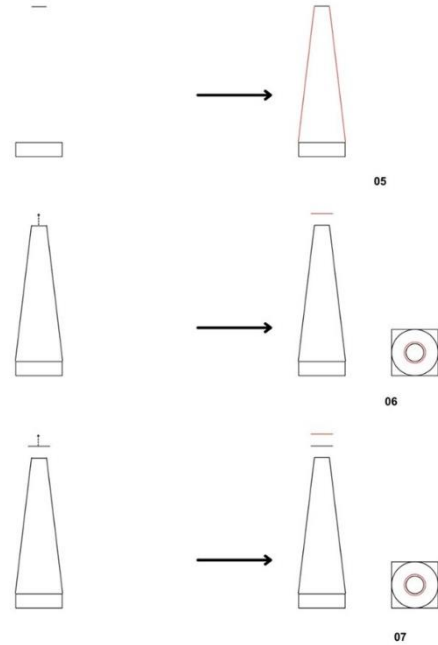


Figure 15: Sequence 5 to 7 Explaining the Chimney Pillar Formation Process  
Source: Personal Documentation (2025)

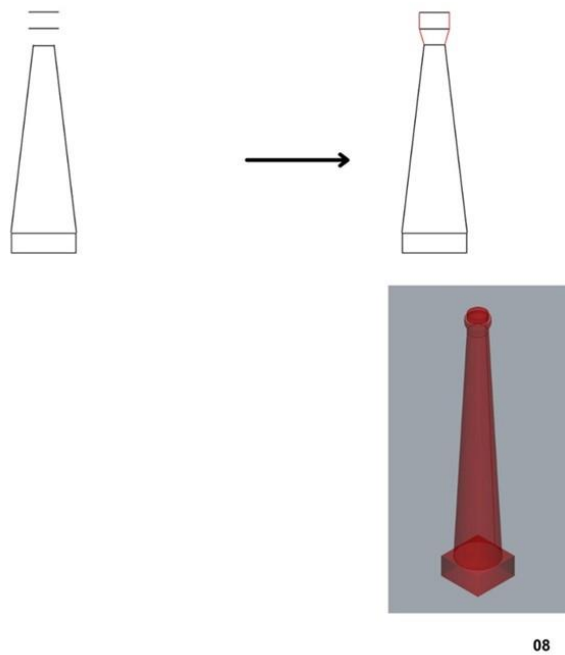


Figure 16: Sequence 8 Explaining the Chimney Formation Process  
Source: Own Document (2025)

## Parameterization of Karangsuwung Sugar Factory Building Elements

1. **Main Plan (Rectangular Plan):** Using the Rectangle component, adjusted with the Number Slider for the X and Y dimensions, then split using Explode Object to define the reference line for the column points.



Figure 17: Formation of Rectangular Plan in Grasshopper  
Source: Personal Document (2025)

### 2. Columns:

**Brick Columns:** Column points are obtained from the Divide Curve on three sides of the reference line, then formed using the Center Box (square dimensions and height multiplied by two). The column position is moved up the Z-axis using Move.

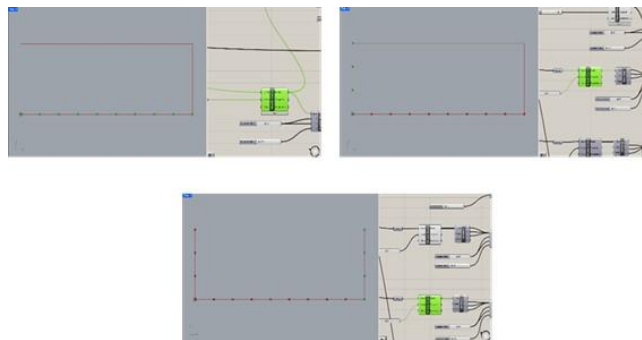


Figure 18: Placing Brick Column Points in Grasshopper  
Source: Personal Document (2025)

**Steel Columns:** The starting point of the X-axis line is modified by moving in the Y direction, and the end point is removed using the Cull Index. Next, the point is duplicated linearly with the Linear Array. The H-shaped steel profile is extruded down the Z-axis.

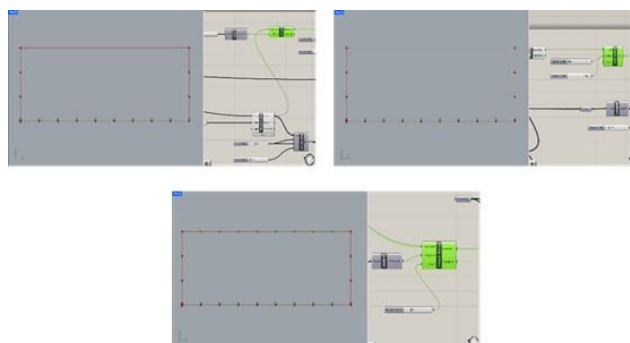


Figure 19: Placing Steel Column Points in Grasshopper  
Source: Personal Document (2025)

3. **Walls:** Using an Offset Curve on the plan line to create the wall thickness on both sides, then extruding it upward to create the height.

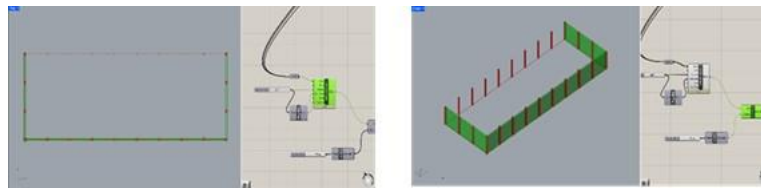


Figure 20: Formation of Walls in Grasshopper  
Source: Personal Document (2025)

4. **Beams:** Formed from the Offset Curve line, moved upward (Move Z), and then extruded.

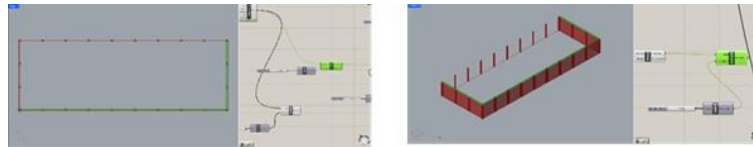


Figure 21: Formation of vBeams in Grasshopper  
Source: Personal Document (2025)

5. **Roofs:** Using the Hibble Roof plugin with inputs of the roof type (Boolean), plan dimensions, and slope angle. The second layer of the roof is created with a smaller size and a higher position.

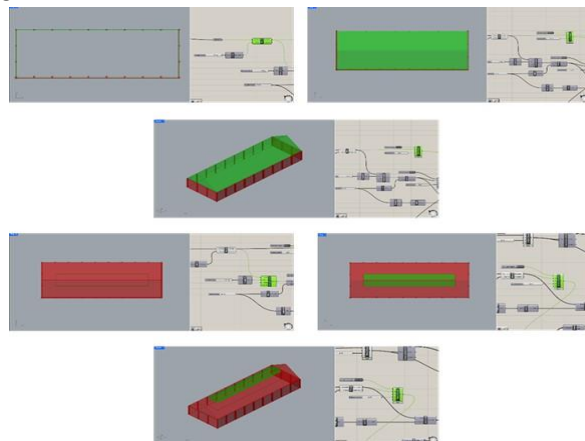


Figure 22: Formation of Roof in Grasshopper  
Source: Personal Document (2025)

6. **Roof Truss:** Using Deconstruct Brep to obtain the slanted lines and Project for the horizontal lines. Then, a 2D Truss from the Lunchbox plugin is used to create the truss, which is duplicated with Linear Array.

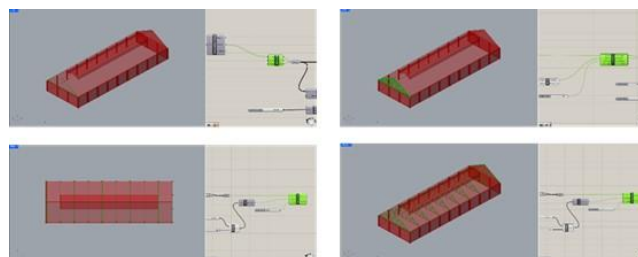


Figure 23: Formation of Roof Truss in Grasshopper  
Source: Personal Document (2025)

7. **Windows:** Using Center Box for the rectangle and Cylinder (with Rotate) for the arch. The window points are derived from Divide Curve, filtered with Dispatch and Cull Index to avoid collisions with columns. The window position is raised to the Z-axis.

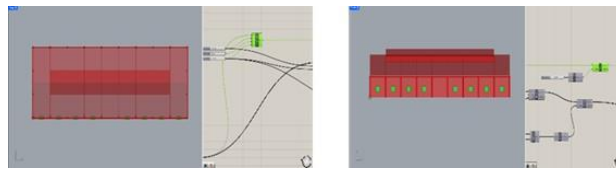


Figure 24: Formation of Window Openings in Grasshopper  
Source: Personal Document (2025)

8. **Doors:** Similar to windows, using Rectangle and Cylinder to create an arch-shaped opening. The points are derived from the Cull Index results.

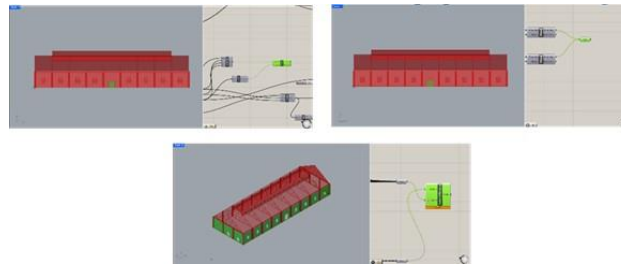


Figure 25: Formation of Door Opening in Grasshopper  
Source: Personal Document (2025)

9. **Chimney:** Using several components, such as Rectangle to create the square base of the chimney and Circle, then using Loft to create the pillars.

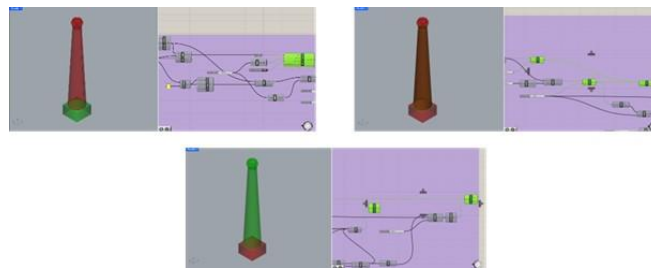


Figure 26: Formation of Chimney in Grasshopper  
Source: Personal Document (2025)

## 5. CONCLUSION AND RECOMMENDATION

### 5.1. Conclusion

The Karangsuwung Sugar Factory holds significant historical, architectural, socio-cultural, and scientific significance. As a witness to the development of the sugar industry from the colonial period to post-independence, the factory played a significant role in the local socio-economic dynamics. Its architecture reflects a transitional colonial style, while socio-cultural values are reflected in the worker community and traditions such as the Kawin Tebu ritual. Scientifically, the factory represents a legacy of 19th-century industrial technology worthy of cultural heritage status under UU No. 11 of 2010.

For conservation, parametric digital modeling with Rhino 3D and Grasshopper was utilized, beginning with sequence diagram analysis to understand the proportions and character of the facade. This approach allows for flexible and accurate design changes based on field data. Its advantages include efficiency, accuracy, and exploration of historical design.

### 5.2. Recommendation

This approach produces a model that not only represents the building's basic geometry but also allows flexibility in design exploration and structural-functional analysis especially for related buildings. To improve accuracy, several recommendations are suggested:

1. **Data Accuracy:** Further study of historical archives, old drawings, and expert interviews.
2. **Scanning Technology:** Use of LiDAR or photogrammetry if possible.
3. **Comparative Study:** Validation through analysis of similar sugar factories from the same period.
4. **Adaptive Reuse:** Exploring future uses, such as a museum or heritage-based education center.

With a more comprehensive approach, the model serves not only as a digital archive but also as a tool for conservation, restoration, and development of Karangsuwung Sugar Factory as a significant historic building.

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