# A New Approach for Classifying Cross-functional Teams in Product Development Projects

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#### Abstract

Developing a complex product in a concurrent engineering environment requires managing information flow among ten or even hundreds of people of different specialties organized in a large number of cross-function product development (PD) teams. This paper proposes an approach based on centrality measures in social networks for modeling and analyzing the information flows among PD teams. One advantage of this approach is that it enables PD project managers to identity the key PD teams based on a proposed new classification system that classifies PD teams under four categories: autonomous, receivers, transmitters, and transceivers. A demonstrative example adapted from the literature is presented.

#### **Keywords**

Concurrent Engineering, Product Development Projects, Information Flows, Social Network Analysis

# 1. Introduction

To overcome the limitation of a lengthy and traditional serial product development process, many companies opted to adopt concurrent engineering—a management and engineering philosophy for product development that emerged in the 1980s (Creese and Moore 1990). In addition to shortening product development time, and thus time to the market, the reported benefits of this practice include reduced costs, fewer engineering changes, reduction of defects, rework and scrap, higher quality and return on assets (Lawson and Karandikar 1994).

In concurrent engineering, the product development process can be accelerated through performing overlapped activities simultaneously by cross-functional product development (PD) teams. These teams need to continuously exchange information on specified tasks to integrate the product's final structure (Batallas and Yassine 2006). Performing overlapped activities simultaneously necessary for accelerating the development process, but, at the same time, it increases the complexity of communication and coordination among PD teams (Loch and Terwiesch 1998), especially those PD teams involved in the development of complex products—such as automobiles, airplanes, and others—which require the involvement of hundreds or even thousands of specialists. For instance, the number of people involved in developing an automobile can reach over 1600, whereas the number of those working on the development of an airplane can reach over 16,0000 (Smith and Eppinger 1998). Therefore, effective information flow is one of the most important success factors in PD (Newman 2001; Yang et al. 2014). The first step towards this achievement is to have a modeling tool for capturing and analyzing information flows among PD teams. A brief review of the studies that have addressed this issue is given below.

# 2. Literature Review

McCord and Eppinger (1993) provide, perhaps, one of the earliest studies tackling the the issue of how to capture and analyze information flows among PD teams. In that study, Design structure matrix (DSM) was used to capture the frequency and direction of information flow among PD teams in an automobile engine development project. Browning (1998; 1999) investigated mechanisms among cross-functional PD teams and then applied it to the development of a

Boeing F/A-18E/F program. This study was then complemented by the work of Eppinger (2001), in which clustering was used to reorganize the PD teams to improve in-stream integration. In Batallas and Yassine (2006), DSM usage is complemented with social network analysis (SNA) in order to identify critical team players in PD networks as well as to form an information leaders team—a central team that can deal with large amounts of information, which can often cause a system bottleneck. Most recently, Yang et al. (2014) proposed to use a DSM based approach for measuring interaction strength among PD teams, and then to use a two-stage clustering criterion model for clustering organizational units in order to reduce coordination time.

It is clear from the above brief review that few studies have dealt with issue of modeling and analyzing information flows among PD teams. The most common tools in these studies are DSM and SNA. DSM was originally developed by Steward (1981) for representing the interactions among components of system, product, or process. Since then, DSM has become one of the most widely used modeling frameworks across several areas of research, including engineering management, engineering design, systems engineering, and management/organization science (Browning, 2016). A traditional DSM is an  $n \ge n$  square matrix, where n is the number of elements to be modeled (e.g., PD teams). In this matrix, the elements are listed at the top and along the left-hand side. If element *i* depends on element *j* (e.g., PD team *i* needs information from PD team *j*), then a mark "•" or "×" is inserted in cell  $e_{ij}$ . Otherwise, cell  $e_{ij}$  is left blank. Alternatively, "ones" and "zeros" are used instead of marks and empty cells. In some DSM applications, the weighted relationships among actors are considered. One of the limitations of DSM is that it does not reveal accumulated or multilevel interdependencies. Thus, it was found unsuitable for the management of the complexity and interdependency of research and development projects (Laslo, 2010).

SNA was the other tool used for modeling and analyzing information flow among PD teams. Early SNA applications had foundations in sociology, anthropology, and psychology (Tichy, Tushman, & Fombrun, 1979); because of that, most of these applications were in the field of sociometry. However, in the past three decades, SNA has been increasingly applied to modeling interactions among non-human objects. A major step in the use of SNA is to visualize the relationships among the actors—the objects being investigated, such as people, organizations, factors, etc. In addition to visualizing the problem, SNA involves analyzing the structure of the network using a set of network-level measures and node-level measures. Degree centrality, closeness centrality, betweenness centrality, and four brokerage measures (internal coordinator, external coordinator, gatekeeper, and liaison), which were used by Batallas and Yassine (2006), are examples of node-level measures. However, the main limitation of the study by Batallas and Yassine (2006) is the use of binary relations (0 or 1) to quantify information flows among PD teams in addition to the use of a large number of measures.

# 3. Research Objectives

Taking into account the highlighted limitations of relevant previous studies, this current paper proposes an approach that models information flows among PD teams by a weighted SNA. Then based on in-degree centrality and outdegree centrality measures, PD teams are classified into four categories: autonomous, receivers, transmitters, and transceivers. This classification system helps PD project managers in identifying the key PD teams. Therefore, using a weighted SNA for modeling information flows and proposing a new classification system based on two measures only are the contributions of this study.

# 4. The Proposed Approach

The proposed approach for analyzing interdependencies among PD teams involves three major steps: (1) mapping of interdependencies, (2) constructing a network, and (3) performing quantitative analysis. These steps are explained through a demonstrative example adapted from McCord and Eppinger (1993), which involves redesigning a small block V-8 automotive engine at General Motors.

#### 4.1 Mapping of Interdependencies

In this step, an  $n \ge n$  adjacency matrix is prepared, where n represents the number of PD teams. In this demonstrative example, 22 cross-functional PD teams were formed, and each was assigned to work on the design of the following major components and systems:

- 1. Engine Block
- 2. Cylinder Heads
- 3. Camshaft/Valve Train
- 4. Pistons
- 5. Connecting Rods
- 6. Crankshaft
- 7. Flywheel
- 8. Accessory Drive

- 9. Lubrication
- 10. Water Pump/Cooling
- 11. Intake Manifold
- 12. Exhaust
- 13. E.G.R.
- 14. Air Cleaner
- 15. A.I.R.

- 16. Fuel System
- 17. Throttle Body
- 18. EVAP
- 19. Ignition
- 20. Engine control module
- 21. Electrical System
- 22. Engine Assembly

A cross-functional PD team was defined as a group of people with different specialties who work together and hold regular meetings.

The elements of the adjacency matrix are weights representing the frequency of information exchange. If there is an information flow from PD team *i* to PD team *j*, then element  $e_{ij}$  (the element in row *i* and column *j*) is assigned 5, 3, or 1; otherwise,  $e_{ij}$  takes a zero value. Whereas 5 means high frequency of information exchange, 3 means medium frequency of information exchange, and 1 means low frequency of information exchange. For instance, in the prepared adjacency matrix shown in Figure 1,  $e_{26} = 3$  means that the frequency of information flow from PD team 2 to PD team 6 was rated as medium

PD Teams	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1. Engine Block	0	5	5	5	3	5	1	5	5	5	3	1	1	0	1	0	0	0	5	1	5	3
2. Cylinder Heads	5	0	5	5	1	3	0	5	1	5	5	5	3	1	0	0	0	0	5	1	1	5
3. Camshaft/Valve Train	5	5	0	3	0	1	0	1	3	3	1	0	0	0	0	0	0	0	5	1	3	3
4. Pistons	5	3	1	0	5	5	0	0	3	3	0	0	0	0	0	0	0	0	1	0	1	5
5. Connecting Rods	1	0	0	3	0	5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3
6. Crankshaft	5	1	1	3	5	0	5	3	3	0	0	0	0	0	0	0	0	0	5	3	1	5
7. Flywheel	1	0	0	1	0	5	0	0	1	0	0	0	0	0	0	0	0	0	5	1	3	3
8. Accessory Drive	5	5	0	0	0	3	0	0	1	5	5	1	1	5	5	3	3	0	3	1	1	3
9. Lubrication	5	1	3	3	3	5	1	1	0	3	1	1	0	0	0	0	0	0	1	1	3	5
10 Water Pump/Cooling	5	5	1	3	1	1	0	5	1	0	5	1	1	0	1	1	3	0	1	5	1	3
11. Intake Manifold	1	5	1	1	0	0	0	5	0	3	0	5	5	5	3	5	5	1	3	3	1	5
12. Exhaust	1	5	0	0	0	0	0	3	1	0	5	0	5	1	5	0	0	0	5	1	5	3
13. E.G.R.	1	1	0	0	0	0	0	3	0	1	5	5	0	0	1	1	3	0	1	3	1	3
14. Air Cleaner	0	0	0	0	0	0	0	3	0	1	3	1	0	0	3	1	5	0	0	0	0	0
15 A.I.R.	0	3	0	0	0	0	0	5	0	0	3	5	1	5	0	1	1	0	0	3	1	3
16. Fuel System	0	3	0	3	0	0	0	5	0	1	5	3	1	1	0	0	3	3	5	5	3	5
17. Throttle Body	0	1	0	0	0	0	0	5	0	1	5	0	1	5	1	1	0	5	1	3	0	3
18. EVAP	0	0	0	0	0	0	0	1	0	0	5	0	0	0	0	1	5	0	0	5	1	1
19. Ignition	5	3	1	1	0	3	0	1	1	0	3	3	1	0	0	0	1	0	0	5	5	1
20 E.C.M	0	0	0	0	0	1	0	1	0	0	3	3	5	0	3	0	5	3	5	0	5	3
21. Electrical System	5	1	1	0	0	0	3	1	3	1	0	1	1	0	1	3	0	1	5	5	0	5
22. Engine Assembly	3	5	3	5	3	3	3	3	5	3	5	3	3	0	3	3	3	0	5	3	5	0

Figure 1. Adjacency matrix

#### 4.2 Network Visualization

In order to comprehend the interactions among the PD teams in the project, it would be useful to convert the adjacency matrix to a network consisting of nodes and arcs—where the nodes represent the teams, and the arcs represent the existence of information flows among them. A visualized network can be useful for improving the decision makers' performances in such tasks as detecting and comparing trends or discovering patterns of information flows among PD teams. The network can be easily plotted using any of the SNA software packages with inputting an adjacency matrix. These packages often have several features related to network plotting— including the ability to display the weights on the arcs, to make an arc thickness reflecting the weight, to plot node size by out-degree or in-degree values, and other abilities. For the demonstrative example, the Social Network Visualizer (SocNetV) software package was used for constructing the network shown in Figure 2 as well as for performing all the computations presented here. In this network, the nodes are sized to reflect their corresponding out-degree values. Accordingly, as reflected by its node sizes, PD team 22 has the maximum out-degree values.



Figure 2. Interactions among PD teams

#### 4.3 Quantitative Analysis and Results

In this step, the interdependencies among PD teams in terms of information flows are analyzed using in-degree centrality and out-degree centrality measures. These measures are indicators of the extent to which PD teams depend on others in terms of receiving and transmitting information. The in-degree centrality of PD team j can be computed by adding all the values of column j of the adjacency matrix, whereas the out-degree centrality of factor i can be computed by adding all the values of row i of the adjacency matrix. The computed out-degree centrality and in-degree centrality values for the demonstrative example are given in Table 1.

In order to classify PD teams, a plot is constructed to represent the values of out-degree versus in-degree centrality. Similarly to the driving power-dependence diagram used in cross-impact matrix multiplication applied to classification (MICMAC), the plot is divided into four quadrants (Al Zaabi and Bashir 2018). As shown in Figure 3, the first quadrant contains teams 4, 5, 6, 7, 9, 12, 13, 14, 15, and 17. These PD teams have relatively low out-degree centrality and relatively low in-degree centrality; therefore, they can be classified as autonomous PD teams. The second quadrant contains PD teams with relatively low out-degree centrality but relatively high in-degree centrality (classified as receivers). These teams are 19, 20, and 21. The third quadrant contains transceivers (PD teams 1, 2, 8, 11, and 22),

which have relatively high out-degree and in-degree centrality. The fourth quadrant contains transmitters (PD teams 10 and 16): these have relatively high out-degree centrality but low in-degree centrality.

Autonomous PD teams have the least amount of information exchange with other PD teams. On the other hand, transceivers acquire/send information from/to other many PD teams. Therefore, mangers should pay particular attention to streamlining information exchange between transceivers and other teams to avoid possible project bottlenecks, but they should also keep in mind that these PD teams have opportunities to become potential project integrators and innovation diffusers (Kazanjian et al. 2000).

PD Team	In-degree centrality	Out-Degree centrality	PD Team	In-degree centrality	Out-Degree centrality
1	53	59	12	38	40
2	52	56	13	29	29
3	22	34	14	23	17
4	36	32	15	27	31
5	21	13	16	20	46
6	40	40	17	37	32
7	13	20	18	13	19
8	56	50	19	61	34
9	29	37	20	50	37
10	35	44	21	46	37
11	62	57	22	70	69

Table 1. In-degree and out-degree centrality values



Figure 3. Out-in-degree centrality diagram

# 5. Conclusions

Modeling and analyzing information flows among PD teams is a challenging issue for PD projects. Design structure matrix and social networks analysis were found to be most commonly used tools in the literature. Taking into account some limitations of previous relevant studies, this paper presented an approach for modeling information flows among PD teams consisting of three major steps: mapping interdependencies, network visualization and then classifying the PD teams according to their in-degree and out-degree centrality values into four categories—autonomous, receivers,

transmitters, and transceivers. The usefulness of the proposed approach was demonstrated through an illustrative example adapted from the literature and involving a PD project comprising of 22 PD teams working on developing an automobile engine.

Lastly, in addition to the measures used in this study and in previous studies, there are likely other measures that may be useful for analyzing information flows and other metrics that may be useful for analyzing interdependences from different perspectives. This could be explored in a future study.

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#### **Biography**

Hamdi Bashir received his Ph.D. degree in 2000 from McGill University, Montreal, Canada. Currently, he is an Associate Professor of Industrial Engineering and Engineering Management at the University of Sharjah. Prior to joining this university, Dr. Bashir has held faculty positions at Sultan Qaboos University, University of Alberta, and Concordia University. During his academic career, Dr. Bashir has taught a wide variety of courses related to industrial engineering and

engineering management at both undergraduate and postgraduate levels. Dr. Bashir's research interests are in the areas of: Project management (portfolio management, stakeholder management, and project performance), Manufacturing systems (design of cellular manufacturing systems and applications of group technology), Quality management (total quality management (TQM) and excellence models), and Health care management (industrial Engineering applications in health care systems). Dr. Bashir is a senior member of the Institute of Industrial Engineers (IIE) and he was a registered professional engineer with Association of Professional Engineers, Geologists, and Geophysicists of Alberta (APEGGA), Canada.