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Review on Scheduling using Dependency Structure Matrix

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Abstract - *Numerous methods are used to plan and schedule the start and end of activities and to coordinate the flow of information in processes. Dependency Structure Matrix (DSM) is a useful tool in project scheduling when approaching information dependency issues between activities and it is potential model as conventional planning tools cannot model iterations. DSM is especially useful when processes are complex and iterative. DSM provides an effective representation for process systems of activities and their interactions. The Process DSM can be analyzed via DSM sequencing analysis and several algorithms have been developed to identify coupled blocks of activities. DSM methods is a vast area of research and future work is required for development of better DSM analysis tools for handling large matrices, sequencing and clustering methods for specialized situations, and further innovations in visualization and display of DSM models*

Key Words: Dependency Structure Matrix, Process DSM, iterations, dependencies, scheduling

1. INTRODUCTION

Project management is largely concerned with the management of process flows and there are several methods used for planning, organizing, monitoring, and optimizing complex design projects like Critical Path Method (CPM), Programme Evaluation Review Technique (PERT), Gantt charts and Critical Path Method. However, the most commonly used CPM approach is based on workflow and is not effective in handling iterations, which is a characteristic of design projects. Dependency Structure Matrix, or Design Structure Matrix (DSM), a new technique for the description of information flow is a useful tool to analyze complex engineering projects. A DSM is a square matrix that shows relationships between elements in a system and is a network modeling tool used to represent the elements comprising a system and their interactions. This paper is intended to review the current trends in researches based on DSM.

1.1 Dependency Structure Matrix (DSM)

A DSM is a square matrix where the diagonal cells typically represent the system elements and the off-diagonal cells represent relationships among the elements. In the matrix layout the system element names are placed down the side of the matrix as row headings and across the top as column headings in the same order. If there exists an edge from node i to node j, then the value of element in row i, column j is marked with an X or considered as unity. Such DSM containing single kind of off-diagonal mark is called as binary DSM.

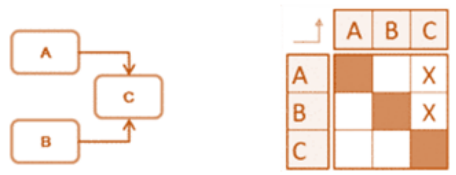

Fig -1: Binary Matrix Representation

A numerical DSM is the one in which weighted dependencies of the elements are represented. In such a case, a numerical DSM is used. Equally, an additional column can be used to represent the weight of an element. Also symbols, shadings, or colors instead of just the binary marks can be used in each of the off-diagonal cells.

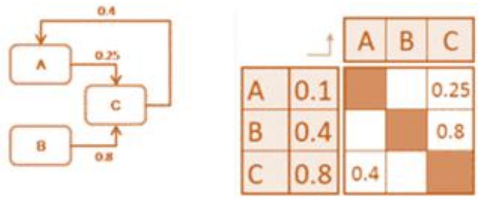

Fig -2: Numerical Matrix Representation

1.2 Types of DSM

Almost all DSM models to date may be classified into four types within two main categories [1]. The first category consists of static architecture models, representing systems whose elements exist simultaneously. Types of applications in this category include systems such as products whose components physically interact with one another and organizations whose members communicate with one another. These are called as Product DSM and Organisation DSM respectively. The second category consists of systems whose elements may be actuated over time such as types of processes, represented as activity-based process models and low-level parameter-based models. These are called Process DSM and Parameter DSM respectively. Scheduling of an information flow in a project can be done by the Process DSM Model and researches on the same are reviewed in this paper.

2. ADVANCES AND INNOVATIONS IN PROCESS DSM

Cheng H et al. (2011) proposed an optimization model of task assignment problem, which incorporates factors like multiskilled employees and their skill levels, task iteration and the precedence constraints. The relative skill levels of employees were modeled by fuzzy numbers, and membership function is introduced to describe the confidential levels of the duration the task takes. The research intended to minimize the duration of the project and balance the workloads of the employees attending the project. A genetic algorithm is utilized to find the optimum solution with regards to the considered objectives. A case of a die product development project is used to illustrate the problem the results verify the feasibility and effectiveness of this algorithm.

Gunawan I et al. (2012) developed a model for improving planning, execution and management of complex engineering projects using DSM methods. DSM methods can be applied to identify loops or circuits for project scheduling improvement. As a case study, path searching method, powers of the adjacency matrix and the reachability matrix methods were implemented to reduce design iterations or rework in a complex engineering project. By applying the DSM methods, the project duration was minimized and hence the total cost of the project was reduced significantly.

Shi Q et al.(2012) proposed a fuzzy approach for DSM-based project scheduling to address the problem that the overlap caused by the vagueness and impreciseness of information dependency between activities. This algorithm is regarded as another branch of fuzzy approaches for project scheduling with its purpose to solve the problem of fuzzy interdependent relationships between activities caused by information flow rather than general work flow. The researchers describe the overlap and duration of activities as fuzzy numbers and put forth a systematic algorithm to calculate the time variables of activities. An example was provided to demonstrate the effectiveness of the algorithm.

Senthilkumar V et al. (2013) proposed a structured methodology called design interface management system (diMs) to form the drawing design structure matrix. This study utilized a case study approach to test the effectiveness of the diMs methodology and tool to manage the design interface processes. The effectiveness was tested by comparing the design interface management criteria of two design groups (a test group and a control group) working on a two separate but similar projects. The testing was conducted through a comparative study of two design cases of a large airport design process. The performance of the design management process of the test group that used diMs was compared with the control group that used existing design management practices

Srour I M et al. (2013) proposed framework to schedule the design phase of construction projects by capturing and using the experience of practitioners. The research presented a four-step process for scheduling the design phase of fast-tracked construction projects while taking into consideration information exchange among project activities. The process starts with capturing and quantifying this exchange of dependency information. Dependency structure matrix aids in generating the shortest schedule based on dependencies among the different design disciplines. An algorithm is designed to calculate the shortest possible schedule for the design phase of a construction project. The algorithm was validated in the context of a real-world case study, a fast-tracked multi-billion dollar educational facility project in the Arabian Peninsula.

Qian Y et al. (2014) proposed scheduling technique to find an activity sequence that minimizes the total feedback length using DSM method, for the development of pressure reducers in a Chinese company. Seventy two activities involved in the projects were identified and then established the information dependencies among the activities and build a DSM. The interrelated activities are reorganized with the objective of minimizing total feedback lengths. Application results have shown that the complex information relations among activities in pressure reducer design can be clearly represented by the DSM.

Zhang Y et al. (2014) proposed the Reward Markov Chain method to do accurate duration estimation for projects that contain iterative processes. The research discusses the applicability of DSM to prefabrication projects. An example model that demonstrates the application of DSM is then developed and used to demonstrate determining an optimal schedule in terms of total feedback distance. The research has not considered the overlapped iteration and further work is required to validate the approach against a comprehensive set of case studies drawn from industry.

Gaertner T et al. (2014) proposed the method which is intended to improve the planning of project timelines and required resources and capacities. It is done to ensure tighter synchronization between the project teams, to serve as a guide for prioritizing tasks in parallel projects, as well as to serve as a basis for anticipating changes to the project stages when development changes or delays need to be accommodated. A project schedule for functional integration projects in the automotive industry was developed which were determined by multi-level dependencies, iterative processing, limited resources, last-minute changes, and a multi-project working environment

Lin J et al. (2015) describes an effective approach for determining the activity sequence with minimum total feedback time using a design structure matrix (DSM) in identifying an appropriate sequence of many coupled activities for managing product development projects. A new formulation of the optimization problem is proposed, which allows us to obtain optimal solutions in a reasonable amount of time for problems up to forty coupled activities. Also rules are proposed, which can be conveniently used by management to reduce the total feedback time.

Piccolo S et al. (2018) developed a methodology to aggregate multiple data sources into a Multiple Domain Matrix formed from the DSM and show that its structural properties correlate with task execution time. The research combined and analysed multiple data sources from a large-scale design project, showing that task completion time relates to the structure of the project as captured by a Multiple Domain Matrix (MDM). Statistical analyses showed that task execution time correlates positively with the size of the task, the number of interfaces with other tasks, and the number of people allocated to the task

3. CONCLUSIONS

The design and development of complex engineering products require the efforts and collaboration of hundreds of participants from diverse backgrounds resulting in complex relationships among both people and tasks. Many of the traditional project management tools like Programme Evaluation Review Technique, Gantt Charts, and Critical Path Method do not address problems arising from this complexity. While these tools allow the modelling of sequential and parallel processes, they fail to address feedback and iteration, which is common in complex product development (PD) projects. To address this issue, matrix-based tool called the Design Structure Matrix (DSM) has evolved. This method differs from traditional project-management tools because it focuses on representing information flows rather than work flows.

DSM provides an effective representation for process systems of activities and their interactions. DSM method due to its advantages in good system representation and analysis techniques have led to their increasing use in a variety of contexts, including product development, project planning, project management, systems engineering, and organization design. The different researchers have applied DSM techniques on scheduling of prefabrication or modular construction, MEP systems, rework scenarios in AEC (Architecture, Engineering Construction) Industry, Healthcare services, and in manufacturing industries. Some researches emphasized on reducing the cycle time, thereby reducing cost whereas some researches aimed at improved time estimates. Different algorithms were used in solving the matrix and new algorithms were proposed in some of the researches.

Researchers are developing new capabilities to extract data from other sources to build system models rapidly. Further work is also needed to broaden the understanding, acceptance, and adoption of DSM into the mainstream methods of project management.

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