Fabrication Scheduling of Electrical House of FPSO using Dependency Structure Matrix

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ABSTRACT

Electric House is a complete power plant system that supplies the electrical distribution network to site. Installation this power plant system have used in the world wide especially in industrial, utilities, renewable energy, outdoor switchgear and moveable substation. As we can see, in offshore industries application, Electrical House can be installed in Floating Production and Storage Offloading (FPSO). Since, engineering work is procedural and repeatable, complexity process will repeat again and again. Thus, problem happens stemming when complex processes which involves interdependent (feedback and iteration) in designing and fabricating process that affect the schedule of the project. Project management tools such as CPM, PERT and Gantt widely used to scheduling application do not address complexity of the interdependency and feedback iteration. In this research discusses scheduling of FPSO E-House module Fabrication Model using Dependency Structure Matrix (DSM) method in order to address the complexity. Partitioning DSM process which minimize the amount of iteration (iteration) within the process. As a result, reducing probability of iteration will affect to the time reduction to complete the project

KEY WORDS: *Floating Production and Storage Offloading; Electric House; Dependency Structure Matrix.*

NOMENCLATURE

DSM	: Dependency Structure Matrix
FPSO	: Floating Production, Storage and Offloading
CPM	: Critical Path Method

1.0 INTRODUCTION

The increasing demand world-wide on oil and gas have given big impact in massive growth of offshore industry .Various companies oil and gas compete in step to design Floating Production, Storage and Offloading (FPSO) with complete Electric House (E-House). FPSO is a floating vessel used for the processing and storage of oil and gas. A FPSO is designed to receive oil or gas produced from nearby platforms or subsea template, process it, and store it until oil or gas can be offloaded onto a tanker or transported through a pipeline.

Electric house (E-House) is industrial electric plant which represents an innovative approach especially in oil and gas sector. The E-House with complete electrical and control equipment are located inside a single fabricated steel building. E- House also contain all necessary electrical equipment for the operation of the plant like medium and low voltage switchgear, the electrical control system, the motor control center, and transformers.

Installation E-House also gives various benefits such as reduce risk, reduce cost, reduce delivery time and ensure long- term support causes interest to clients, but more challenging in order to design and fabricate E-House due to the complexity of the processes and systems. Therefore, applying Dependency Structure Matrix (DSM) is the solution to address complexity and interdependency of fabrication and scheduling process. Floating Production Storage Offloading (FPSO) is standalone structure that do not need external infrastructure such as pipelines. The gas and oil are offloaded to a shuttle tanker at regular intervals which is depending on production and storage capacity. The FPSO currently is with a high storage capacity and deck load. The wellheads or subsea risers from the sea bottom are located on a central turret so that the ship can rotate freely to point into wind, waves or current. A variation of FPSO uses a circular hull, which shows the same profile to wind, waves and current regardless of direction. It does not rotate and therefore does not need a rotating turret.

1.1 Problem Statement

Since traditional management tools including PERT, CPM and Gantt chart cannot address feedback and iteration of the complex project. They only allow modeling of sequential and parallel process only. Dependencies structure matrix (DSM) present the new approach to improve the traditional management tools because of difficulties to reschedule of certain project due to repetition procedure and iteration of the complex project. As Adler et al (1996) have discussed about the problem of traditional tools where these tools fail in aiding firms to speed new products to market.

Therefore, this research is carried out to develop Design Structure matrix (DSM) scheduling for fabrication Electric House of FPSO and their application. The critical problem in this research is to identify the sequence that minimizes expected project completion time the sum of the expected stage times of all the activities for a set of activities with given activity completion times and iteration probabilities.

1.2 Research Objective

Main aim of this research is to develop Dependency Structure matrix (DSM) model scheduling for fabrication Electric House of FPSO Fabrication process is complex processes where need a managing tools to rescheduling the process properly. Suitable approach will reduce the cost and time risk in project. Analyze the comparison of the traditional management tools with the new approach basic theory of the DSM.

1.3 Scope of Study

This research will focus on the develop DSM model on the Electric House fabrication scheduling of FPSO. Fabrication scheduling of E-House is specially designed and manufactured according to individual set of requirements defined by the customer and will be installed on FPSO. Understanding FPSO E-House model and Dependency Structure Matrix (DSM) method is important in order to develop DSM model

2.0 LITERATURE REVIEW

Due to demanding the safety requirement in the oil and gas industries, E-houses represent an innovative approach to the electric power plants where it is completely designed and installed on FPSO. As Eppinger said "Engineering work is procedural and repeatable". Complexity process will repeat again and again. Thus, problem happens stemming when complex processes which involves interdependent (feedback and iteration) in designing and fabricating of E-House. Various method use in project management such as PERT, CPM even GANTT also could not allow feedback and iteration of engineering work. They only allow for simple sequential and parallel process.

Originally, DSM proposed by Professor Don Steward of California State University, Sacramento (1970's). He explained benefit of DSM method "to develop an effective engineering plan, showing where estimates to be used, how design iterations and reviews are handled and how information flows during the design work". ". Researcher has determined DSM is powerful management tool to plan sequence activity by feedback present and can manage the exchange. A model based method for organizing tasks in product development.

According to reference book introduction to design structure method, DSM is one of the new technique to help people especially project engineer to have better design, develop and manage complex system. This book defines DSM as a network modeling tool represent the element comprising and interactions in designed structure. DSM commonly use in engineering management area. However widely used in health care management, public policy, financial system and etc. This book focuses on DSM research and applications to date for complex system. Next, DSM reviewed their application by Browning (2001) and continued development other researcher Vieira and Richardson (2002) take a more practical approach by defining a method for analyzing software component dependencies.

Further development research on where DSM was began at NASA, Intel and General Motors until DSM research community exists late 1990s. DSM community massive growth involve worldwide researcher from various universities such as Australia, South America, Europe and Asia. DSM community also acts as software developers and consultants to DSM users. Various documents and different application had developed by researcher and can be found on DSM community website which is (www.dsmweb.org). This website proves the new development of DSM theory.

Research done by scientist before about DSM was proven more advantages of DSM method. According J.U. Maheswari, K. Varghese (2005) because of DSM in matrix form, they easy to read, able to translate to systematic mapping and easy to identify the sequences. They also said that even DSM powerful tool to plan sequence activity, however its application in scheduling is very limited. So far, DSM used enable to calculate the critical path by assigning the amount of effort or work done as duration each activity. Besides, advantages of DSM include also compact format, visual nature, intuitive representation, powerful analytical capacity, and flexibility.

DSMs have been developed for planning and managing projects in the building construction, photographic, semiconductor, automotive, aerospace, telecom, and electronics industries written by R. Browning (1998). This research shows important to improve project management tool of complex project by using Dependency Structure Matrix (DSM) method in offshore industries and develop DSM software for scheduling E-House fabrication of FPSO.

Indra Gunawan and Kamarul Ahsan (2010) said since traditional tool such as CPM and PERT do not work to address interdependency activities in terms of feedback and iteration, DSM approach to solve the problem since DSM used to represent the dependencies and show the sequence of activity that would be performed. In additional they use DSM to account for feedback and iteration.

Dr.Sc.Amra Talic-Cikmis (2013) used DSM method for solving problem in wind tunnel "Armfield C15-10" where is present the experiment of fluid flow over the air profiles. Because of DSM power, new computational DSM aid known as PSM 32 software is introduced. He agreed that DSM can minimize feedback within the design process

3.0 DEPENDENCY STRUCTURE MATRIX

What is Dependency Structure Matrix (DSM) all about? DSM is known as design structure matrix, dependency source matrix, and dependency structure method which is a basic matrix tool approach as management tools. A DSM also can be define as square matrix that have equal number of rows and columns (m x n). DSM also is general method representing the relationship between the activities of the project and provides concise way to present complex project.

3.1 DSM Data Types

Browing, (2001) have introduced where DSM can be represent in four different types data with different type analysis method with different application.

- **Task-Based** where data represent in task and activity relationship. This DSM type execute in project scheduling, sequence activities and minimize time cycle. Analysis method for this kind of data implement Partitioning, Tearing, Banding, Simulation and Eigenvalue Analysis.
- **Parameter-Based** is type of data which represent parameter decision points and necessary precedents. This type usually used for low level activity sequencing and process construction. Analysis method for parameter-based use Partitioning, Tearing, Banding, Simulation and Eigenvalue Analysis.
- **Team-Based** represent multi-team interface characteristics which use for organizational design, interface management, and team integration. Clustering as analysis method.
- **Component-based** is multi component relationship use in system architecture, engineering and design. Method use for analyze is clustering.

3.2 Type of Task Dependencies of DSM

According to (Yassine, 2005) dependencies can be divided into 3 types which are dependent, independent and interdependent as shown in the Figure.1 Sequential is dependent information where activity-2 related to activity-1. After activity-1 is completed, activity-2 is continued. This means one activity influences the decision and behavior of another activity. Besides, Parallel is known as independent information where relationship have not influence between two activities. For example, activity-2 does not interact with activity-3. Both activities can be performed simultaneously. Contrast for coupled relation where activity-2 influence flow activity-3 and activity-3 influence flow activity 2 (intertwined).

Figure.2 shows basic matrix activities schedule in matrix form and their relationship. Mark "x" in upper side is the continuity of the activities and lower side is the repetition activity. Refer to row activity-1, Activity-1 provides information to activity-2 and 4 which mean after finish activity-1 at certain time, flow proceed to activity-2 and activity-4 which is independently and not related to each other therefore the process can flow as parallel.

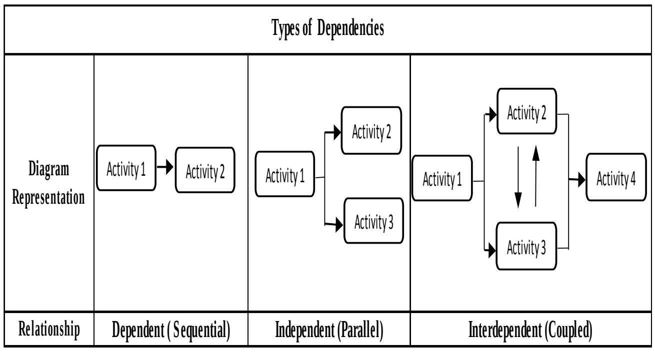


Figure 1: Types of dependency structure matrix

	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5	Activity 6
Activity 1		×		×		
Activity 2			×			
Activity 3		×			×	
Activity 4					×	×
Activity 5						×
Activity 6						

Figure 2: Shows the DSM in matrix layout

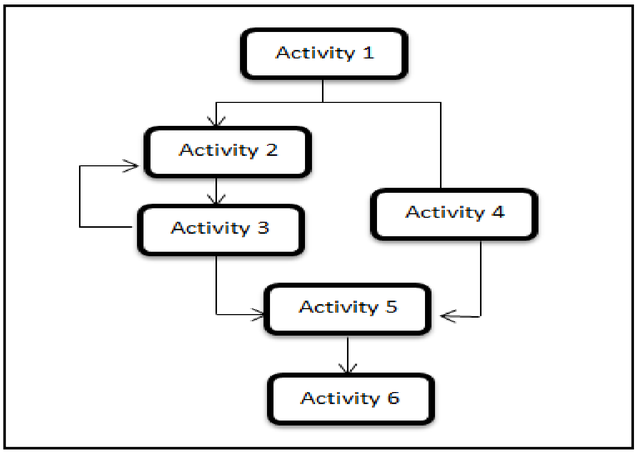
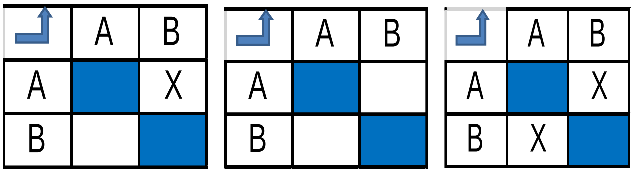


Figure 3: Shows the sequence of the DSM matrix

Of particular interest are cases where marks appear in the lower- triangular region of DSM. Activity-2 will have to make assumption about the information it needs from activity-3. Iteration may occur before activity-3 is begun and activity-2 is rework. Dependent relationship can be seen in activity-5 to 6 where after complete activity-5, activity 6 is continued till finish.

Mark at the lower- triangular reveal the chance of having iteration, which could have given impact on cost and schedule. In order to reducing the impact, bring the marks to the above or close to the diagonal which call partitioning analysis.

3.3 Type of Dependencies in Matrix Form



Dependent (Sequential) Independent (Parallel) Interdependent (Coupled)

Figure 4: Type of dependencies in matrix form.

3.4 DSM Partitioning Analysis

Partitioning is the sequencing or reordering of the rows and columns of DSM with new arrangement which does not have feedback and looping mark at the below diagonal. The mark below diagonal is transformed into the above diagonal. Main goal of partitioning analysis is to eliminate the feedback and looping marks to move as close as the diagonal.

3.4.1 Path Searching

In path searching, information flow is traced either backwards or forwards until a task is encountered twice. All tasks between the first and second occurrence of the task constitute a loop of information flow. When all loops have been identified, and all tasks have been scheduled, the sequencing is complete and the matrix is in block triangular form.

An example of the path searching partition proceeds are started from original DSM as shown in Figure.5. Task F does not depend on information from any other tasks as indicated by an empty column. Schedule task F first in the matrix and remove it from further consideration as shown in the Figure.5.b. Task E does not provide information to any tasks in the matrix as indicated by an empty row. Schedule task E last in the matrix and remove it from further consideration as shown in the Figure.5.c. Now, no tasks have empty rows or columns. A loop exists and can be traced starting with any of the remaining tasks. In this case, we select task A and trace its dependence on task C. Task C is simultaneously dependent upon information from task A. Since task A and task C are in a loop, collapse one into the other and represent them in a single, composite task (i.e. task CA) as shown in the Figure.5.d. Task CA has an empty column indicating that it is not part of any other loop. Schedule it last and remove it from further consideration as shown in the Figure.5.e. Trace dependency starting with any unscheduled task: task B depends on task G which depends on task D which depends on task B. This final loop includes all the remaining unscheduled tasks as shown in the Figure.5.f.

The final partitioned matrix is shown in the Figure.5.g.

	A	B	C	D	E	F	G
A			X				
B			X	X			
C	X						
D	X						X
E							
F			X		X		X
G		X	X				

Figure 5.a

	A	B	C	D	E	F	G
A			X				
B			X	X			
C	X						
D	X						X
E							
F			X		X		X
G		X	X				

Figure.5.b

	F	A	B	C	D	E	G
F				X		X	X
A				X			
B				X	X		
C		X				X	
D		X					X
E							
G			X	X			

Figure.5.c

	F	A	B	C	D	G	E
F				X		X	X

A				X			
B				X	X		
C		X					X
D		X					
G			X	X			
E							

Figure 5.d

	F	B	D	G	C	A	E
F				X	X		X
B			X		X		
D				X			
G		X				X	
C						X	X
A					X		
E							

Figure.5.e

	F	CA	B	D	G	E
F		X			X	X
CA	X					X
B		X		X		
D		X			X	
G		X	X			
E						

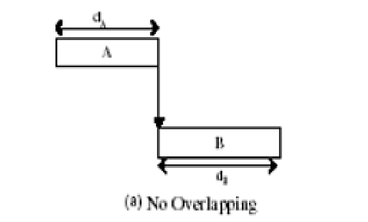
Figure.5.f

	F	B	D	G	CA	E
F				X	X	X
B			X		X	
D					X	
G		X			X	
CA						X
E						

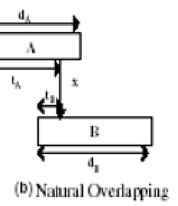
Figure.5.g

Figure 5: An example of the path searching partition.

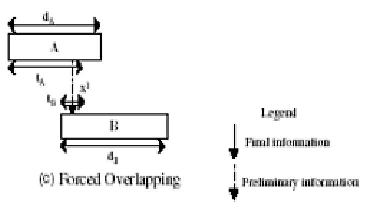
3.5 Type of Overlapping



Activity A give information to B. The duration of A is assumed to be d_A while B is d_B



A release certain piece of information 'x' after t_A which is less than d_A and B require information after t_B which is less than d_b



A is forced to release 'x' (in form 'x[1]') even or before t_A and/or B requires information before t_B

Figure 6: Type of overlapping of activities.

3.6 DSM Estimation Project Duration

According J.Uma Maheswari and Korshy Varghese (2005) proposed estimate the project Duration using DSM as formula below:

$$(ES)_i = (ES)_i + A_{ii}, \quad 0< i \leq n \quad (1)$$

$$(ES)_j = MAX[(EF)_i + A_{ji}], \quad 0< i \leq n,\ 0< j \leq n \quad (2)$$

Normal project Duration= $MAX[(EF)_j]$, $0 < j \leq n$ (3)

4.0 E-HOUSE CONSTRUCTION

Electric House is a complete power plant system that supplies the electrical distribution network to site. Installation this power plant system have used in the world wide especially in industrial, utilities, renewable energy, outdoor switchgear and moveable substation. As we can see, in offshore industries application, Electrical House can be installed in Floating Production and Storage Offloading (FPSO).

Despite Electric House contains medium and low switchgear voltage, but in sea application, Electric House practically functioning as power plant to control medium voltage power supply. Electric House is specially designed which consist of several main components which are switchgear room, emergency room, battery room, and transformer room. Before complete Electric House system is introduced, FPSO vessel received their medium voltage switchgear, auxiliaries' equipment and air conditioning systems from multiple electrical equipment suppliers and fabricator. As a result, increases in risk of integration error and costs probability system breakdown. Therefore, complete Electric House system act as solution.

There are many steps in fabrication sequence of E-House of FPSO as follows:

a) Temporary Stool Arrangement
b) Transportation Beam Arrangement
c) Column installation on Base Framing
d) 1st Floor Main Framing installation on Column
e) 1st Floor Secondary Framing to be installed on Main Framing.
f) Diagonal racing to be installed on 1st Floor Framing to Column
g) Column to be installed on 1st Floor Framing
h) Main Frame and Secondary member for Roof Framing to be installed onto Column
i) Floor plating 1st floor framing
j) Roof plating Installation
k) Crimped wall installed on module framing
l) Raised Floor Framing & Walkway Installation

Figure.7.a

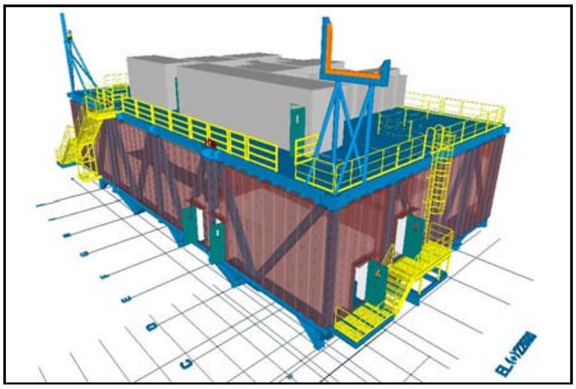


Figure.7.b

Figure 7: (a) Fabrication of the E-house and (b) Fabrication of a 3D model E-house.

E-house Fabrication Scheduling if Microsoft project manager is shown in the Figure.8 and development of DSM in visual basic program is shown in Figures 9 - 11.

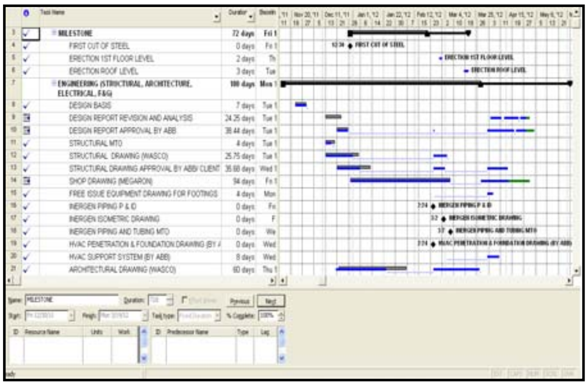


Figure 8: Schedule of FPSO E-house.

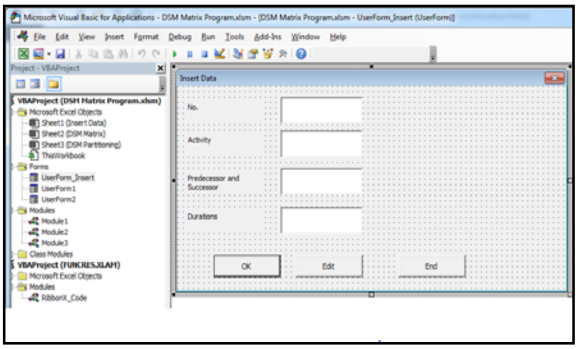


Figure 9: Microsoft Office Excel Visual Basic Programming for

DSM.

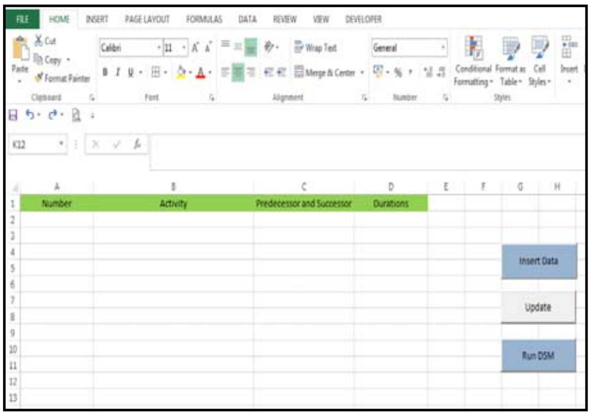


Figure 10: User Interface of DSM software

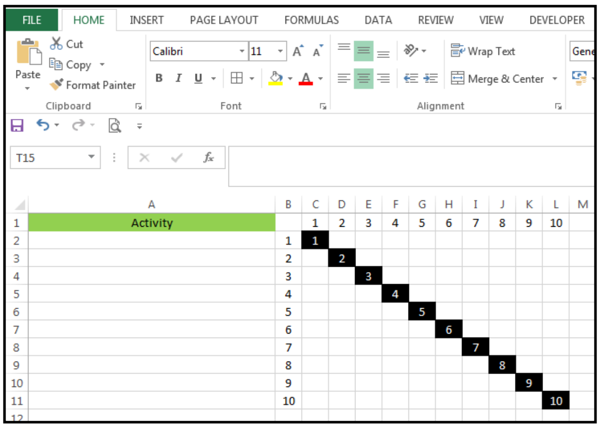


Figure 11: Sample User Insert number of element for DSM

5.0 RESULTS AND DISCUSSION

The scheduling of Electrical house of FPSO has been evaluated using the Dependency Structure Matrix model. The 1st stage of the Dependency Structure Matrix Model is shown in Figures.12 and 13. The overall result show a matrix form 134 by 134 completed with mark that show the dependencies of each activity. The dependencies include dependent, independent and interdependent. In this DSM form, below the diagonal show probability of interdependent activities which means activities that require rework and iteration. While, upper the diagonal show the sequences of the information flow.

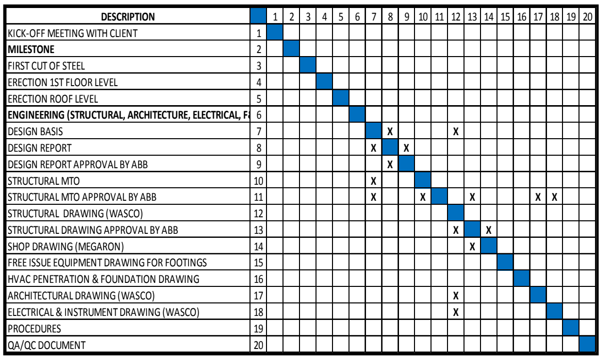


Figure 12: 1st Stage Dependency Structure Matrix Model

Since the DSM model in 134x134 matrix, it difficult to apply partitioning DSM analysis, the DSM model have be divided into 8 stages that transformed DSM model into smaller DSM matrix model as shown in Figure.14. Once the DSM is partitioned, activity in series are identified and executed sequentially. Independent activity can be executed concurrently. For interdependent activity ones, upfront planning is necessary.

A long the column, the first column show activates information. Second column and first row show the number of activities which important to identify the relationship of the activities. Major activities show in the DSM which include milestone, engineering (structural, architecture, electrical, etc), procurement, structural fabrication / installation, fabrication of the vertical columns/ wall, erection, blasting and painting, architectural fabrication/ installation, mechanical, electrical, testing and commissioning, preparation for load out.

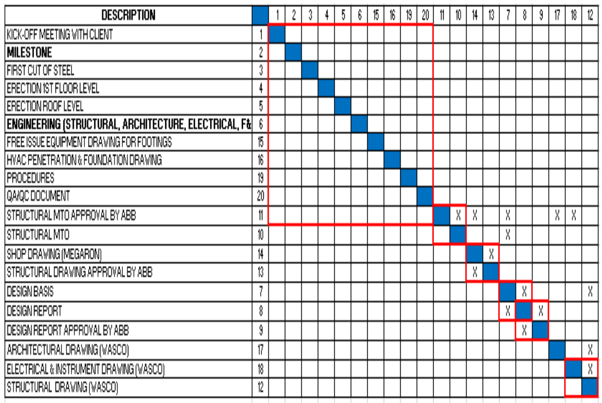


Figure 13: 1st Stage Partitioning Dependency Structure Matrix Model

STAGES	ACTIVITIES	NO. OF ITERATION BEFORE PARTITIONING	NO. OF ITERATION AFTER PARTITIONING
1	MILESTONE & ENGINEERING (STRUCTURAL, ARCHITECTURE, ELECTRICAL, F&G)	9	3
2	PROCUREMENT	1	1
3	STRUCTURAL FABRICATION / INSTALLATION	13	12
4	FABRICATION OF THE ROOF DECK	8	5
5	FABRICATION & INSTALLATION SUPPORT AND FOUNDATION	1	1
6	FABRICATION OF THE VERTICAL COLUMNS/ WALL, ERECTION, BLASTING AND PAINTING	16	15
7	MECHANICAL, ELECTRICAL	7	7
8	FREE ISSUED EQUIPMENT, TESTING AND COMMISSIONING,PREPARATION FOR LOAD OUT	7	7
	TOTAL	62	51

Figure 14: Number of iteration.

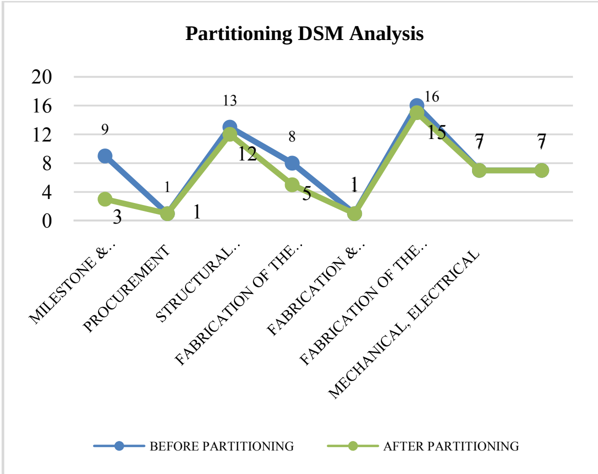


Figure 15: Partitioning DSM analysis.

In major activities also have sub activities such structural material, architecture material, electrical and instrument material, free issue, preparation, fabrication of the 1st floor deck, fabrication of the roof deck, fabrication & installation support and foundation, small power & lighting, instrument & equipment supply by client and free issued equipment.

In the partitioning of the DSM analysis, the differences of the DSM analysis before and after show reduction of iteration, even stage 5, 7, and 8 show same which do not show the reduction of the iteration as shown in Figure.15. This is because, some activities are not effect when applying the partitioning DSM, due to sequence constrained and in this research partitioning focusing on addressed to activities with no overlapping time and DSM basically rearranged the activities into parallel sequences.

Partitioning DSM model analysis, require procedure as step path searching. This method is processed reorder the sequence and minimizes the number of iteration and feedback. According the partitioning analysis DSM model result, reordering the activities by path searching enable the activities execute either dependent or independent only relationship into small block. In addition, in this research, only consider activities which no overlapping and ignoring the others. This is due to difficulties to address the overlapping activities. The DSM model also indicates the number of iteration where probability to rework again which is important to identify the interdependent activities of the whole activities.

In this research, application of DSM to the Electrical-House fabrication scheduling of FPSO shows reduction time in order to complete the project. Figure 6.6, shows reduction time of DSM Analysis which means by applying the DSM method time to complete the project reduced from actual time 130 days to 123 days as shown in Figures.16 and 17. Even only 5.4 percent improvement of DSM scheduling, but it will affect the overall schedule. Reduction of time will give benefit due to reduce risk and cost of the overall project.

STAGES	ACTIVITIES	Microsoft Project (Days)	DSM (Days)
1	MILESTONE & ENGINEERING (STRUCTURAL, ARCHITECTURE, ELECTRICAL, F&G)	125	124
2	PROCUREMENT	91	90
3	STRUCTURAL FABRICATION / INSTALLATION	62	61
4	FABRICATION OF THE ROOF DECK	27	26
5	FABRICATION & INSTALLATION SUPPORT AND FOUNDATION	16	16
6	FABRICATION OF THE VERTICAL COLUMNS/ WALL, ERECTION, BLASTING AND PAINTING	68	67
7	MECHANICAL, ELECTRICAL	40	40
8	FREE ISSUED EQUIPMENT, TESTING AND COMMISSIONING,PREPARATION FOR LOAD OUT	5	5
	TIME TO COMPLETE	130	123

Figure 16: Time reduction according stages.

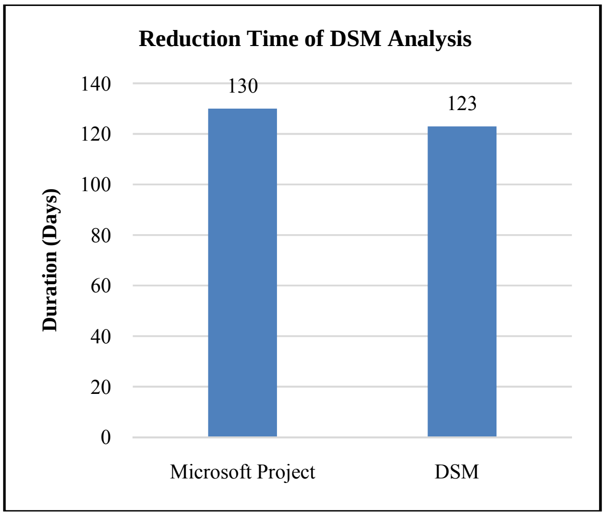


Figure 17: Time reduction using DSM compared to Microsoft project.

6.0 CONCLUSION

As conclusion of the study, Dependency Structure Matrix model has been applied for scheduling for fabrication of electric house of FPSO. The simulation results show construction time reduced 7 days due easy in managing of information exchange and plan the sequence.

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