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Applying Multidomain Matrix to Develop Communication Structure for Custom Home Design and Building Projects

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Abstract

The custom home is one of the most complex projects. It involves several disciplines and teams, including internal and external organizations, during the project life cycle. There is information exchange continuously across the teams and often necessary to iterate back and forth between phases. Communication is thus the key to effective project management. This paper deals with the complex structure of the project communication of custom home projects. The objective of this paper is to develop the communication structure for the custom home design and building industry. MDM (Multidomain Matrix) was chosen to address the issue of complex communication processes among teams involved in the project. The four domains; phase, team, activity, and document; were taken into account for forming the MDM. The developed MDM represents team coordination, workflow (activities), and data flow in each phase. It helps support the development of the prototype web-based application for defining data flow, access authorization, and the project communication structure. The results of the testing of the prototype web-based application with the pilot project show that it reduced the lead time of getting information from 3-5 days to 1 day and the number of missing requests is reduced to zero.

Keywords: MDM, DSM, Project communication, Custom home, Construction project.

1. INTRODUCTION

A project is considered complex in nature. There are various disciplines and organizations (teams, groups, and individuals) that get involved during the project life cycle. Every team has its view, limits, and constraints regarding its framework. This different perspective leads to diverse priorities and sequences for executing their tasks. Yet, they might work from different locations and working times. This challenges the project manager to coordinate and integrate them working together and be on the same page at any time of the project.

Construction is often described as a complex process. Many researchers have explored the design phase of a construction project (Maheswari and Varghese, 2005; Maheswari et al., 2006; Senthikumar et al., 2010; Dehghan and Ruwanpura, 2011; Krinner et al., 2011; Mujumdar et al., 2014; Dehghan et al., 2015; Mujumdar and Maheswari, 2018). The design phase is the focal point of the project life cycle that every team should pay attention to before the construction phase. But in reality, many projects started construction before the design was completed. Custom home design and building project is one of those. The construction phase typically begins just after the building permit has been approved and is performed parallelly in the detailed design phase. One major characteristic of a custom home project is that it is not a linear pattern. It is a custom-made project designed to meet the needs of the client (the project owner) and often necessary to iterate back and forth between phases. It allows the client to get involved at any time during the project life cycle to get and satisfy their requirements as much as possible. On one hand, this distinctive character is a strength of the custom home design and building industry. On the other hand, it often leads to increase change requests (scope changes, improvement changes) from the client. It would generate additional burdens and confusions for whom it concerns. For instance, if the client requests to add a bathtub in a bathroom, it regularly affects the design team, procurement team, cost estimator, planner, and building (installation) team. Moreover, there might be some unforeseen events during the construction such as technical problems, limits, and constraints that might enforce to change the original design, the drawing for construction, and the project baseline. In this circumstance, if these information exchanges are not identified and distributed to the related teams, it can lead to unexpected mistakes and reworks. If we draw a communication network of a custom home project to depict communications among people (nodes), it can be illustrated in Figure 1. Furthermore, this abundant information exchange does not exist only in the design and the construction phases but occur continuously since the first step of the contracting process through the project closing. In this study, Multidomain Matrix (MDM) was chosen to address the issue of complex information exchange across organizations.

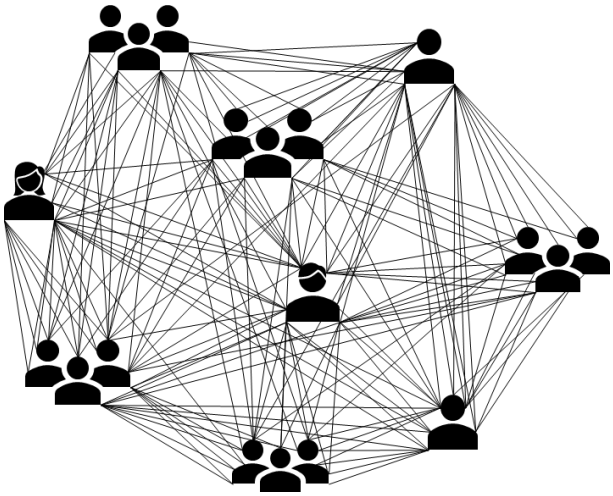


Figure 1 A communication network represented by a node-link diagram.

Design Structure Matrix (DSM) is a square matrix that is used to represent relationships between elements in a system, project, or process. It was first introduced by Steward (1981) in the 1960s then further developed by Browning (2001), Browning (2016), Yassine (2004), and many researchers. It has been widely used for managing complex systems, product development, project management, organization design, etc.

MDM is an extension of DSM. It combines and represents simultaneously two or more DSM models in different domains. Each DSM is on the diagonal of MDM and the off the diagonal blocks are Domain Mapping Matrix (DMM). DSM represents the interactions among the elements of the domain. DMM is a matrix mapping the domain of one DSM to the domain of another DSM (Eppinger and Browning, 2012). DMM has been widely applied to map across domains e.g., Quality Function Deployment (QFD) originated by Yoji Akao uses as the relationship matrix in the four-phase model (Hauser and Clausing, 1988). Axiomatic Design (AD) (Suh, 2001) uses for mapping between the customer, functional, physical, and process domains in the design of mechanical systems. Responsibility Matrix (RM) in project management (Larson and Gray, 2021).

The objective of this paper is to develop the communication structure for the custom home design and building industry. To reduce the issues of missing information and communication lead time during the project management. It applied MDM to develop the project communication structure that concerns various disciplines and organization units, processes, activities, documents, and information. It is organized into four sections. Following this introduction, the second section explains the proposed structured approach for forming an MDM for a project communication structure. The third section presents the MDM development of a project communication structure and the prototype web-based application for a case study custom home company. The fourth section discusses the conclusion and the scope for future work.

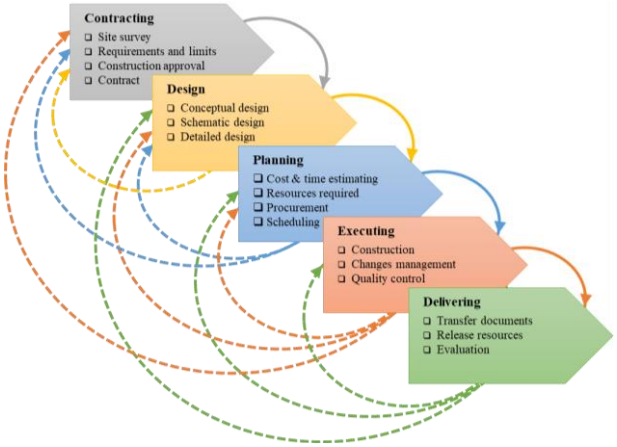


Figure 2 Life cycle of a custom home project.

2. METHODOLOGY

In general, the life cycle of a custom home design and building project can be divided into five phases as illustrated in Figure 2. It is common to go through phases and back and forth again to account for changes or new information gained. This abundant information is exchanged among and across the organization, internal and external, through the project communication channels. The project communication plan is thus critical to the project's success. The project communication plan commonly defines the frequency and manner of communication with project stakeholders and those who are affected by the project. It is expected to ensure that all stakeholders keep informed necessary information and help them work together cohesively through the project. In practice, however, with thousands of information exchange back and forth across several organizations, it is hard to identify and clarify to all related individuals. Accordingly, MDM was chosen to develop the project communication structure for a custom home project. The procedures of building the MDM for the project communication structure are briefly portrayed as shown in Figure 3. The section elaborates on the methodology for building the MDM.

2.1 Identify the domains in MDM

This process is a top-down approach that explores the domains forming the MDM. This first step identifies the domains concerning the project. In this paper, the author took into account four domains as follows: phase, team, activity, and document. These four domains were used to establish the communication structure of the custom home and design company.

The phase domain addresses the five phases of the project life cycle as shown in Figure 2. One phase can be divided into several sub-phases if required. The team domain illustrates the Organization Breakdown Structure (OBS) of the project. It identifies the organization units (departments, teams, individuals) who get involved in

each phase. Furthermore, it can define even individuals (the lowest level units) if necessary. The activity domain

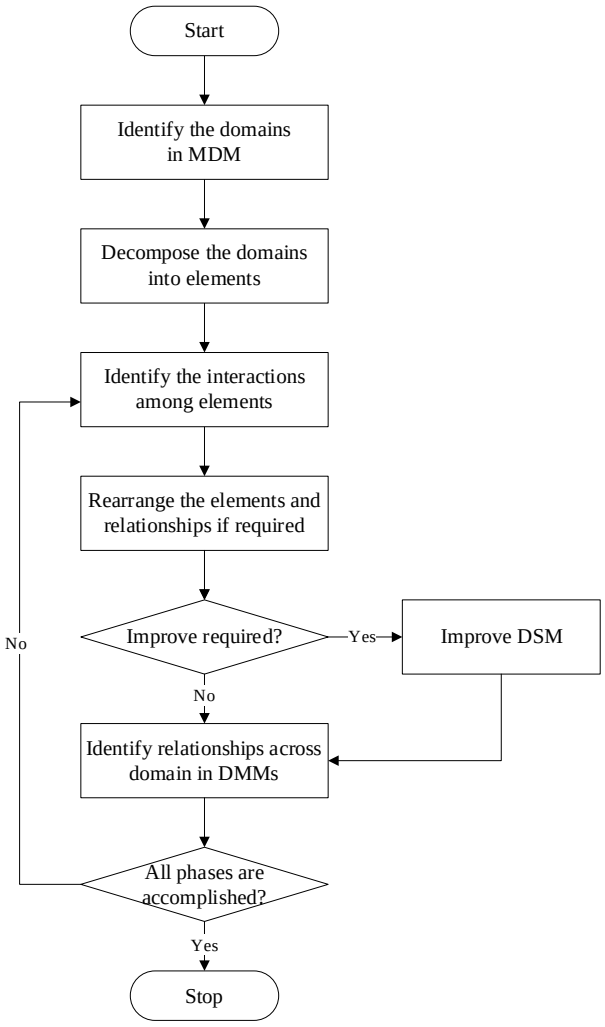


Figure 3 The approach of the proposed MDM methodology.

addresses work packages, tasks, and events occurring in each phase. Work Breakdown Structure (WBS) was used in this domain to assure that all activities of each phase are identified. The document domain is separated from the activity domain to addresses the controlled documents (associated with the activities) regarding the quality standards in construction.

2.2 Decompose the domains

This step decomposes the domains into their constituent elements. The top-down approach was used to break down the domains into units, activities, or entities perhaps through several hierarchical levels.

With the numerous elements of the project, this study considered one phase at a time to avoid confusion of abundant information. Select a phase (or a sub-phase) and draw a square matrix (1x1) labeling the row and the column with the selected phase. Then decompose the successor domain (team domain) its constituent organization units involved in the phase. Draw a square matrix with empty cells labeling the rows and the columns with its elements (organization units). Repeat this step for the activity and document domains. Then combine the square matrices of the four domains into a larger model by placing them on the diagonal to form an MDM, as illustrated by example in Figure 4. This hypothetical example MDM consists of one phase (P1); two teams (T1 and T2), three activities (A1, A2, and A3), and four documents (D1, D2, D3, and D4).

2.3 Identify the interactions

The bottom-up approach was used from this step forward. It begins with the document domain (lowest domain). This step establishes relationships among the elements of each domain for forming a DSM. The relationships are represented by the 'X' mark in the cells. This step requires brainstorming of experts and/or the persons who are working on that domain to obtain reliable information and minimal inputs.

2.4 Rearrange the elements and relationships

If there are any feedback marks ('X') in the upper triangular matrix, they should be rearranged to the lower triangular matrix to avoid any feedback loops or coupled blocks. Otherwise, skip this step.

2.5 Improve DSM (if required)

In case that there are feedback loops or coupled blocks in any DSM after rearrangement. That DSM might need to be improved. However, this step regularly requires the experts to check for the appropriateness of 'X' marks. Some methods are widely used at present, depending on the architecture DSM, e.g., clustering, partitioning, aggregation, tearing, etc. These methods are described elaborately in Eppinger and Browning (2012). Otherwise, go to the next step.

2.6 Identify relationships across domain

As mentioned earlier that DMM is a matrix mapping between two domains. It allows establishing the relationships of the elements of one domain to the elements of another domain. This paper proposed the project communication structure for the custom home project as illustrated in Table 1.

This step began from the Document DSM, the relationships in the Document-Activity DMM define which documents (information) are required for which activities in the Activity domain. While the relationships in the Activity-Document DMM define which documents are produced by which activities. Once these two DMMs have been accomplished, repeat steps 2.3-2.6 for the preceding domains (activity, team, and phase) to complete the entire MDM model.

The essence of mapping across the domains (DMMs) is to ensure that the people in the project know 'what' they get involved in, in which way, and with whom. Therefore, a RACI (Responsible, Accountable, Consult

and Inform) chart was applied to define the interactions for the DMMs which are concerned with people (the team domain). The RACI chart is a useful tool to ensure clear assignment of roles and responsibilities when the project consists of various disciplines and teams (PMI, 2017).

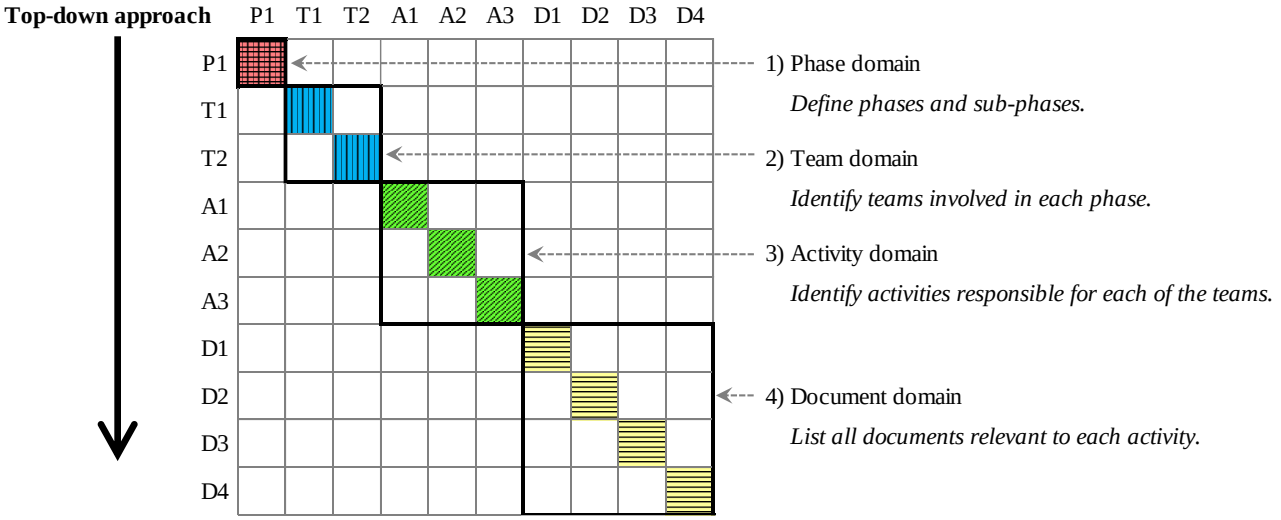


Figure 4 Decompose the four domains for forming the MDM.

Table 1 Structure of DSMs and DMMs for forming MDM.

Phase DSM • Identify the interactions among phases of the project.	**Team-Phase DMM** • Identify the roles (I) of the teams required in each phase.		
Phase-Team DMM • Identify the roles (R, A, C) of the teams required in each phase.	**Team DSM** • Identify the interactions among organization units (departments, teams, and individuals).	**Activity-Team DMM** • Identify the activities (output) required for the teams.	**Team-Document DMM** • Identify documents (information) associated with the activities required for teams.
	Team-Activity DMM • Identify the activities produced by the teams.	**Activity DSM** • Identify the interactions among activities.	**Document-Activity DMM** • Identify documents (information) required for activities.
	Team-Document DMM • Identify the documents associated with the activities produced by the teams.	**Activity-Document DMM** • Identify the documents produced by the activities.	**Document DSM** • Identify the interactions among documents.

The relationships in those DMMs are labeled with 'R', 'A', 'C', or 'I' depending on the role of the teams. For the other DMMs that do not concern people, the relationships are labeled with 'X'. Figure 5 shows the procedures for forming the hypothetical example MDM of a single phase.

3. MDM DEVELOPMENT AND CASE STUDY

The proposed methodology was tested with a case study custom home design and building company. This section brought a part of the developed MDM to demonstrate the early phases of the project communication structure of the company. Figure 6 illustrates the project communication structure in the early phases of the company. As mentioned earlier that the custom home project is often necessary to iterate back and forth. This MDM highlights the two feedback loops in the Activity DSM. The first loop is the cycle of conceptual design analysis. This design iteration attempts to extract the true needs of the client and constraints as much as possible. The other design iteration loop attempts to validate the conceptual design before going to the detail design stage. Though the client is the owner, they must be engaged and takes part in the project. The Team

DSM portrays obviously that all teams have to work together to accomplish the tasks. It is noticed that the Document DSM was rearranged due to the feedback marks in the upper triangular matrix. As a result, there are no more feedback loops in the document domain.

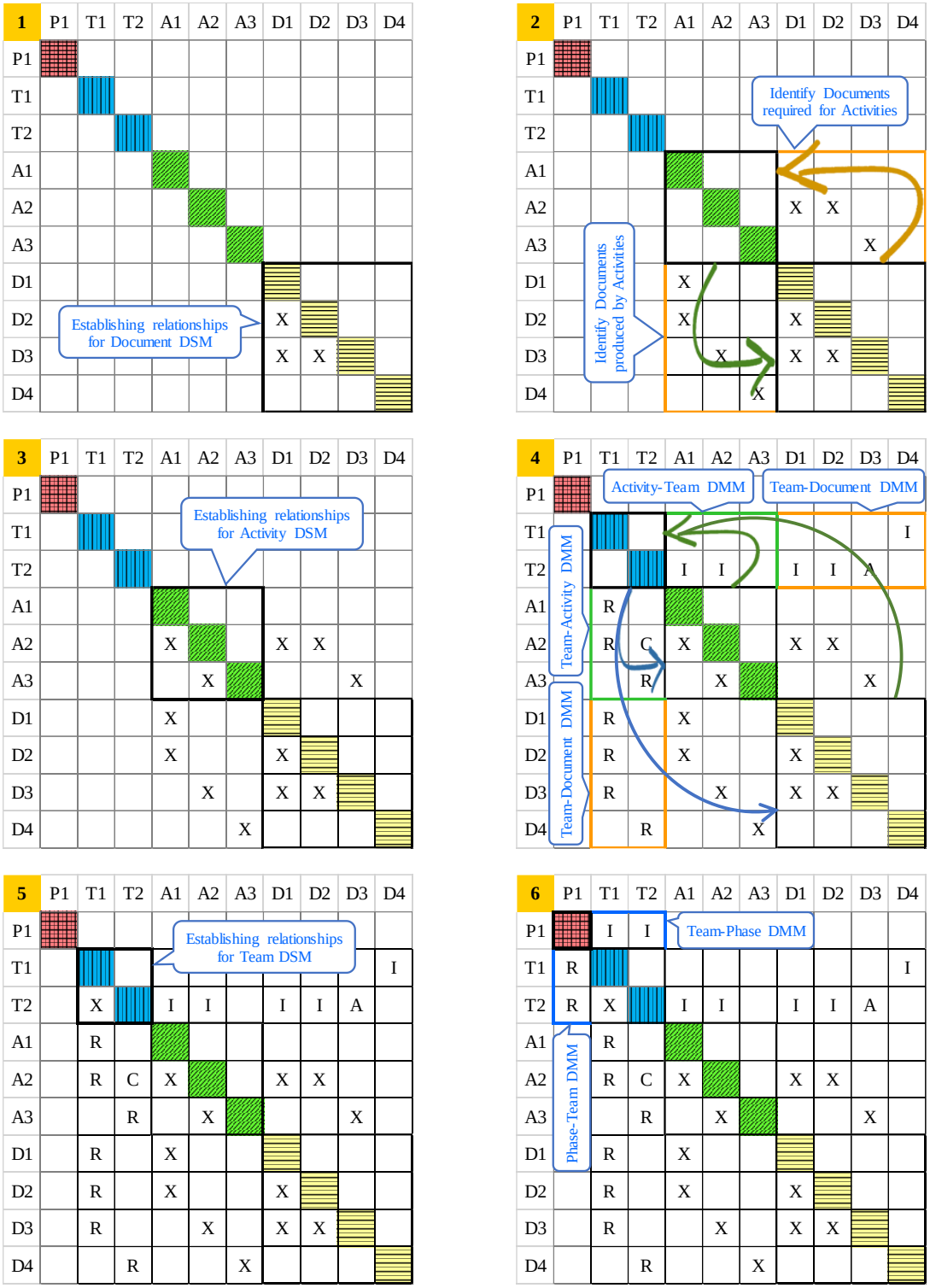
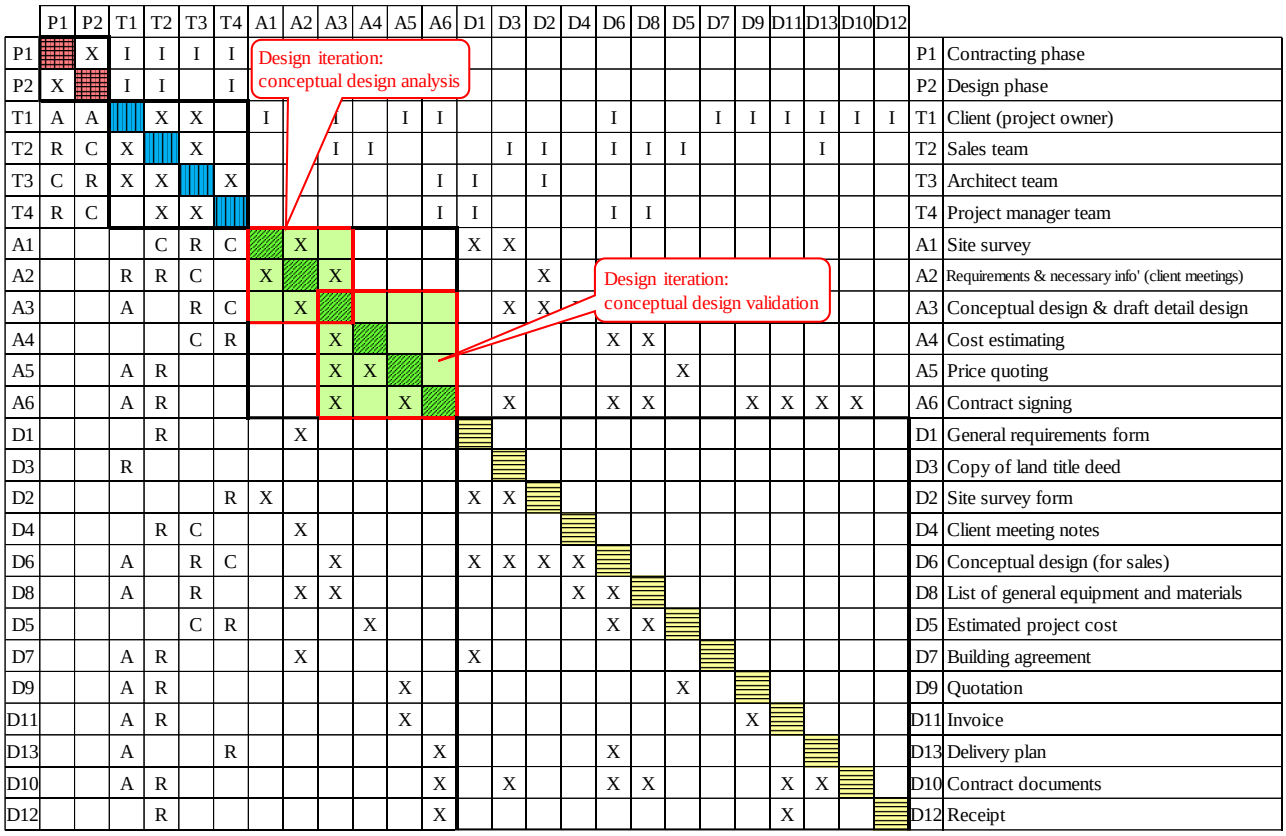


Figure 5 MDM Methodology for the project communication structure.



	P1	P2	T1	T2	T3	T4	A1	A2	A3	A4	A5	A6	D1	D3	D2	D4	D6	D8	D5	D7	D9	D11	D13	D10	D12		
P1		X	I	I	I	I																				P1	Contracting phase
P2	X		I	I		I																				P2	Design phase
T1	A	A		X	X		I		I		I	I					I			I	I	I	I	I	I	T1	Client (project owner)
T2	R	C	X		X				I	I				I	I		I	I	I				I			T2	Sales team
T3	C	R	X	X		X						I	I		I											T3	Architect team
T4	R	C		X	X							I	I				I	I								T4	Project manager team
A1				C	R	C		X					X	X												A1	Site survey
A2			R	R	C		X		X						X											A2	Requirements & necessary info' (client meetings)
A3			A		R	C		X						X	X											A3	Conceptual design & draft detail design
A4					C	R			X								X	X								A4	Cost estimating
A5			A	R					X	X									X							A5	Price quoting
A6			A	R					X		X			X			X	X			X	X	X	X		A6	Contract signing
D1				R				X																		D1	General requirements form
D3			R																							D3	Copy of land title deed
D2						R	X						X	X												D2	Site survey form
D4				R	C			X																		D4	Client meeting notes
D6			A		R	C			X				X	X	X	X										D6	Conceptual design (for sales)
D8			A		R			X	X							X	X									D8	List of general equipment and materials
D5					C	R				X							X	X								D5	Estimated project cost
D7			A	R				X					X													D7	Building agreement
D9			A	R							X								X							D9	Quotation
D11			A	R							X										X					D11	Invoice
D13			A			R						X					X									D13	Delivery plan
D10			A	R								X		X			X	X				X	X			D10	Contract documents
D12				R								X										X				D12	Receipt

Figure 6 MDM of the case study custom home design and building company.

The developed MDM represents team coordination, workflow (activities), and data flow in each phase. At this stage, data flow diagrams (DFD) were written to portray the direction and the flow of data/information that occurred during the project. Figure 7 presents the level 1 DFD that draws the main processes of a project. Figure 8 shows by example a level 2 DFD of the contracting process. This level 2 DFD draws the activities and documents (data store, D) of each process of the project.

The contributions of the MDM and DFD are dedicated to the project communication structure in two aspects. 1) it helps develop a comprehensive responsibility assignment matrix (RAM) for the project. Regarding the DMMs relating to the Team DSM, it helps the teams in the project know what to do, what they get involved in, in which way, and with whom. 2) it helps define different levels of authorization to the teams to access documents and information, excluding the client and people who are outside of the company.

This study applied the taxonomy of the knowledge model proposed by Tichkiewitch and Gaucheron (2000), the entities (documents and information) in the document domain can be classified into three types as follow:

1) Vernacular entity: the documents which are produced and owned by one team. Other teams cannot access such documents.

2) Vehicular entity: the documents which are produced by one team and significantly required for another team(s).

3) Universal entity: the documents which are produced by one team and are accessible for every team in the project.

This paper developed a prototype of a web-based application to demonstrate the proposed project communication structure with the case study company. The access authorization of the documents is classified as follows: create (C), delete (D), edit (E), and view (V). Regarding the MDM and DFD, an example of the defined authorization levels is shown in Figure 9. The prototype allows defining the authorization level of operations on the controlled documents for each team as shown in Figure 10. Yet, the notification system was added to the web-based application to ensure that the teams be on the same page of the project. The developed MDM helps to design the communication structure among the teams for setting the notification. Figure 11 shows an example (document) of the client meeting note using to record any changes and/or update information then distribute to whom it concerns (RACI: responsible, accountable, consult, inform). Regarding the communication structure, the system notifies instantly the teams know what to do, what they get involved in which subject and with whom.

The case study company uses the paper-and-pencil approach to record information as a method for formal communication and uses social applications for informal communication. This approach takes a long lead time for getting documents. The teams often get confused or missing some information during the communication.

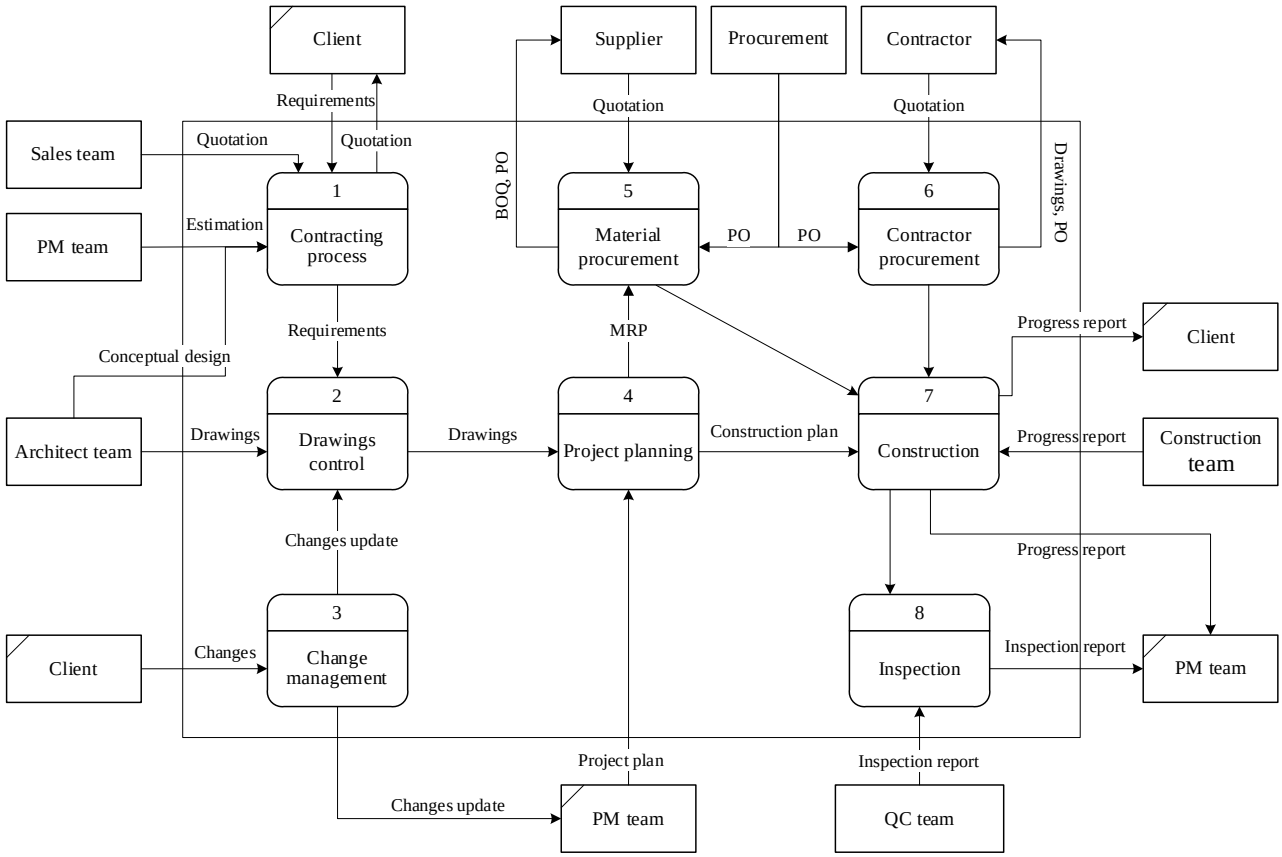


Figure 7 Level 1 DFD.

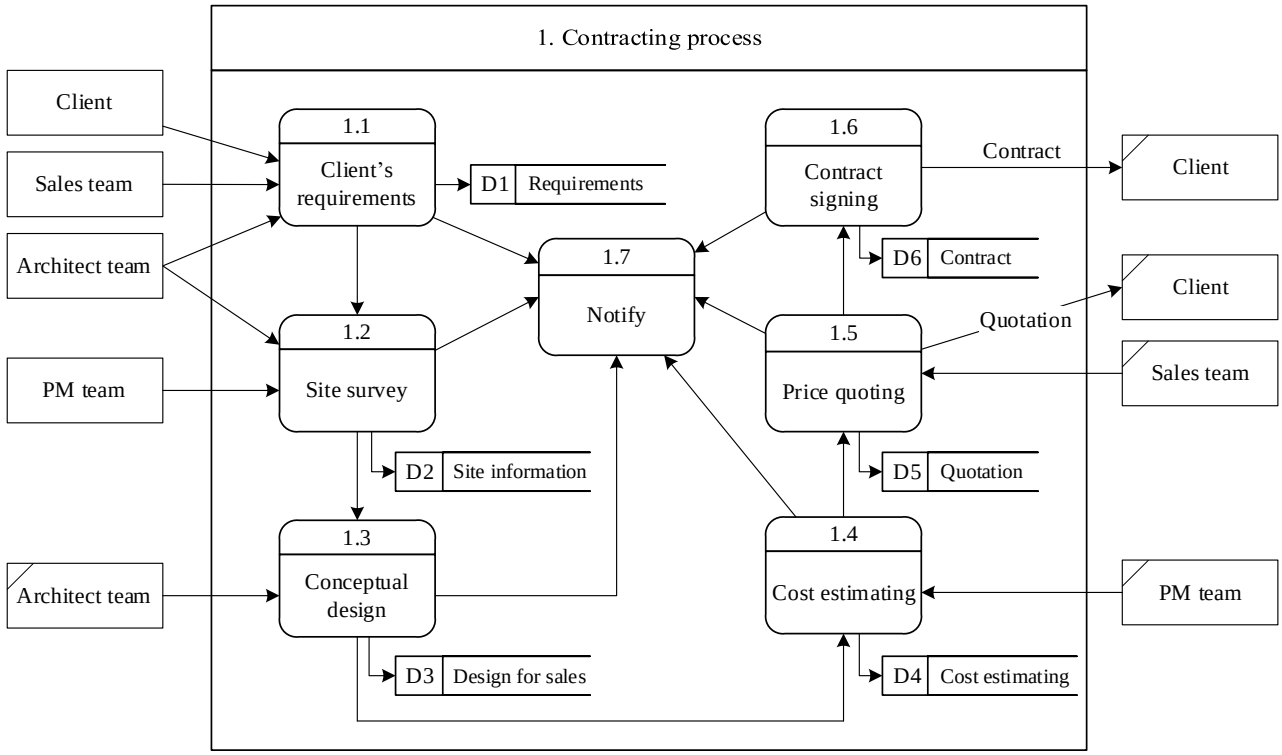


Figure 8 Level 2 DFD.

Controlled documents	General requirements form				Copy of land title deed				Site survey form				Client meeting notes (contracting phase)				Conceptual design (for sales)				....				Construction drawings				Materials purchasing				Client meeting notes (executing phase)				Construction progress (daily report)				Project status				Quality control and inspection				....			
Operations	Create	View	Edit	Delete	Create	View	Edit	Delete	Create	View	Edit	Delete	Create	View	Edit	Delete	Create	View	Edit	Delete	Create	View	Edit	Delete	Create	View	Edit	Delete	Create	View	Edit	Delete	Create	View	Edit	Delete	Create	View	Edit	Delete	Create	View	Edit	Delete	Create	View	Edit	Delete	Create	View	Edit	Delete
Sales team	✓	✓	✓	✓		✓				✓				✓	✓			✓			✓	✓	✓	✓		✓																							
Architect team		✓				✓				✓	✓		✓	✓	✓	✓	✓	✓	✓	✓					✓	✓	✓	✓		✓				✓				✓				✓				✓			
Project manager team		✓				✓			✓	✓	✓	✓						✓								✓				✓			✓	✓	✓	✓		✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓
Procurement team										✓																✓			✓	✓	✓	✓		✓				✓					✓				✓			
Construction team										✓																✓				✓				✓			✓	✓	✓	✓		✓				✓			
QC team																										✓				✓				✓				✓				✓	✓	✓	✓		✓			

Figure 9 User access authorization of the project communication structure.

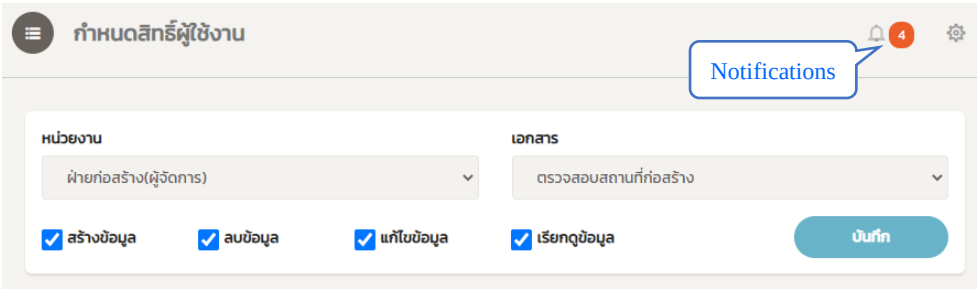


Figure 10 User access control and authorization levels.

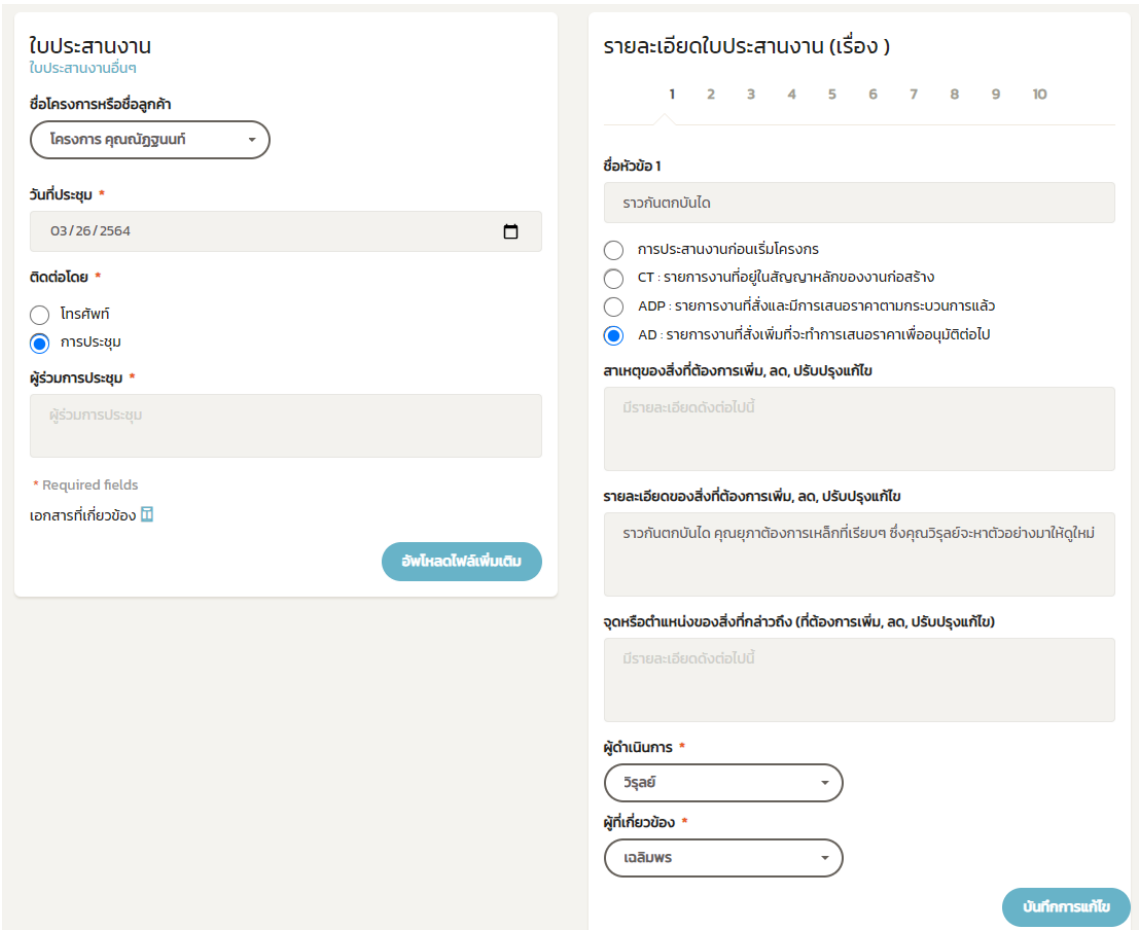


Figure 11 Example of client meeting note.

There is an average of 30-40 requests for change (additional works and deduction works) for a project. Subsequently, there is an average of 20-30 design updates. It usually takes 3-5 days, excluding the processing time of each operation, to deliver documents and to communicate between teams through the process. In addition, there is an average of 10% of those requests that are missed during the communication process.

The prototype web-based application has been tested with a pilot project of the case study company. The web-based application allows the user to fill in the information in the electronic document and instantly distribute it to the person(s) who are concerned. The results to date show that it can reduce the lead time of getting information from 3-5 days to 1 day and the number of missing requests is reduced to zero.

4. Conclusion

This paper focused mainly on the development of the project communication for custom home design and building projects. The proposed method can be applied to develop the communication structure for any custom home design and building company. The four domains (phase, team, activity, and document) were considered in this study. MDM methodology was applied to manage the complex communication structure. DSM was used to represent the constituent elements and interactions among its elements for each domain while DMM was used to map the relationships between the domains. While applying the MDM for the case study company, the author and the company team found that it significantly helps in developing the project communication structure. It allows the participants to perceive the holistic view of the project and the current company's workflow. Yet, it unfolded the complex communication network into a simple representation. Subsequently, some unnecessary entities (activities and documents) were eliminated or revised then rearranged in the proper sequence. DFD was used to clarify the flow of data and information of the communication structure. The developed MDM and DFD defined the permissions granted to each team with different authorization levels. As a result, the prototype web-based application set a user's authorization levels regarding the developed MDM and DFD.

The further study will focus on the extension of the MDM model to take into account in detail the product domain, design parameters, and quality control of construction work. The technical problems in the design and construction phases will be addressed.

5. Acknowledgment

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