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Process Model and its Use in Architecture: An Assessment on the Documentation of Stone Building Elements Production Processes

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Abstract – This research formulates guidelines for documenting stone building element production in contemporary crafting technologies, focusing on semi-automatic processes. Conducting a comprehensive examination of prevalent architecture process models, such as Business Process Modelling Notation (BPMN), Design Structure Matrix (DSM) and Integration Definition for Function Modelling (IDEF), the study employs a semi-systematic literature review to assess their properties. Emphasising input-output dynamics and production-product interdependencies, the research identifies a primary objective in these models: operational management for enhanced efficiency in client interactions and production phases. Applied to stone architectural heritage in Mardin, the process model guideline advocates effective stonework integration within broader architectural contexts. The proposed guidelines provide practical implications for stakeholders, emphasising efficiency improvements in client interactions and production phases. This study contributes original insights by applying process models to stone architectural heritage, highlighting semi-automatic processes and enhancing stonework integration within architectural frameworks. The research extends the applicability of process models, contributing to technological advancements, innovation and automation in architecture, construction and engineering.

Keywords –Process modelling, architectural heritage, digital craft documentation, stonework, architectural technology

I. Introduction

Various definitions and approaches exist regarding the concept of a process. It is defined in dictionary as "a continuous and regular action or succession of actions occurring or performed in a definite manner" [1]. The foundational concepts of action and succession of actions, as per the dictionary meaning, constitute the core of the process definition. While the definition of a process may vary concerning its related sector, these concepts are generally integral to the process definition.

When viewed as a process model, the definition's scope expands to encompass input-output and production-product dimensions. By integrating these concepts, the process is defined as the amalgamation of human, equipment, material, method and environmental variables. These elements contribute to the creation of the final product, be it a product or service [2]. The process model not only aids in managing ongoing operations but also serves as documentation for the process. This study analyses process models utilised in semi-systematic literature reviews, specifically examining those applied in the architectural field. Upon analysing process models used in architecture, construction and industry, various models with distinct notation and flow systems were identified in the literature. Models such as Business Process Modelling Notation (BPMN), Design Structure Matrix (DSM) and Integration Definition for Function Modelling (IDEF0) were obtained within the scope of this study.

This study aims to discuss the concept and notation of the process model in relation to stonemasonry to develop a methodology. Stonemasonry practiced in the city of Mardin, situated in south-eastern Turkey, possesses historical significance. Stone carving, a facet of architectural production, contributes both to creating building elements and embellishments. Consequently, the objective is to establish a model encompassing all elements pertinent to the events involved in the stone processing process. Information obtained from literature reviews and interviews with stonemasons was translated into a BPMN process model. The methodology developed within this study is envisioned to contribute to technological advancements and innovations in the architecture and construction domain, while also documenting the production of stone building elements concerning the process.

Aligned with this study, the relationship between architecture and process models will first be outlined. Subsequently, emphasis will be placed on Mardin's stone architecture and the stone processing techniques that facilitate it. Following this, the methodology formulated based on the gathered data will be elucidated. The methodology will be evaluated under the section titled "Findings and Discussion."

II. Process Model and Architecture

The concept of a process encompasses various parameters. A process can be defined as the amalgamation of human, equipment, material, method and environmental variables, which collectively contribute to the creation of the final outcome, be it a product or a service. Inputs and outputs represent the events, while the sequence of actions constitutes the process. Events, along with the elements realising these events, such as human, equipment and material, form the

inputs of the process. The tools or methods enabling event realisation act as factors facilitating the conversion of inputs into outputs [2]. The concept of a process expands upon the inclusion of the customer factor within the process definition.

Process models serve as tools for expressing processes by creating a notation that encompasses all contributing factors. With their graphical representations, these models aid in both managing and documenting processes. To create a notation for a process, it is essential to first determine the limitations. A process model can then be developed in line with the identified factors. Additionally, predefined process models with different representation types can also be utilised. In this study, process models used in the architecture field are analysed.

One such model is the Design Structure Matrix (DSM), extensively employed in architecture and construction. Literature reviews indicate its use in creating process models for Building Information Modelling (BIM)-based construction projects [3]. DSM, with its representation type, facilitates the holistic analysis of processes. Unlike a linear flow, it employs a matrix system illustrating cross-relationships. Actions or operations are presented as linearly matched in columns and rows, with an "X" marking indicating their relational status [4]. This matrix format allows the observation of relationships among all actions.

The DSM illustrates the actions involved in the architectural project life cycle along with the data relationships among these actions. Actions facilitate data flow by matching above and below the diagonal of the matrix (Figure 1) [5]. Furthermore, it aids in delineating the roles and responsibilities of stakeholders involved and offers insights into project scalability. Thus, regardless of a project's complexity, the entire process can be evaluated through a matrix [3].

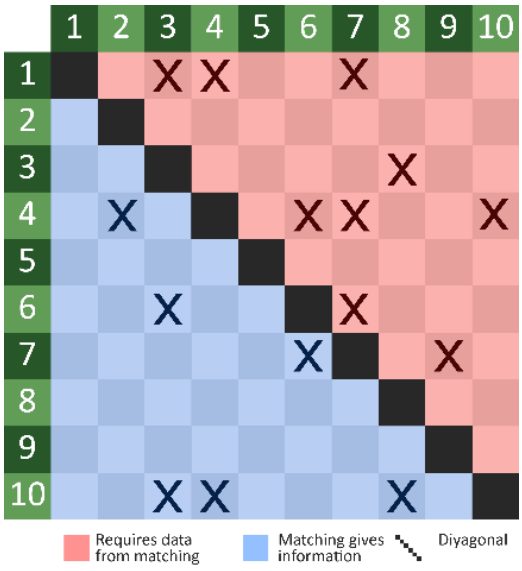

Figure 1 – Data flow within DSM. Illustration by © 2023 Çuha.

Another process model utilised in architecture is Integration Definition for Function Modelling (IDEF0). IDEF0 is a technique employing graphical representations and texts to express interconnected events [6]. It comprises two main components: rectangles and arrows. Input arrows are on the left, output arrows on the right, while top arrows indicate constraining factors. Arrows from below incorporate mechanisms contributing to event occurrence. Events are linearly connected from left to right and top to bottom throughout the model's hierarchy [7].

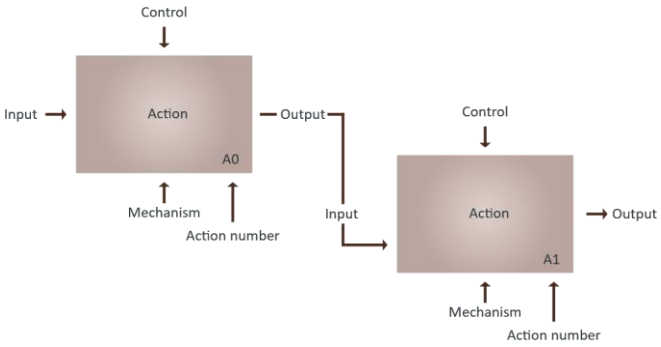

Figure 2 – Hierarchical process flow using IDEF0. Adapted from [7] and redrawn by Çuha.

IDEF0 has been regarded as a suitable model for architectural processes due to its functional capabilities in process management and documentation. It has found utility in modelling architectural project planning, production analysis, creating traditional production models and enabling innovation through technology integration [8], [9]. It has been observed as a preferred model, particularly for detailed production process modelling.

Lastly, Business Process Modelling Notation (BPMN) is examined. BPMN is a graphical representation designed for an easily understandable and user-friendly process model [10]. Its primary objective is to offer a common notation for modelling processes, catering to diverse user types. It has been noted to appeal to technicians, analysts, business professionals and management stakeholders by providing a visually comprehensible representation [11]. Research conducted in the fields of architecture and civil engineering has revealed its usage in designing and constructing structural elements [12]. Within this study's scope, BPMN was chosen to create a process model for stone processing. The method section will provide comprehensive information about BPMN after reviewing the research on stone processing.

III. The Current State of Stone Masonry and Mardin

Mardin is a city located in the south-eastern part of Turkey. Within its historical district, there are structures built using stone craftsmanship, including churches, mosques, madrasahs, monasteries, civil buildings and structures with various functionalities. The common aspect among structures built by craftsmen from different nationalities in different civilisations is stone craftsmanship. Stone craftsmanship, which has reached the present day like a heritage, is both a method of construction and ornamental technique. In this technique, limestone is used as a building material, encompassing not only structure construction but also sculpture and tombstone production.

The process of stonemasonry follows a hierarchy comprising the quarry, workshop and construction site. Different stonemasons with distinct responsibilities operate within each production area. Additionally, tools predominantly made from wood and metal are utilised for stonemasonry. With factors such as the master, transfer vehicles (mount), laborers, etc., the process model of the traditional production technique emerges. In contemporary times, the traditional production system has undergone transformations. Particularly due to technological

advancements, a semi-automatic system of production has emerged. In this production system, computer-aided machines have replaced tools and in some areas, operators have taken the place of craftsmen.

The knowledge transfer of traditional stonemasonry production relies on the master-apprentice relationship. In today's evolving technology landscape, innovative additions are being introduced into this pool of knowledge, alongside some data losses. Factors such as the scarcity of new masters, low profit margins in quarrying and the integration of automated systems like CNC machining drills into production are primary reasons for the changes in this knowledge repository.

This study aimed to create a process model for stonemasonry based on data obtained from literature and interviews. The process model serves the dual purpose of documenting production techniques and providing a guide for construction technique. The method section will provide details about the stonemasonry process model created using BPMN.

IV. The Methodology Employed in Constructing the Process Model Using BPMN

The BPMN method was preferred in the creation of the process model. BPMN was chosen as the method for creating the process model, primarily due to its comprehensive components. Furthermore, it was believed that this choice would better express the process due to its distinct notation, such as pools and lanes, compared to other process models. Business Process Diagram (BPD) was used to model the process, featuring numerous components classified into five main categories: Flow Objects, Connecting Objects, Swimlanes, Data and Artifacts [13]. In the schematic representation, circles represent events, rounded rectangles depict activities, rhombuses indicate gateways and arrows symbolise flow. In modelling the process, event, activity and gateway components are interconnected through the flow component. Additionally, to depict the relationship between different disciplines within the process model, pool and lane components are utilised. Artifacts are used to provide explanations about the process and group related components [10].

Within the scope of this study, stone quarries and stone workshops were examined. Interviews were conducted with the craftsmen working in these areas. By aligning the obtained data from these sources with the data present in the literature, a process model was created. In the stone masonry process, three distinct operations are involved: extracting the stone from the quarry, transforming the stone into building elements in the workshop and shaping the stone into structures at the construction site. BPMN allows for the representation of these different operations using Swimlanes elements. When creating the model for stone masonry, pool components were preferred for the quarry, workshop and construction site instead of lanes. The reason for choosing pools over lanes is the execution of these processes by different enterprises.

The process model was developed using Microsoft Visio. Following the creation of various pools, BPMN components available in the program's template were used to detail the model. Event components play a role in initiating and terminating the flow. There are three types of event components: Start, Intermediate and End events.

Figure 3 – Event types in BPMN. Illustration by © 2023 Çuha.

Upon the initiation of an event, activity and gateway components are introduced into the process. The relationship between all components is established through connecting objects within the category of connecting object flows. Additionally, group and text annotation artefact components are used to provide additional representations of the process. These components were utilised in detailing the stone masonry process model (Figure 4*Figure 4*).

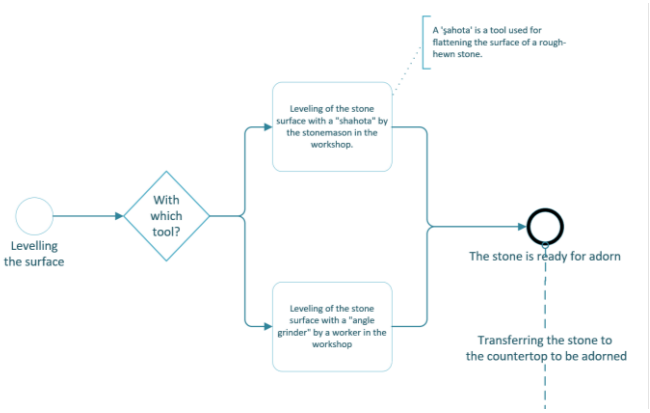

Figure 4 – An exemplary stonemasonry process model created using BPMN. Illustration by © 2023 Çuha.

BPMN encompasses extended modelling components to model complex processes [13]. For instance, in Business to Business (B2B) or Business to Customer (B2C) models, web-based services are required, leading to the utilisation of extended components in process flows to address complexities [14]. In this study, extended components were employed in creating the process model, specifically to illustrate the differences between traditional and semi-automatic production methods (Figure 5).

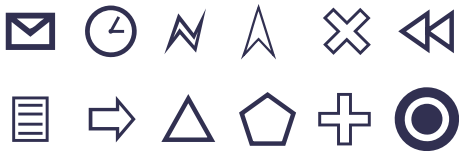

Figure 5 – Expanded components featured in BPMN. Illustration by © 2023 Çuha.

There are several gateway components in BPMN, utilised to manage the convergence and divergence of paths within a process [15]. These gateways allow for creating different scenarios in the flow. In establishing the methodology, several simple gateways and exclusive gateway components were used to illustrate the difference between traditional and semi-automatic production. When the "x" marked gateway component, usually having the same function as the other, was used, it provided the opportunity to choose between traditional and semi-automatic process flows.

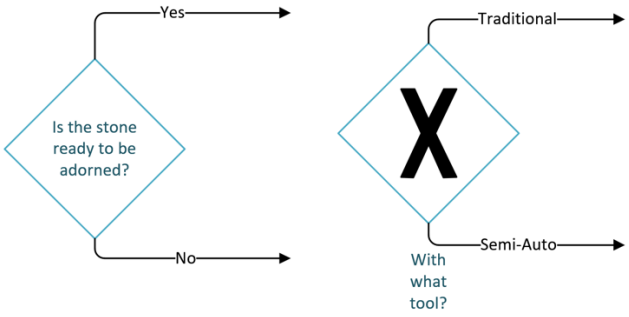

Figure 6 – Transformed gateway component within the scope of the process model. Illustration by © 2023 Çuha.

The Activity, Task and Sub-Process component is used to specify tasks. The iconography placed on the upper-left side of the rounded rectangle indicates its scope. Icons such as manual, user, service, receive, send, script and rule are used to create tasks. For representing Sub-Processes, a "+" sign is placed at the bottom of the rectangle. While BPMN defines them differently, this study used manual (hand sign) tasks to represent traditional activities and service (gear sign) for semi-automatic activities. Tasks were differentiated using solid and empty colours (Figure 7). This facilitated the identification of differences between the two production techniques in the analysis of the process model.

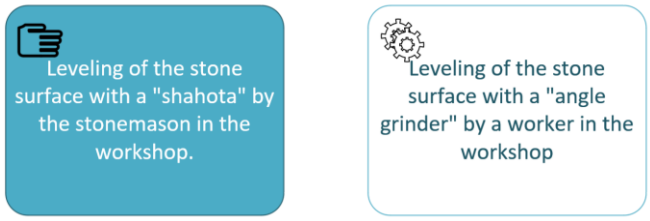

Figure 7 – Representation of traditional and semi-automatic process models. Illustration by © 2023 Çuha.

Dashed line message flow, designed with a dotted line shape, was utilised to depict the connection between different pools in the process model of stone masonry. This facilitated the representation of communication and process transitions between the quarry, workshop and building.

V. Findings and Discussion

Stone masonry is an ancient construction and ornamentation technique. It has been used in the production of buildings in the Mardin region and its surroundings due to the ease of sourcing stone as a building material. Stone masonry was practiced until the late period when reinforced concrete construction methods became prevalent in the region. According to observations, due to changing demands, stone masonry was adapted to create adorned elements in buildings instead of being the primary construction technique. Additionally, in the past, this craft was practiced by Armenian artisans and during the transitional period, by Armenian, Assyrian and Arab artisans. Today, it is observed that stone masonry is continued not due to ethnic diversity but rather due to regional practices. Particularly in the Midyat region, traditional and semi-automatic stone masonry practices in quarries and workshops have been identified. The process model of stone masonry was created to determine the commonalities and divergences between these two methods.

Within the scope of the process, it was understood that stone masonry is carried out in three separate areas: quarry, workshop and building site. BPMN provides a different notation from other process models through its swimlanes elements, allowing the expression of different areas within the process. Moreover, stone masonry has a linear workflow. Considering BPMN's linear flow, this feature was taken into account in choosing the process model. Another advantage of BPMN is that, in addition to its core components, it has many extended components with various definitions. Through these components, relationships within the process were expressed in detail.

It was observed that there were also components absent in BPMN to express elements within the process. Instead of disregarding data within the scope of the process model or creating new models, the extended components were redefined and used. By creating a legend, components whose functionality was altered within the scope of the process model were expressed, providing directives to the model user (reader, analyst, researcher).

Another disadvantage of BPMN was identified in the complexity of the sub-process representation. While aiming for a simple and understandable representation, the model occupies a significant notation area. This necessitates creating sub-processes. In this regard, the hierarchical structure of the IDEF0 is more practical. Furthermore, after the creation of the process model, the relationship between different actions was not fully understood with BPMN. One of the benefits provided by DSM was the ability to provide an overall view of the entire process.

It was determined that the scope of the selected study area has an impact on the changing process models used in architectural and construction fields. Researchers were observed to establish limitations regarding the concept of process and their study areas. In this context, it was observed that their chosen models did not achieve full efficiency and as in this study, there was an effort to create an ideal model.

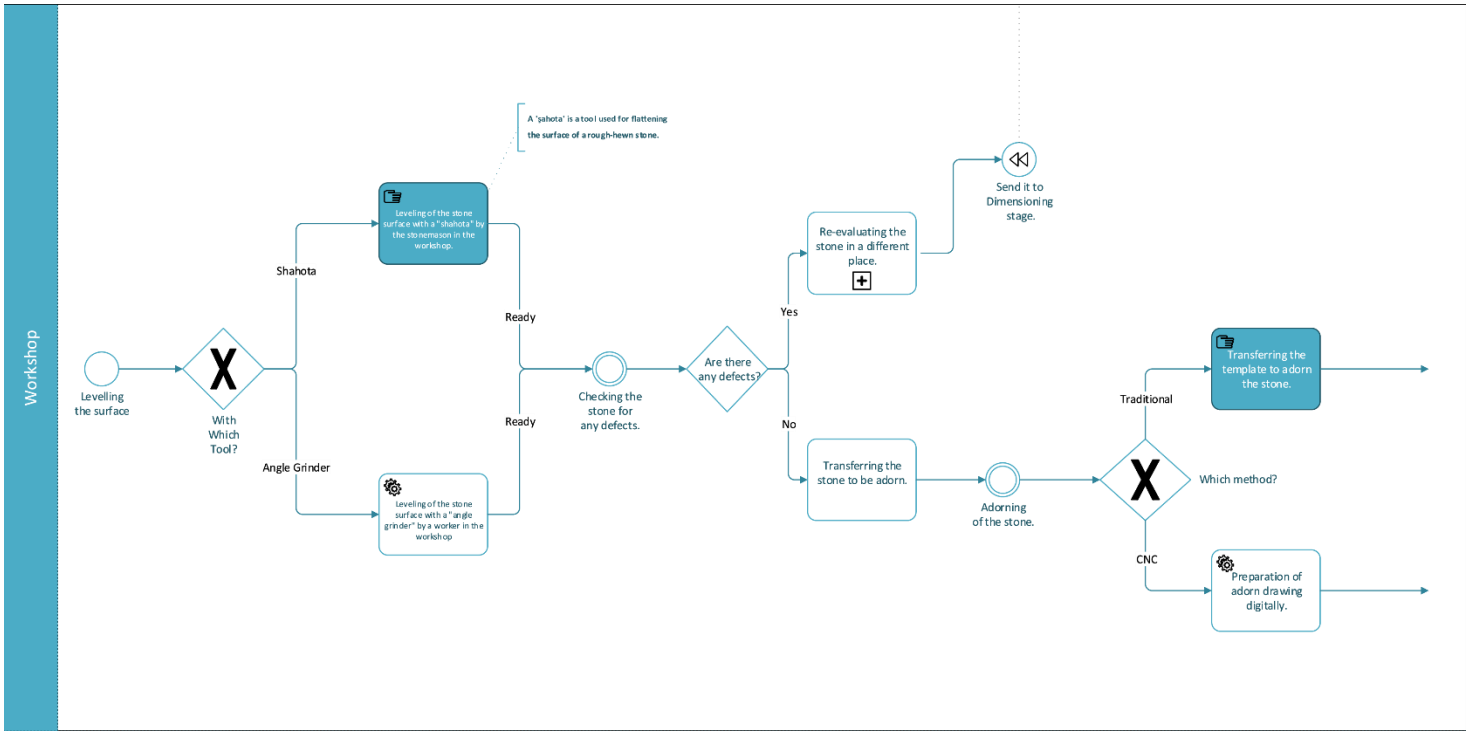

Figure 8 – A segment from the process model depicting the workflow at the stone workshop. Illustration by © 2023 Çuha.

VI. CONCLUSION

The study focuses on the utilisation of stone masonry in building and adorn within Mardin. It delves into the definition of process and process modelling. Existing process models used in architecture are examined, emphasising their scope and approach to the process. The creation stages of the stone masonry process model using Business Process Modelling Notation (BPMN) are discussed. The characteristics of components within the BPMN representation are highlighted. The decisions made and innovations introduced during the creation of the stone masonry process model using BPMN are elaborated upon. The paper emphasises the status of traditional and semi-automatic stone masonry throughout production processes. Identifying the divergent points between manuel and automatic techniques allows for the possibility of establishing a fully-automated stonemasonry system. The use of BPMN based on the modelling of stonemasonry production within architectural processes allows the documentation of the production stages of stone structural elements. It is anticipated that this guide could contribute to advancements in technology, innovation and automation within the fields of architecture, construction and engineering.

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