The Design Structure Matrix (DSM)

Numerical DSMs

In binary DSM notation (where the matrix is populated with "ones" & "zeros" or "X" marks & empty cells) a single attribute was used to convey relationships between different system elements–namely, the "existence" attribute which signifies the existence or absence of a dependency between the different elements.

Compared to binary DSMs, Numerical DSMs (NDSM) could contain a multitude of attributes that provide more detailed information on the relationships between the different system elements. An improved description or capture of these relationships provides a better understanding of the system and allows for the development of more complex and practical partitioning and tearing algorithms. As an example, consider the case where task B depends on information from task A. However, if this information is predictable or have little impact on task B, then the information dependency could be eliminated. Binary DSMs lack the richness of such an argument.

Possible attributes and measures that can be used:

- Level Numbers: Steward (compare *Steward, D. V.: The Design structure system: A method for managing the design of complex systems, IEEE Trans. Eng. Manage., vol. 28, pp. 71-74, 1981*) suggested the use of level numbers instead of a simple "X" mark, for certain marks in the binary matrix. Level numbers reflect the order in which the feedback marks should be torn. The mark with the highest level number will be torn first (q.v., "tearing," discussed above) and the matrix is reordered (i.e., partitioned or sequenced) again. This process is repeated until all feedback marks disappear. Level numbers range from 1 to 9 depending on the engineers judgment of where a good estimate, for a missing information piece, can be made.

- Importance Ratings: A simple verbal scale can be constructed to differentiate between different important levels of the "X" marks. As an example, we can define a 3-level scale as follows:

Numeric Scale	Meaning
1	High Dependency
2	Medium Dependency
3	Low Dependency

Some other attributes depend on the type of DSM used in the representation and analysis of the problem.

For example, in an Activity-based DSM, the following measures can be used (see also *Browning, T. R., Eppinger, S. D.: Modeling Impacts of Process Architecture on Cost and Schedule Risk in Product Development, IEEE Transactions on Engineering Management, 49(4), 2002, pp. 428-442*):

- Dependency Strength: This can be a measure between 0 and 1, where 1 represents an extremely strong dependency. The matrix can, now, be partitioned by minimizing the sum of the dependency strengths below the diagonal.

- Volume of Information Transferred: An actual measure of the volume of the information exchanged (measured in bits) may be utilized in the DSM. Partitioning of such a DSM would require a minimization of the cumulative volume of the feedback information.

- Variability of Information Exchanged: A variability measure can be devised to reflect the uncertainty in the information exchanged between tasks. This measure can be the statistical variance of outputs for that task accumulated from previous executions of the task (or a similar one). However, if we lack such historical data, a subjective measure can be devised to reflect this variability in task outputs (Compare *Yassine, Falkenburg, A. D., Chelst, K.: Engineering design management: An information structure approach, International Journal of Production Research, vol. 37, 1999*).

- Probability of Repetition: This number reflects the probability of one activity causing rework in another. Feedback relationships represent the probability of having to loop back (i.e. iteration) to earlier (upstream) activities after a downstream activity was performed, while feed-forward relationships can represent the probability of a second-order rework following an iteration.

- Partitioning algorithms can be devised to order the tasks in this DSM such that the probability of iteration or the project duration is minimized. Browning (2002) devised a simulation algorithm to perform such a task. An excel macro that performs Monte Carlo simulation of the DSM is available to download in the tool section (https://dsmweborg.wordpress.com/excel-macros-for-partitioning-und-simulation/).

- Impact strength: This can be visualized as the fraction of the original work that has to be repeated should an iteration occur. This measure is usually utilized in conjunction with the probability of repetition measure, above, to simulate the effect of iterations on project duration.