Data Analysis Procedure

Overview

Our analysis explores the impact of employee connectivity within Silicon's R&D department on the outcomes of team projects. By investigating knowledge exchange patterns among team members, we identify key connectivity metrics that can potentially enhance project performance. The assessment is designed to discover the relationship between employee's connectivity indicators with teams' project success, duration of project and project novelty.

Steps of the Analysis

Using data from Q1 2024 on team structures and project outcomes, alongside knowledge exchange network data from Q4 2023, we observed that the connections and information shared among employees in 2023 contributed significantly to the performance of newly formed teams in 2024. This finding underscores the importance of past collaboration in shaping future team success.
To explore this further, we analyzed several key metrics that indicate the level of connectivity for each team member:

- **Node Degree:** This metric reflects the number of colleagues an employee interacts with, providing insight into their direct connectivity within the network (networkx.org, n.d.).
- **Clustering Coefficient:** This measures the density of connections within an employee's immediate network, indicating the extent to which they are embedded in a cohesive group. Higher values suggest that the employee is in a tightly communicated network, which implies stronger bondings and collaboration between team members (Hansen et al., 2011).
- **Burt's Constraint:** This metric measures the redundancy of information available to an employee. Higher constraint values suggest that an employee's connections are well-connected and that the employee has less access to unique and independent sources of information. Lower constraint values suggest that an employee is likely positioned as a bridge, offering him/her access to diverse, non-overlapping information (Everett and Borgatti, 2020).
- **Node Betweenness Centrality (NBC):** This indicates how often an employee serves as a bridge or broker in the flow of information across the department. Higher NBC scores imply a central role in facilitating communication between different individuals or groups. (Hansen et al., 2020)
- **Team Size:** Team size is considered to understand its potential impact on project outcomes, providing a contextual dimension for team dynamics.

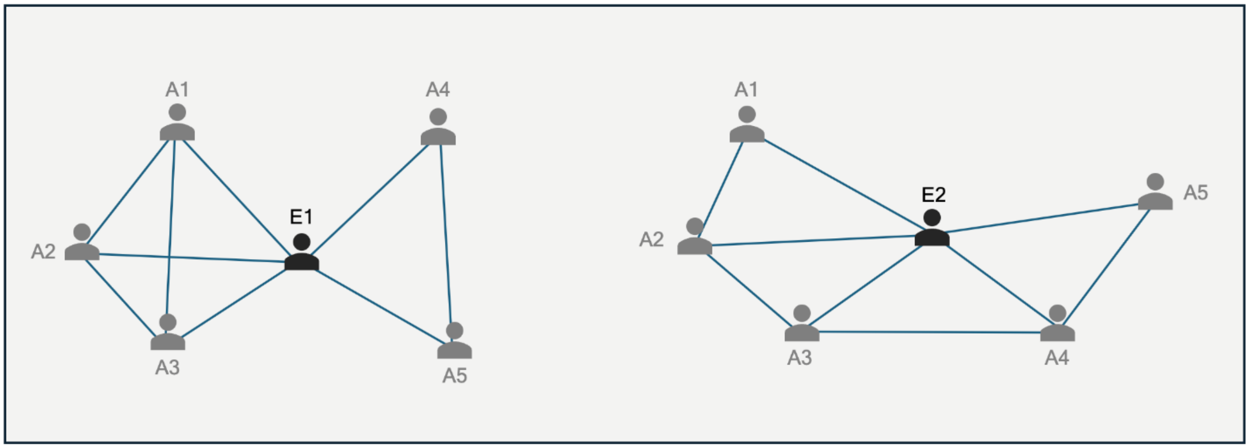

Figure 1,Individual connectivity metrics representation

As illustrated in the graph above, employee E1 and E2 share the same Node degree and the same Clustering Coefficient, but exhibit different NBC and Burt's constraint, indicating different levels of access to non-redundant information. Therefore, we decided that it is necessary to investigate all 4 metrics to have the most comprehensive view of each team's capabilities to accomplish their projects.

Once these individual metrics were collected, we aggregated them at the team level to evaluate the "bonding" and "bridging" capital of each team. This aggregation allowed us to assess the relative connectivity strength of each team across the R&D department. By examining these team-level metrics, we could observe variations in performance and identify teams with particularly strong or weak collaborative structures.

To further investigate the relationship between connectivity metrics and project outcomes, we performed a regression analysis correlating the indicators with key performance measures: success rate, project duration, and innovation. The analysis revealed several key metrics that significantly contribute to project outcomes. From these findings, we were able to draw conclusions about the importance of specific connectivity factors and offer actionable recommendations for Silicon's R&D teams.

Results

Defining Economic Efficiency

For Silicon's R&D Department we have classified economic efficiency (EE) in the following formula:

$$EE = \frac{Outcome}{Cost} = \frac{Success\ Rate * Novelty\ Score}{Team\ Size * Duration}$$

EE is an attempt of maximizing the outcomes of being a successful project, while considering the novelty of the project, while trying to minimize the duration of the project and manpower to achieve it.

Initial Relationships

We first began our investigation on team related data in the first quarter of 2024, namely we analyzed the project outcomes in relation to the size of each team.

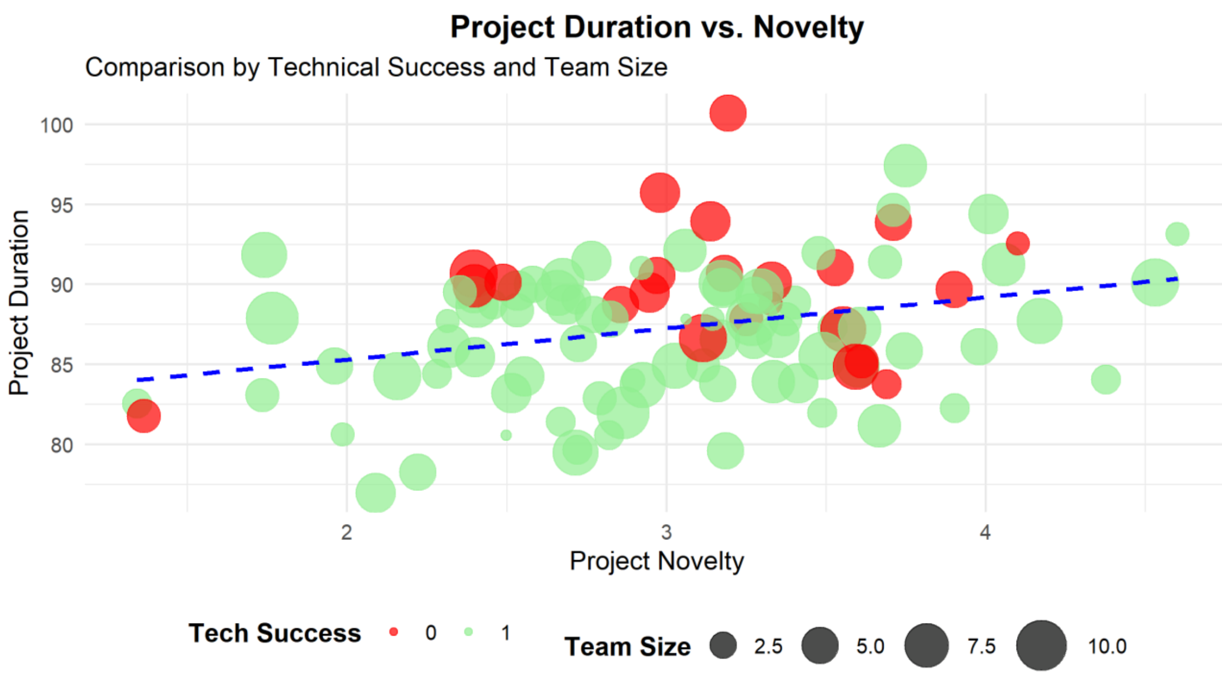

Figure 2, Exploration of team dynamics and outcomes

Figure 2 displays a general trend of novelty increasing with duration, the colors also show the predominance of abandoned project being above the fitted line, illustrating how a longer duration can be an indication of a project being abandoned. Team size, however, displayed by the size of the points, is uncorrelated to the project outcomes.

Knowledge Exchange Network

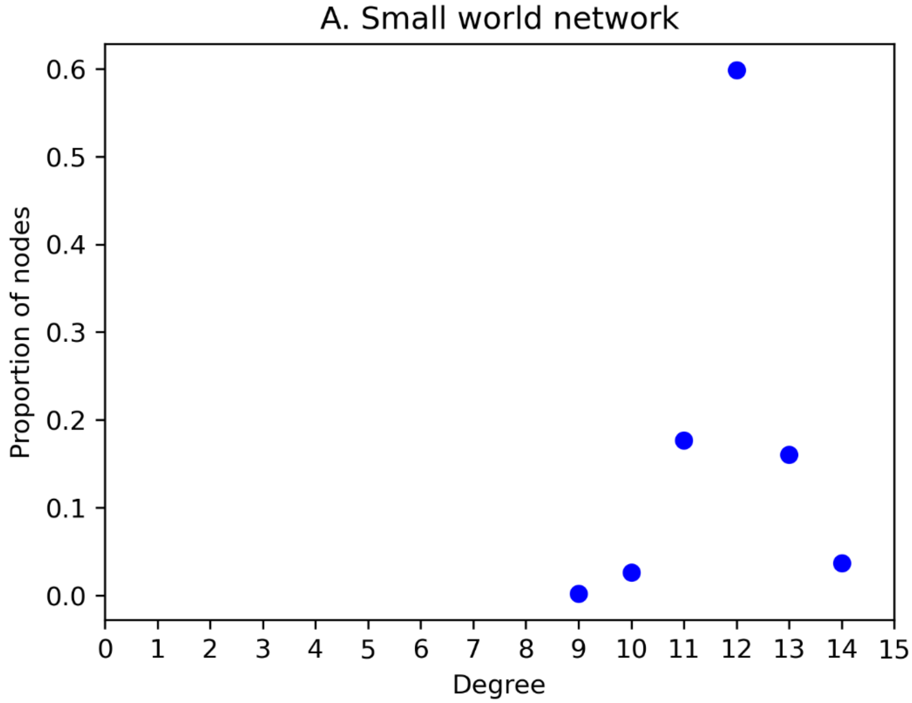

Figure 3, Distribution of node degrees in KE network Q4 2023

The node degrees within the Knowledge Exchange of Q4 2023 generally follow a normal distribution with a mean of 12 degrees or connections, with a range from 9-14 degrees. This illustrates that individuals were highly connected in this period and were exchanging information to many colleagues in the department regardless of their position.

This provides an important insight that this network is dense, and knowledge sharing is highly common, meaning the delivery of unique information from other teams isn't necessarily attributed to a lead engineer or information broker.

In addition, according to the survey in comparison to the employees in Q1 2024, the employee with ID 0 is no longer part of the R&D department, and no information on employee 543's connection in the previous quarter are available.

Statistical Evidence

To follow on and statistically cement the relationships between variables we have run multiple linear regression models, which include the team level network metrics: node betweenness centrality, clustering coefficients, node degree, and Burt's Constraint. We separated our analysis to identify how the experience in Q4 2023 impacted Q1 2024 project outcomes.

We begin by looking at all our variables as predictors and their respective variance inflation factors (VIF), which measures the correlation of a predictor with the rest of the predictor groups. We removed the variables with the highest VIF scores incrementally until no score was higher than 5 to avoid any multicollinearity in the model.

Table 1, VIF scores for collinearity testing among independent variables

Predictor variable	Team ID	Team Size	Employee ID	Node degree	Clustering Coefficient	Burt's Constraint	NBC	Success rate
VIF score	1.06	1.08	1.17	4.43	58.11	66.89	10.73	1.39

The VIF illustrated that the Burts Constraint and Clustering Coefficient were both highly correlated. To alleviate this collinearity, we tested all variables in 2 separate models but found that the only significant variables for Project Novelty and Duration were the four-network metrics calculated.

1. Project Novelty

Table 2, Estimated Beta results for simple linear regressions on Novelty

Independent Variable	*Clustering Coefficient*	*Burt's Constraint*	*Node Betweenness Centrality*	*Node degree*
Beta (p-values)	-7.1 (0.04%)	-30.6 (0.005%)	124.1 (0.01%)	0.4 (5.8%)

The table above shows how the network metrics are all highly significant except for node degree in predicting novelty. As Clustering and Burt's constraint falls, the project has a higher likelihood of being more novel and innovative. This is logical since employees with lower constraints and clustering mean that their connections are more valuable in delivering new information from separated groups. On the other hand, Node betweenness centrality has a positive relationship with novelty, since the more an employee is positioned centrally and has the shortest path to deliver information which leads to that employee gaining lots of new information and perspectives.

The nature of the Novelty scores is subject to management sentiments, views and opinions. These network estimates could not only be a factor on the impact of the novelty of the project, but also could show the impact on manager perspectives.

2. Project Duration

Table 3, Estimated Beta results for simple linear regressions on Duration

Independent Variable	*Clustering Coefficient*	*Burt's Constraint*	*Node Betweenness Centrality*	*Node degree*
Beta (p-values)	-62.7 (0.04%)	-336.6 (1e-8)	1264.3 (1e-8)	-2.7 (3.3%)

Similarly to Project Novelty, the relationship between clustering and Burt's constraint is negatively related to the duration of the project. Meaning as the clustering of an employees' network increases, the duration of the project falls. Whereas the node betweenness centrality has a positive relationship. For the project duration we note that the significance level of the node degree is below 5% and the other variables are highly significant.

3. Project Success Rate

Since the project success rate is a binary variable, we decided to utilize the logistic regression models to avoid any model biases and a more defined predictive model. We ran multiple logistic regression models on all the network analytics as well as project outcomes. The results of the significant variables are below:

Independent Variable	*Clustering Coefficient*	*Burt's Constraint*	*Node Betweenness Centrality*	*Project Duration*
Beta (p-values)	27.3 (2e-4)	121.3 (2e-4)	-459.7 (7e-5)	-0.2 (0.31%)

Clustering and Burt's constraint now have a positive relationship with success, meaning as they increase the likelihood of the project succeeding increases. Whereas as the NBC increases, the likelihood of project success decreases substantially. The project duration was also a significant predictor unlike the novelty, and has a negative relationship too, indicating that higher duration projects are more likely to fail. Since NBC was the most significant, we attempted to visually produce how the logistic model would predict success as seen below ((Liang and Zeger, 1989):

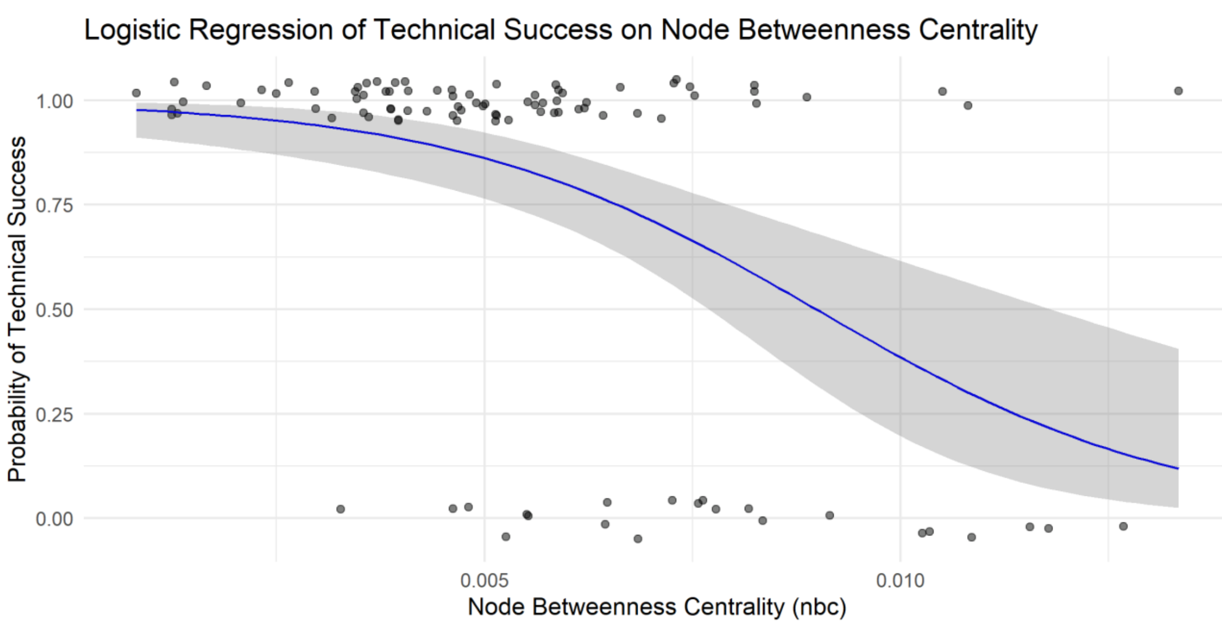

Figure 4, Prediction of Logistic model of success using NBC

Figure 4 illustrates how the low NBC's from the previous quarter tend to be the successful projects of this quarter with some clear outliers.

Summary of results

All the regressions ran above generally passed the post-diagnostic tests, with stochastic and random variance, however, the residuals did fail to accurately resemble a normal distribution. These diagnostics can be found in the Appendix A and B.

Statistically, the knowledge exchange network of the previous quarter does have an impact on this quarter's project outcomes. The Duration and Novelty of the project move in unison with the network metrics. This means that attempting to improve the novelty of projects through the network of employees is likely to also increase the duration of the project and decrease the project's probability of success.

At Silicon's R&D department, where a linear and constant improvement within the microprocessor and transistor industries has been occurring for many years, the balance between the outcome of the R&D teams is essential to maintaining a competitive edge in this market.

Business recommendations

Based on our analysis, we propose a series of actionable recommendations that Silicon can implement to enhance node betweenness centrality and introduce structured quality control checkpoints, while improving clustering and Burt's constraint. These steps aim to boost both the novelty and efficiency of R&D projects, maximizing creative output without extending project timelines unnecessarily.

Increase Node Betweenness Centrality to Foster Innovation

A semiconductor company like Silicon is directly related to the transistor and microprocessor industries, therefore we believe novelty is of utmost importance for Silicon. Moor's Law, stating that the "transistor count per chip continues to double every two years", is a good goal to strive towards. Since improving the efficiency and size of semiconductors would directly and similarly improve transistors. (Hattori, 2021)

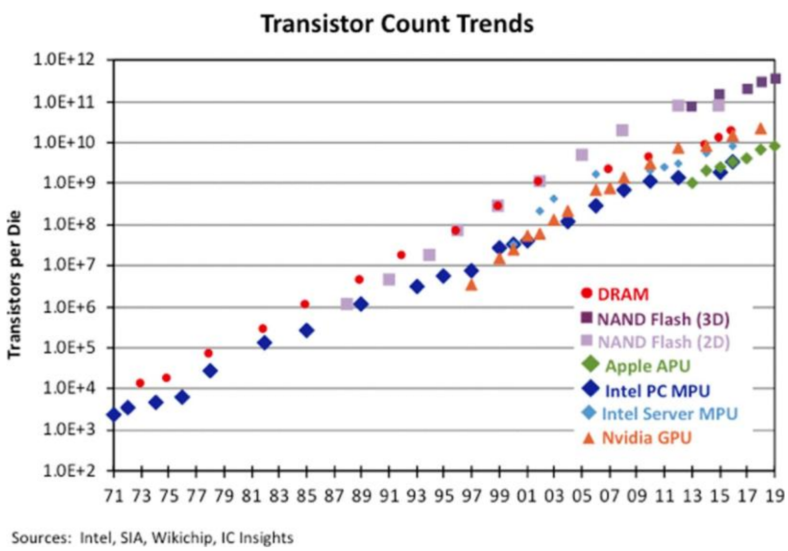

Figure 5, Transistor count trend over 50 years

Figure 5, shows that the trend for Moor's law has remained to be linear even now, therefore, ensuring that Silicon's semiconductors remain in line with the market demands and retains its competitive edge, our primary goal is to improve innovativeness of Silicon's teams.

Node betweenness centrality highlights individuals who act as bridges across different parts of the network, facilitating access to diverse knowledge sources. High centrality allows key team members to connect separate subgroups, fostering innovation by bringing in fresh perspectives. (Freeman, 1977) By increasing centrality strategically, Silicon can enhance project novelty without lengthening timelines (as we found the node betweenness to cause), as more efficient information flows reduce the need for repeated coordination. (Freeman, 1977; Reagans and McEvily, 2003)

Implementation Strategies:

- Appoint "Information Ambassadors": Designating individuals within each team as "information ambassadors" who share insights across projects or departments helps create vital links between groups. These ambassadors encourage knowledge flow that drives innovation without extensive meetings or timeline impacts, as information is exchanged efficiently through central figures. (Obstfeld, 2005) Keeping these knowledge exchange sessions time-limited and scheduled on a weekly or biweekly basis, should improve innovativeness without significant increase in duration. Performing said meeting over virtual medium, should further decrease time spent, but could harm connectiveness. (Obstfeld, 2005; Gawande, 2010)
- Weekly Bulletins: Implementing a medium for the teams to share their progress on a weekly basis and adding a requirement for other teams to review a certain number of other teams' posts (e.g. 5). This exposure brings back new ideas and perspectives to home teams, sparking creativity without introducing coordination complexities, and allows for improvement recommendations sharing. Additionally, implementing cross-team interaction, allowing employees to know other teams' projects is crucial for our recommendation on quality control checkpoints, mentioned later in the report. (Cooper, 1990)

Implement Regular Quality Control Checkpoints

Introducing periodic quality control checkpoints allows Silicon to monitor progress. If a project runs longer than expected, implementing additional progress reports or quality checks can help assess alignment with objectives and identify bottlenecks, ensuring that extended timelines do not compromise project outcomes.

By establishing quality control checks at defined project milestones, Silicon can assess alignment, address challenges early, and ensure the project remains on track. These checkpoints allow highly connected teams to maintain their creative output while avoiding prolonged timelines.

Additionally, as seen on Figure 2, some projects take significantly longer to fail, this increases duration and costs for Silicon R&D. We recommend creating a rigorous quality test at a certain time that assesses the likelihood of the project failing withing the next week. If the project were to fail the test (i.e. failure likelihood is high), Silicon should either abandon the project early or provide additional assistance to ensure success, which would be decided by looking at the opportunity cost of either option. (Tsai, 2001)

In the event of abandoning the project, Silicon can cut the costs associated with the continuation of the project or redistribute the labor and funding to other projects that are succeeding. Returning to 'Weekly Bulletins' mentioned earlier in the report, would allow a more fluid redistribution of labor, since employees will be more knowledgeable about other team's projects.

However, in the event that the project is considered of high importance, where abandonment is highly discouraged, additional support should be directed towards it to improve the project's chances of success. 'Weekly Bulletins' should support this action by keeping teams informed about each other's projects. Although quality control may initially increase duration, the improvement to overall duration and costs that it would yield from abandoning failing projects early, should justify it.

Quality control checkpoints, especially for projects extending beyond anticipated durations, help maintain project standards and manage connectivity-related challenges, ensuring that projects are both innovative and timely.

Further Recommendations for Enhanced Insights and Implementation

To further improve these recommendations, we suggest gathering more information about internal team structures and relationships across R&D teams. Understanding each team's reporting hierarchy would clarify decision-making pathways, improving connectivity and reducing redundant communication (Freeman, 1977). Additionally, mapping relationships between teams (e.g., Team 1 and Team 2) within R&D could reveal opportunities for cross-team synergies, enabling Silicon to maximize knowledge-sharing across projects with related goals.

By implementing these targeted recommendations and gathering further structural insights, Silicon can optimize team connectivity, clustering, and information flow to enhance both innovation and efficiency. These strategies offer Silicon a robust framework to foster creativity and maintain project timelines, ensuring balanced and productive R&D outcomes

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Appendices

Appendix A: Residual plots for Novelty

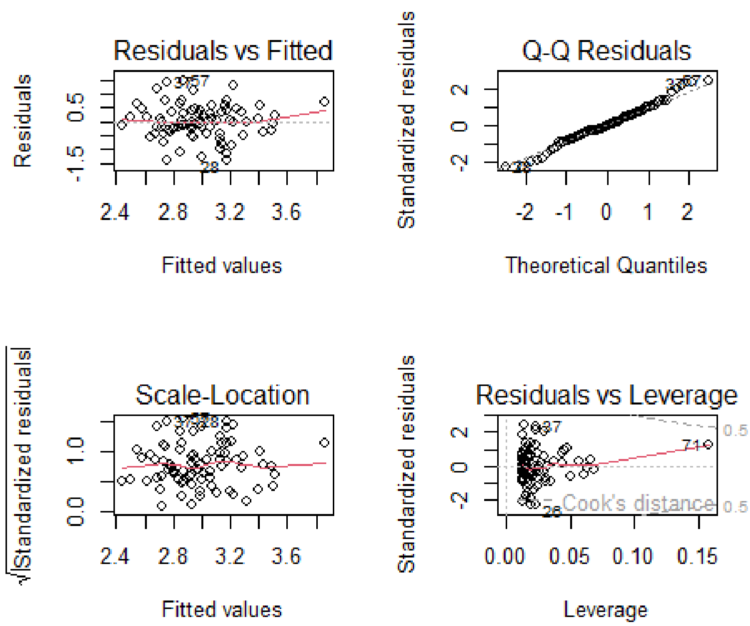

Figure 6: Clustering Coefficient

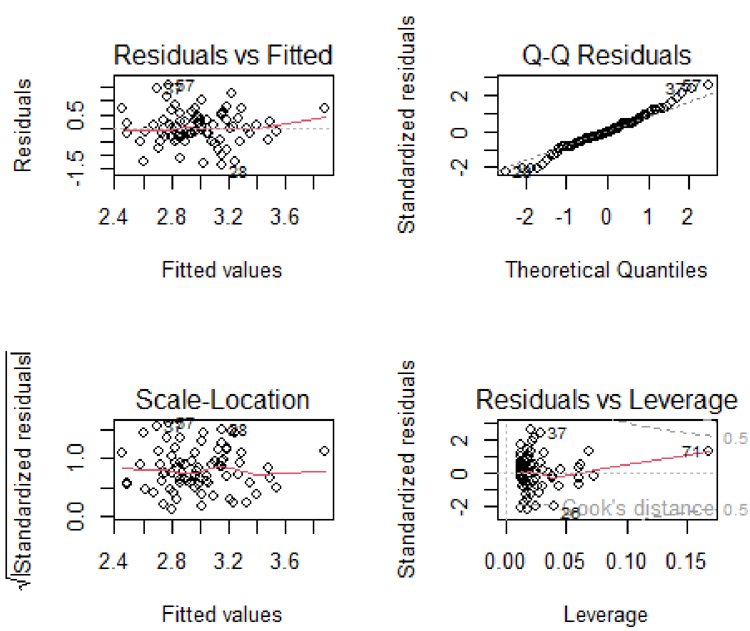

Figure 7: Burt's Constraint

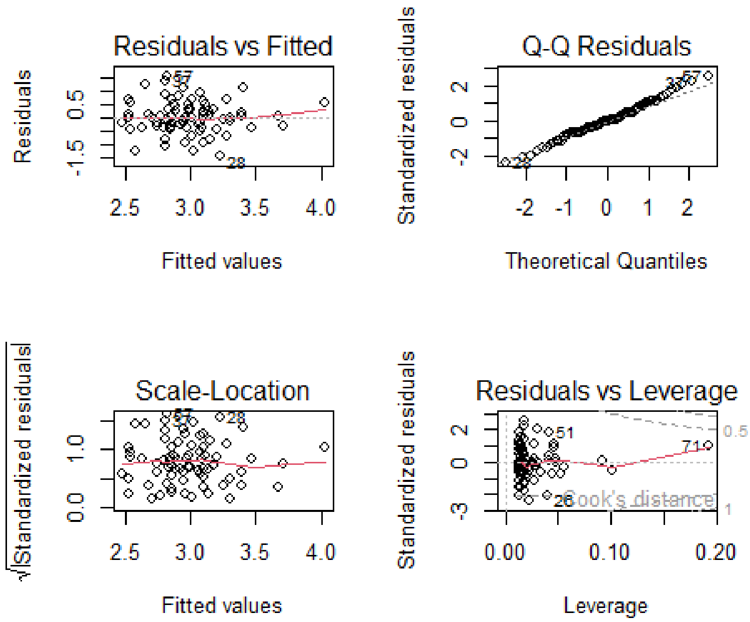

Figure 8: Node Betweenness Centrality

Appendix B: Residual plots for Duration

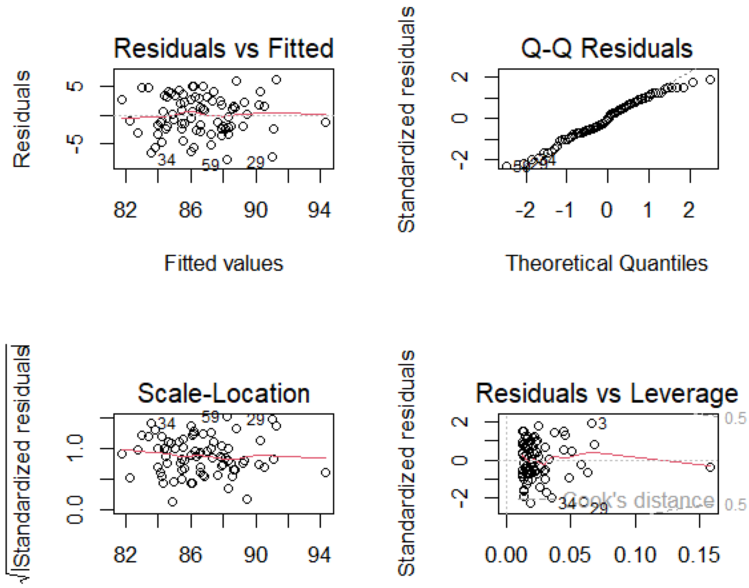

Figure 9: Clustering Coefficient

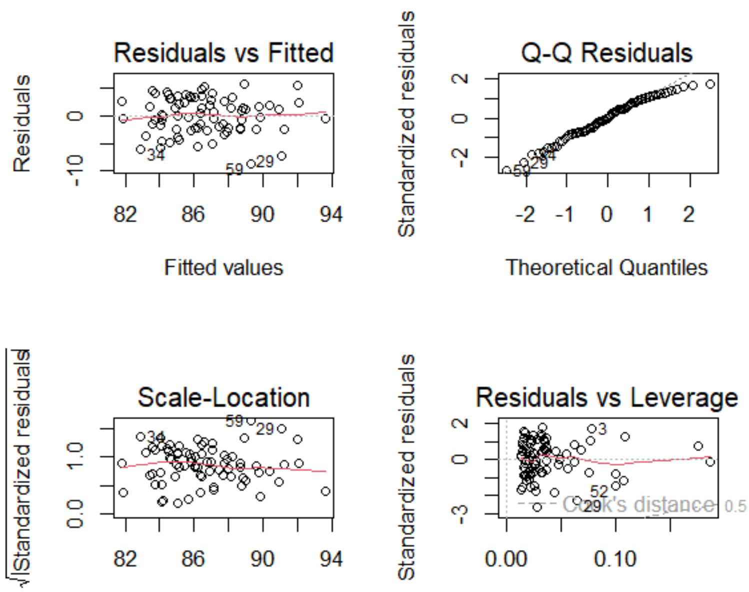

Figure 10: Burt's Constraint

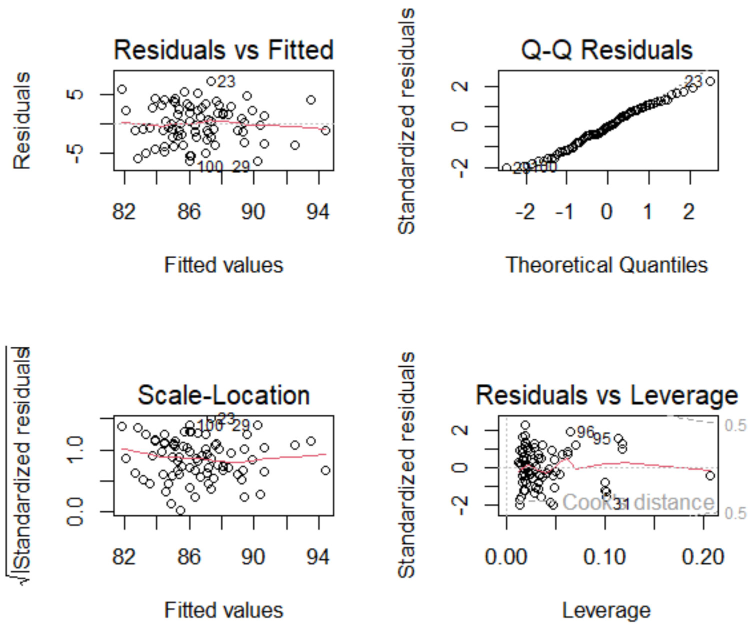

Figure 11: Node Betweenness Centrality