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Project Scheduling of New Product Development Process in Automotive Industry in Indonesia Using Design Structure Matrix (DSM)

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Abstract. Innovation technology and development of customer needs diversification drive products to be more complex and the complexity changes the product life cycle become faster than before. Many industries try to create a more rapid new product development (NPD) process in order to enter the market and gain customer earlier than their competitors. Therefore, optimal timing and scheduling become important factors in the success of NPD process. This paper aims to perform project scheduling in NPD process of automotive industry in Indonesia by using Design Structure Matrix (DSM) and the result was compared with Critical Path Method (CPM) as one of conventional project scheduling method. DSM manage every task and information flow within a project including possibility of rework activity that might be occurred in NPD process. The results showed the scheduling technique using DSM calculated shorter development process duration rather than using CPM. DSM also considered possibility of rework activity that might be happened in the real situation.

1. Introduction

Development of science and technology, and diversification of customer needs, products tend to involve more functions, which in turn, drive products more complex than ever before [1]. Rapid changes in technology have led to an increasingly fast pace of product release and also changed the competitiveness level in the market [2]. New product development (NPD) project is essential for a firm facing changing demands and intensively competitive markets [3]. Rapid periodic product release to market is an important factor for company to gain competitive advantage, higher profits, market share and as an opportunity to survey within the market place [4].

Products tend to be more complex than before because of the growth of customer needs and market competition. Development of complex products like automotive industry claim skills of various disciplines e.g. engineering, IT or chemistry [5]. The process also requires repeatedly interaction and iteration and also effective coordination within other department. The successful development process in the automotive industry depends on planning, scheduling and managing all the activity efficiently and effectively.

Project management is a knowledge to manage project by using modern management techniques to achieve predetermined objectives of scope, cost, time, quality and participation satisfaction [6]. The most popular and commonly used techniques in the network-based project management are Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) [7][8]. Critical path is important element in project scheduling by using CPM and PERT and also becoming advantage of both



methods [9]. The limitation of CPM and PERT are not effective in managing the iterative and interrelated project information flow that often occurs in the product development project [10].

Due to the higher complexity level, with the iterative interaction within the organization, a project needs a better method to plan, manage and control all the process. The design structure matrix (DSM) is one of the methods used to model and analyses iterations in the design process [11]. Due to the possibility of considering iteration process, DSM method can accommodate more effective project scheduling compared with a traditional method like CPM [12].

The aim of this research is to apply DSM in NPD process of the automotive industry in Indonesia. This research would give a recommendation time completion of the project and which method is suitable for a project with higher complexity level.

2. Literature Review

2.1. Project Management

According to Kerzner (1979), project management is the planning, arranging, directing, and controlling all resources in certain period to achieve determined target [13]. Project Management Institute (PMI) states that project management is utilization of knowledge, skills, tools, and techniques as in a period of project activities to fulfill project goals and objectives [14].

Historically, project management has started since ancient history. The Great Pyramid of Giza, The Great Wall of China, the Coliseum, the hanging gardens of Babylon and the Stonehenge were the real example of project during that time [15]. Modern project management is started by Henry Gantt (1861 – 1919) and known as the creator of Gantt chart [16]. The next era of project management is started when the development of CPM/PERT [16]. These methods became important in the advancement of project management. The next method of project management is DSM. DSM has been developed since 1960 by Don Steward, a professor from America, but was more highlighted in 1980 through publications from Steward [17]. DSM was developed to cover the limitations of the CPM/PERT method by allowing the probability of network logic and estimation of the time of each activity, as well as the repetition of activities.

2.2 Sequential (SE) and Concurrent Engineering (CE)

There are two kinds of processes in NPD, namely serial or sequential (SE) and concurrent engineering (CE). In sequential engineering each design phase will begin after the previous phase is completed [18]. Concurrent engineering began around 1990 as one of the new management cycles focused on time as critical [18]. This process analyzes the time and duration of each activity in all related organizations (from the design phase to manufacturing) with the aim of reducing activity time without eliminating quality and selling value in the final product [18]. In CE, all activities and phases are carried out in parallel. The fundamental difference between CE and SE is the involvement of departments in the product development process [19]. CE involves other departments in solving problems that arise in the early stages of product development. In contrast to SE, SE takes too much time to develop concepts at an early stage. Figure 1 shows difference between CE and SE.

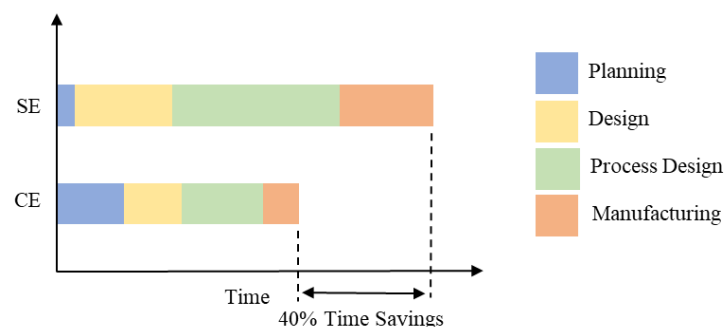


Figure 1. Difference between CE and SE (19).

2.3 Design Structure Matrix (DSM)

DSM was developed by Donald Steward, a doctor from America, in 1981 (20). DSM is a matrix that is used for planning and analyzing product development processes [21]. DSM is represented by an $n \times n$ square matrix, where n is total of components (e.g., parts in a product, tasks of a project, departments within an organization) to be modeled [22]. In DSM method, every tasks or activity are assumed has information to be given to other activity and has information dependency from other activity [11]. The tasks or activities are listed in the sequential process. DSM is used to model different types of systems and not only the tasks of a design process. Dependency in information flow lead to a sequence relationship. There are three types of sequence relationship in DSM: serial, parallel and coupled. Figure 2 shows types of sequence relationship in DSM.

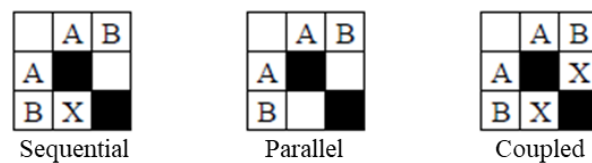


Figure 2. Type of sequence relationship in DSM (23).

Optimization in DSM can be done by partitioning process that use analytical method and common optimization process are clustering [19]. The partitioning and clustering algorithm are mainly used in order to reorder the sequence of activities in certain rule that aims to minimized dependency among tasks and the modularization of mutually related activities [24]. Figure 3 shows example of DSM matrix.

As DSM is able to show iteration process in a project, it makes DSM suitable for use in NPD process. Nguyen (2015) in his research used DSM to model the collaborative design of the Automotive Powertrain System, whose process has various task decompositions and design iteration. The result showed DSM can give a good reflection on dependencies and restriction between design steps, and can have an effective control on the iteration happening in design process, so as to improve design efficiency and shorten developing time [25].

Amalia (2018) in her research showed use of DSM in aircraft development project. The aircraft development project requires high technology and influenced by high uncertainty factor and also huge budget and involvement of many parties including government and related vendors [12]. The result showed DSM has more effective project scheduling compared to traditional method like CPM. The total completion time of project is shorter than the original duration.

	A	B	C	D	E	F	G	H	I	J	K
A	X			X							X
B		X		X							
C			X	X			X		X		
D				X							
E					X		X				
F						X		X		X	
G			X		X		X				
H								X			
I			X	X			X	X	X		
J										X	
K				X		X					X

Figure 3. Example of DSM Matrix (23).

3. Methodology

The methods of this paper consist of data collection, data processing by using DSM and CPM, and comparative analysis of the results. The primary data was collected from the master schedule of new model car development in one of the automotive brand in Indonesia. The data were analyzed to compute duration and also the predecessor and successor for each activity. Validation of the data was done by consulting with project manager as PIC of this project.

All the data information were input to software in CPM and DSM method. In CPM, the software calculated the total lead time needed to accomplish the project and showed critical path of the project. The critical path showed some activities that could be obstacle to finish the project in time. In DSM, optimization was done by partitioning and tearing process. Total project duration was also calculated by using equal starting time data in CPM.

4. Result and Discussion

4.1. Data Collection

The data consists of activities for all departments related, activity's period and also milestone as target for each activity. In this study, the data is concurrent engineering (CE). Some of activities could be proceed concurrently based on the dependency. The data is collected based on master schedule of NPD process in automotive industry. The product itself is categorized as new model, not minor change model. The difference from current product line up is exist on car categorization, new platform, new engine and safety features. As new model in current product line up, activity duration and information flow between activities become more complex than minor change development.

4.2 Project Scheduling by using CPM

Project scheduling was done by using Critical Path Method and implemented in Microsoft Project. All the data in table 1 was input, included also the sequence and the predecessor for each activity in order to analyse the critical path of this project. Milestone was also input in order to control the target for each activity. In resources, it was assumed there was only single resource for all activities in same department. There were total 10 departments involved and there were also 10 people assumed assigned in this project. It consists of marketing, cost planning, styling, product planning, design engineering, performance design, purchasing, production engineering, production preparation and control, and homologation. Activity in one department has predecessor from activity in different department. The information flow in this project is also cross department. Moreover, each milestone also requires information from all department. Figure 4 shows data processing by using CPM. It shows the milestone (activity 2 until activity 8) and 10 departments involved in the project.

Table 1. Activity list of NPD process.

No	Activity Name	Duration (Days)	No	Activity Name	Duration (Days)	No	Activity Name	Duration (Days)
1	MKT1	130	51	PPD11	20	101	PE2	20
2	MKT2	175	52	PPD12	40	102	PE3	40
3	CP1	20	53	PPD13	55	103	PE4	20
4	CP2	75	54	PPD14	55	104	PE5	50
5	CP3	60	55	PPD15	75	105	PE6	20
...								
50	PPD10	165	100	PE1	105	143	HOMO12	20

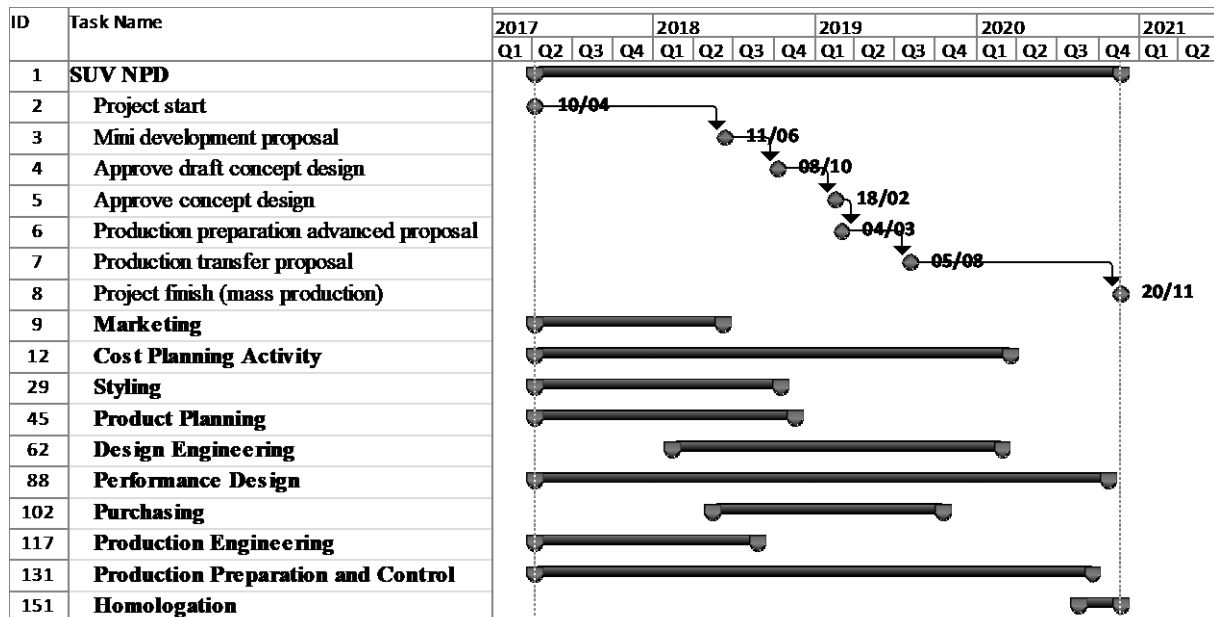


Figure 4. Gantt Chart of NPD Process in automotive industry.

Critical path is advantage of CPM method. By understanding critical path of a project, it could be a consideration to give more attention to activities within the critical path. Those activities could be a cause of project delay. Critical path in CPM method also depends on start time of an activity. Even though a serial of activities has short duration, it could be a critical path if its predecessor starts late. Moreover, decision of predecessor and successor of an activity is important in effective project scheduling.

Figure 5 shows critical path in automotive NPD. Activities in designing interior and exterior of automotive part, die making and shipping process became critical path in this project. These activities need a better concern to achieve certain goals in the project. The total time needed to finish the project was obtained, the total duration was 940 days.

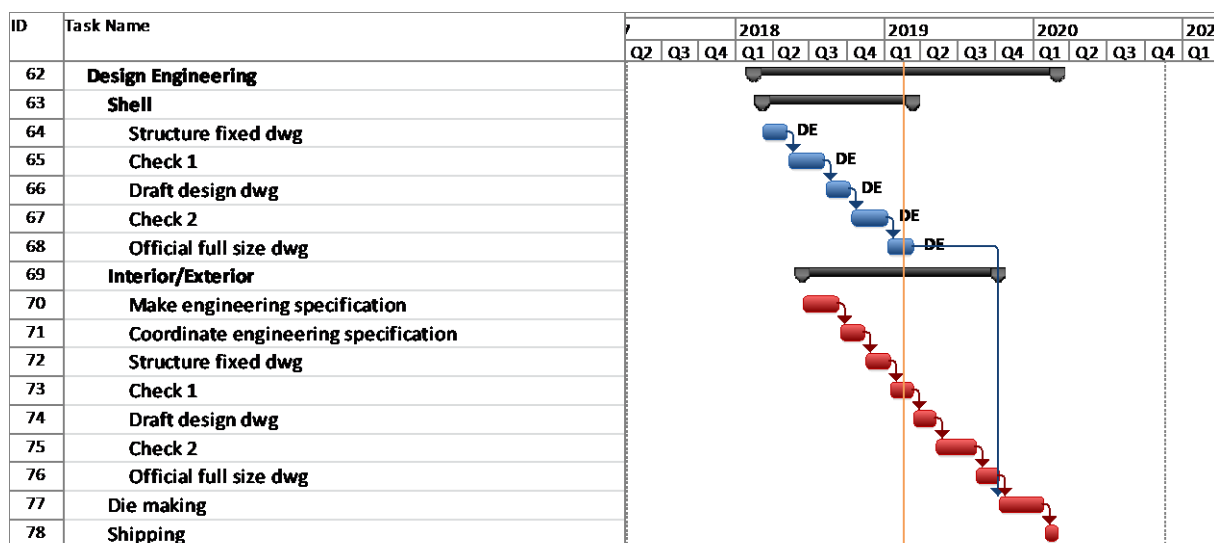


Figure 5. Critical Path in automotive NPD.

4.3 Data Processing by using DSM

DSM method was performed by using ProjectDSM software. The input data used in DSM is same as input data in CPM, it consisted of activity name, duration, resource and predecessor. The difference is possibility of rework activity that cannot be implemented in CPM. In CPM, rework activity only can be input as additional activity. Figure 6 shows dependency matrix of some activities in automotive NPD. In ProjectDSM, dependency matrix will be created in arbitrary sequence. The red marks above the diagonal are mostly rework activities. Possibility and information of rework activities in this study are decided based on experience of previous project in automotive NPD.

#	Component	91	92	93	94	95	96	97	98	99	100	101	102	103	104
91	Approve draft concept design	●													
92	Complete make the scenario for profit achievement		●						●						
93	Exterior styling data			●		●									
94	Approve concept design	●			●										
95	Styling fix data			●		●		●							
96	Production preparation advanced proposal				●		●								
97	Styling data					●		●							
98	Production transfer proposal		●				●	●	●						
99	Structure fixed dwg									●					
100	Make engineering specification										●		●		
101	Check 1									●		●			
102	Coordinate engineering specification										●		●		
103	Structure fixed dwg												●	●	
104	Draft design dwg											●			●

Figure 6. Dependency matrix of automotive NPD.

Optimization process in DSM method is created through partitioning and tearing process. By partitioning, the arbitrary sequence is reordered in order to minimize feedback marks and try to move all above diagonal dependencies under the diagonal to arrive at a waterfall sequence of tasks or process steps. On the other words, form of the matrix is close to block triangular. Basic algorithm of partitioning proses are as follow:

1. Identify element(s) without input from other elements (empty row). Place in top of the DSM matrix.
2. Identify element(s) without output to other elements (empty column). Place in end top of the DSM matrix.

Figure 7 shows dependency matrix after partition process of activities in Figure 6. All activities was reordered and sequence of activities number 91 to 104 in figure 6 and 7 is different. The additional red mark previously are above diagonal and after partition become closer to diagonal.

#	Component	91	92	93	94	95	96	97	98	99	100	101	102	103	104
91	Structure fixed dwg	●									●				
92	Make engineering specification		●		●								●		
93	Check 1	●		●											
94	Coordinate engineering specification		●		●								●		
95	Structure fixed dwg				●	●							●		
96	Draft design dwg			●			●				●				
97	Check 2						●	●							
98	Check 1					●			●						
99	Draft design dwg								●	●			●		
100	Official full size dwg							●			●			●	
101	Check 2								●			●			
102	Official full size dwg											●	●	●	
103	Die making										●		●	●	●
104	Shipping													●	●

Figure 7. Dependency matrix of automotive NPD after partitioning process.

Tearing process aims to break coupled block into smaller ones in order to reduce iterations. The process is removing feedback mark in large block resulted from partitioning and try to make the feedback mark closer to diagonal.

In ProjectDSM, tearing process in one block could be done by promotion, delay, and simplify. Promote will move the activity to front of the block, while delay will move the activity to end of the block. Both of these process will remove one or more dependency within the activities in the block. In this study, simplify process was used because this process will only remove one dependency. The dependency removed had low possibility of rework activity happened in real situation. Promote and delay was not considered in this study because some activities in one block were serial sequence relationship and could not be reordered.

Figure 8 shows dependency matrix after partitioning and tearing process. The red circle in purple and pink block indicated torn or removed activity that had low possibility of rework activity. After tearing and partitioning, one big pink block in Figure 7 was divided into two block, purple and light blue block.

The total duration to finish the project based on DSM method was 757 days. This number considered rework activity with duration assumption was 50% from original duration. Total resources in DSM method was set into 10 people same as in CPM method. In comparison with original duration from CPM method, it was improved from 940 days. There were some rework activities that cannot be removed. Based on project experience, those rework activities has a great possibility to occur during the project.

5. Conclusion

Project scheduling of automotive NPD in this study was performed by using DSM method and CPM method. In comparison with CPM as traditional project scheduling technique, DSM method was able to consider the probability of rework activity. Total duration to finish the project in DSM method (757 days) was faster than CPM method (940 days). DSM made the reduction of total duration also depicted possibility of completion project time in the real situation. Deep knowledge of a project is crucial factor in project scheduling, especially in determining information flow and dependency among activity and also possibility of rework activity that could be obstacle within a project.

#	Component	91	92	93	94	95	96	97	98	99	100	101	102	103	104
91	Make engineering specification	●	●					●							
92	Coordinate engineering specification	●	●					●							
93	Structure fixed dwg		●	●				●							
94	Check 1				●										
95	Draft design dwg				●	●		●							
96	Check 2					●	●								
97	Official full size dwg						●	●						○	
98	Structure fixed dwg								●				○		
99	Check 1								●	●					
100	Draft design dwg									●	●		●		
101	Check 2										●	●			
102	Official full size dwg											●	●	●	
103	Die making							●					●	●	●
104	Shipping													●	●

Figure 8. Dependency matrix after tearing and partitioning process.

For further study, DSM could be combined with other method for more advanced and effective project scheduling. Cost that was not considered in this study could be consideration as an important decision element in project scheduling.

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