SMM638 — Network Analytics

Final course project submission template

The target business analytics problem of your choice (500 words)

In recent years, Apple has been planning to gradually shift some of its manufacturers outside of China and to parts of Southern Asia, such as India and Vietnam (Malcolm Owen, 2022). The possible reasons are, firstly, China has been implementing strict zero-Covid policies since the coronavirus outbreak, leading to production delays of Apple's products. For example, Apple's largest assembly plant in Zhengzhou, China, was temporarily shut down due to the Chinese government's strict COVID-19 lockdown policies (Monica Miller, 2022). Secondly, tensions between China and the USA have intensified since 2018, causing Apple to face increasing pressure placed by the US government which attempts to cut ties with China (Anna Akins, 2021). Although it is challenging for Apple to reduce its reliance on China, where more than 90% of Apple's products are produced (Jack Ramage, 2022), the rising risks of relying on China have resulted in Apple having to revaluate its supply chain strategy.

Apple supply chain is a global network which is composed of thousands of businesses and facilities across 52 countries, from designing centres, materials suppliers, and assembly plants to retail stores (Apple Annual Progress Report, 2022). In terms of production, around 50% of Apple's suppliers' production sites were in China mainland until 2019 (Josh Horwitz, 2022). Some of the reasons to why China has been playing an important role in Apple's production system include; firstly, China has a huge labour population to support the high demand from Apple's customers (Giovanni Pino, 2018). Secondly, according to GlobalData Thematic Research (2021), most of the suppliers are situated close to Chinese assembly factories, resulting in lowering shipping costs. However, after the coronavirus pandemic, the percentage of Apple's suppliers' production sites in China has declined from 41% to 36% in 2020 and 2021 respectively (Josh Horwitz, 2022), which indicates that Apple is attempting to ease its dependency on China. However, the cost of reshaping the supply chain network is huge, and Apple must consider multiple factors when seeking other alternative production locations, including labour costs, taxes and transportation costs and so on. In addition to the costs, according to Bloomberg analysis (Bryce Baschuk et al., 2022), it is estimated that Apple requires roughly eight years to move merely 10% of production out of China. Hence, it is worth analysing if Apple's recent movement of dumping China is necessary. Should Apple replan its supply chain strategy or keep relying on its long-term friend, China?

The justification for the choice of the problem (300 words)

A set of interconnected organizations whose various processes and activities generate value can be described as a supply chain network (Slack N, Lewis M, 2011). Therefore, it is essential for businesses to design their supply chain network which could help companies achieve their long-term strategic goals.[1] Supply chain network not only shows the flow of materials, goods and information but also the links between organizations such as R&D, suppliers, manufacturers and distributions centres and so on (Tompkins International, 2016). Therefore, designing a supply chain network must consider a variety of different aspects such as logistics and location of facilities. More importantly, finding the shortest-distance distribution on a network is one of the approaches to optimise the supply chain network.

Moreover, it is essential for a business to adjust its supply chain network based on recent global issues happening in the world. For example, the recent trade war between China and the USA and the COVID-19 pandemic had a huge impact on the global supply chain, causing businesses to restructure their supply chain network. In addition, one of the most impactful factors is transportation costs. During the pandemic, shipping costs have dramatically soared between 2020 and 2021 (Yan Carrière-Swallow et al., 2022), rising to approximately 230%. Apple CEO Tim Cook states that the price of freight Apple paid is higher than he expected (Grace Kay, 2021). It is clear that transportation costs are taking up a large percentage of the total business costs nowadays.

For these reasons, it is important to apply network theory to find out some feasible ways for Apple to reduce the transportation costs when diversifying its supply chain network and lower the long-term risks of continuously depending heavily on only a few important nodes.

The network dataset suited to address the chosen problem (500 words)

The network analysis requires a geographical overview of Apple's supply chain network data, and the observed time could be the year before China–United States trade war happened (because we would like to understand the structure of Apple's supply chain before it attempts to shift production sites).

A brief picture of Apple's supply chain is that suppliers provide resources that Apple requires, and those components and materials are shipped to assembly sites (mainly in China). After the products are finished made, they are sent to customers directly from assembly sites or warehouses where the products are distributed to retail stores and other distributors (Quick Book, 2020).

Therefore, on the inbound supply chain aspect, the required data includes Apple’s contracted and partnered suppliers and assembly plants (we exclude the R&D centres and warehouses because we only focus on the production line). Additionally, the attributes included in the nodes contain the exact geographical location of each node (because we would like to know the geographical dispersion of suppliers and assembly plants). The connections of each node not only show the direct movement of materials but also the geographical distance between each node which is considered as edge weights (i.e. when the geographical distance between an assembly plant and a supplier is 10 km, the edge weight is set to ten. In this case, the more weights between two nodes are, the longer the distance is).

The primary reason why we only consider geographical distance between suppliers and assembly plants as the edge weight is that we would like to calculate the transportation cost when suppliers ship material to assembly plants. Plus, in recent years, Apple has been facing huge pressure from rising shipping costs due to the pandemic, in order words, if Apple is seeking other alternative locations to replace China, Apple might attempt to minimize the shipping costs.

Main steps of the analysis (300 words)

Firstly, to identify the geographical disperse of nodes and whether they were categorised as suppliers or assembly sites, we would plot a graph which mapped their relationship with each other. Secondly, we would use NetworkX Python Module to calculate three network parameters (discussed below) to investigate the characteristics of the direct and weighted network:

1. Weighted Degree `Graph.degree()`: calculate the sum of the edge weights for edges incident to that node (Newman, 2010).
2. Degree centrality `degree_centrality()`: calculate the number of edges a node has. The higher the degree, the more central a node is (Newman, 2010).
3. Eigenvector centrality `eigenvector_centrality()`: measure the level of importance of a node within a network. High eigenvector centrality indicates a node is connected to other modes with high eigenvector centrality as well (Jennifer Golbeck, 2013).

The interpretation of each parameter would include the following : the weighted degree of each node measures how far they are close to each other, which will help us understand the distance between suppliers and assembly sites. Further, it could be explained by degree centrality than how many suppliers are needed by which assembly sites. Lastly, the eigenvector centrality would further explain which suppliers or assembly factories are playing an important role in the network.

Once we identify which nodes are assembly plants with a high degree centrality (represented as central authority) or have high eigenvector centrality, we could use the equation below to calculate the average distance between those assembly plants and suppliers which connect with them.

$$Average\ Distance = \frac{Weighted\ Degree}{Degree\ Centrality}$$

Lastly, would be calculating the estimated total transportation cost:

$$Assume\ Transportation\ Cost\ Per\ Kilometer = X$$

$$where\ X\ is\ in\ terms\ of\ US\ dollars\ and\ varing\ depends\ on\ different\ nodes'\ locations$$

$$Total\ Transportation\ Cost = X \times Average\ Distance$$

$$\Rightarrow Total\ Transportation\ Cost = X \times \frac{Weighted\ Degree}{Degree\ Centrality}$$

The justification for each step (600 words)

Plotting the Graph

My first step includes plotting the map graph in order to gain a brief picture of the dispersion of each node, this is essential in order to understand Appel's supply chain strategy. For example, how Apple placed their production sites, based on their suppliers location.

Degree Centrality

The next step includes calculating the degree centrality in order to identify which node the supplier is or an assembly, plant which normally has a high degree centrality. A high degree centrality will indicate that a node has a large number of connections to other nodes in the mentioned network. In this case, it will help me identify which in deify which node would that work as a supplier or as an assembly plant. For example, a node as an assembly plant would normally show a high degree centrality. This means that there are many nodes connected to it. On the other hand, a node which has been identified as a supplier has shown to have a relatively low degree centrality.

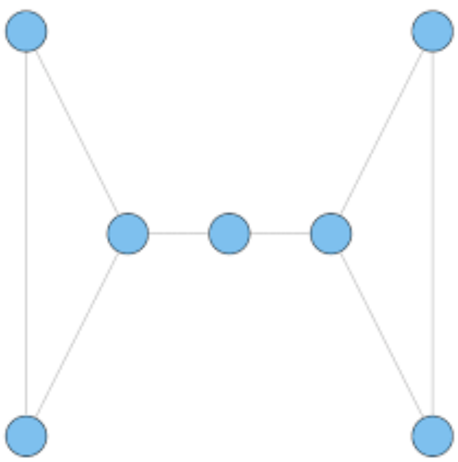

Figure 1. Degree Centrality

Eigenvector Centrality

The next step of my analysis includes measuring the eigenvector centrality. This will reveal the influence of nodes based on the importance of its neighbors in a network. In my project, measuring the eigenvector centrality will help me find the assembly plant or the suppliers which have been playing an influential role in Apple's supply chain network. For example, it essential for Apple to fully consider potential risks when they are attempting to ease its dependency on the important and influential nodes.

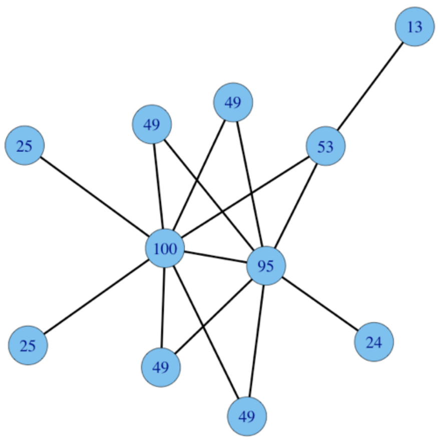

Figure 2. Eigenvector Centrality

Weighted Degree

The last step of my analysis includes measuring the weighted degree in order to obtain the distance between each node. This is needed for the calculation of the average distance.

Total Transportation Costs

The main reason to why we would choose to calculate the total transportation costs is to gain an understanding of the amount production, in addition to the costs of the total shipping. In addition, it reveals how many suppliers we need to support the assembly plant.

Set of possible actionable business analytics emerging from the project (300 words)

Restructuring a supply chain network could not be done overnight, however, having a clear criterion would help Apple to lower their potential risks when they are choosing their next assembly plant destinations. Further, based on the analysis I have mentioned above, on top of the consideration of the number of suppliers an assembly plant would potentially require, Apple would manage to optimize the distance between suppliers and assembly plants in order to reduce the total transportation costs with an affordable price level. Hence, this will be a clear benchmark for Apple to potentially restructure their supply chain network

However, if there are other alternative locations which would not be able to meet the benchmark we derived from the analysis for now, one suggestion for apple would include suspending its plan of moving production sites to the mentioned areas and wait for a more suitable timing to take action. For example, an alternative is when the shipping costs are dropping.

Furthermore, we would be able to identify some important nodes in the network from the analysis. Instead of reducing the reliance on them, an alternative way can include being more feasible when applying, in order to strengthen the relationship between those important nodes and take the precautions to evade abrupt future interruptions in the supply chain network.

References

Newman, M.E.J. (2010). *Networks : an introduction*. Oxford ; New York: Oxford University Press.

Golbeck, J. (2013). *Analyzing the social web*. Amsterdam: Elsevier.

Lewis, N. (2019). *Operations Strategy.* S.L.: Pearson Education Limited.

Büttner, K. and Krieter, J. (2018). Comparison of weighted and unweighted network analysis in the case of a pig trade network in Northern Germany. *Preventive Veterinary Medicine*, 156, pp.49–57.

AppleInsider (2022). *Apple tells suppliers to plan for shift of manufacturing out of China*. Available at: https://appleinsider.com/articles/22/12/03/apple-tells-suppliers-to-plan-for-shift-of-manufacturing-out-of-china [Accessed 13 Dec. 2022].

BBC News (2022), *Apple: iPhone shipments delayed over China Covid lockdown*. Available at: https://www.bbc.co.uk/news/business-63538042 [Accessed 13 Dec. 2022].

Akins, A. (2021). *Apple to face continued pressure to curb reliance on China under Biden – experts*. Available at: https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/apple-to-face-continued-pressure-to-curb-reliance-on-china-under-biden-8211-experts-61817634 [Accessed 13 Dec. 2022].

Ramage, J. (2022). *Apple reportedly aiming to boost production outside China due to COVID*. Available at: https://www.euronews.com/next/2022/05/23/apple-eyes-moving-production-outside-of-china-as-covid-supply-chain-snags-threaten-sales-r [Accessed 13 Dec. 2022].

Apple (2022). *People and Environment in Our Supply Chain*. Available at: https://www.apple.com/supplier-responsibility/pdf/Apple_SR_2022_Progress_Report.pdf [Accessed 13 Dec. 2022].

Horwitz, J. (2022). *Analysis: Apple supply chain data shows receding exposure to China as risks mount*. Available at: https://www.reuters.com/technology/apple-supply-chain-data-shows-receding-exposure-china-risks-mount-2022-11-30/ [Accessed 13 Dec. 2022].

Sourci.com.au. (2018). *Why Does Apple Manufacture in China?* Available at: https://sourci.com.au/blog/why-does-apple-manufacture-in-china/ [Accessed 13 Dec. 2022].

GlobalData Thematic Research (2021). *Apple diversifies supply chain but keeps China at the center - Verdict*. [online] Verdict. Available at: https://www.verdict.co.uk/apple-supply-chain-china/ [Accessed 13 Dec. 2022].

Bloomberg (2022). *Apple's Tech Supply Chain Shows Difficulty of Dumping China*. Available at: https://www.bloomberg.com/news/articles/2022-09-30/apple-s-tech-supply-chain-shows-difficulty-of-dumping-china [Accessed 13 Dec. 2022].

Tompkins International (2016). *What Is Supply Chain Network Design & Why Is It Important?* Available at:

http://www.supplychain247.com/papers/what_is_supply_chain_network_design_why_is_it_important [Accessed 13 Dec. 2022].

Grace Kay (2021). *Tim Cook says Apple is 'paying more for freight' than he'd like, as experts predict shipping costs for businesses have yet to hit their peak*. Available at: https://www.businessinsider.com/tim-cook-apple-paying-more-freight-supply-constraints-ipad-iphone-2021-7?r=US&IR=T [Accessed 13 Dec. 2022].

Quickbooks (2020). *Apple Supply Chain - The Best Supply Chain in the World*. Available at: https://quickbooks.intuit.com/r/supply-chain/apple-the-best-supply-chain-in-the-world/ [Accessed 13 Dec. 2022].

IMF (2022). *How Soaring Shipping Costs Raise Prices Around the World*. [online] Available at: https://www.imf.org/en/Blogs/Articles/2022/03/28/how-soaring-shipping-costs-raise-prices-around-the-world [Accessed 13 Dec. 2022].