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.

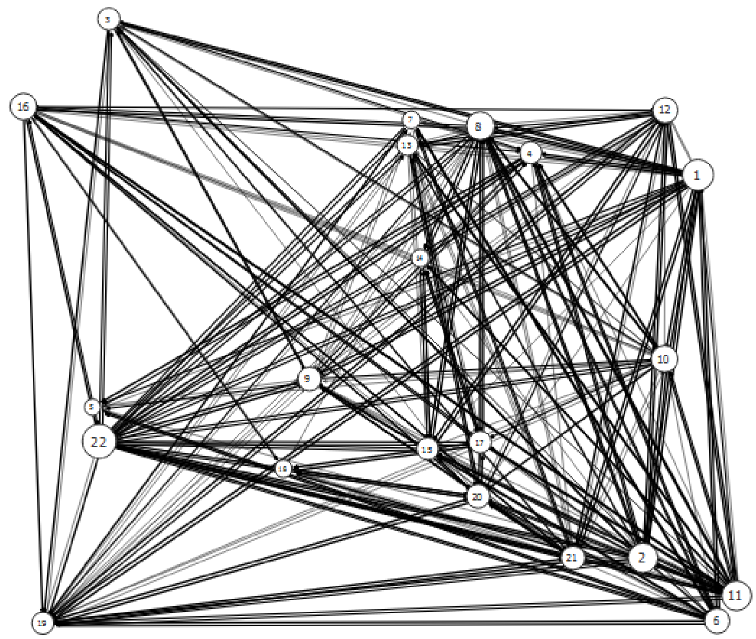

Figure 2. Interactions among PD teams

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).

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

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

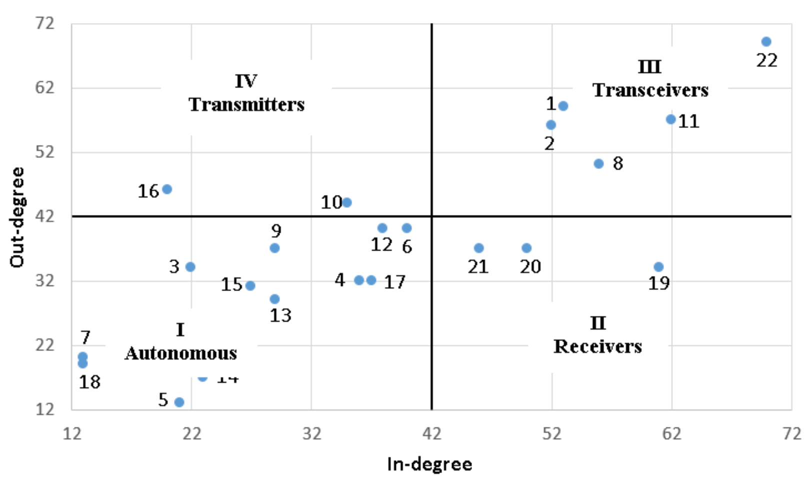

Figure 3. Out-in-degree centrality diagram

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

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