This chart presents the **degree distribution of the London Tube Network**. The x represents the degree, the number of direct connections a station has to other stations. The y shows the probability of a station having 'k' connections. The range of 'k' values is too limited to determine the long-tail characteristic of a power law distribution. The majority of stations have 2 connections, the tallest bar, which represents the highest probability. There is a significant drop in probability for stations with 1 or 3 connections, and the probability continues to decrease for stations with more connections.

In an **ER** graph with n nodes, the maximum possible number of edges is "**C n choose 2**" (assuming no self-loops). the maximum number of edges is 95,703. round the probability to 4 decimal places

The **BA model** (show equation)
is based on the idea of network growth. The network starts with a small number of nodes and grows over time by adding new nodes. algorithm continues to grow nodes and edges on initial network. **(show initial_graph code chunk)**
If initial_graph is specified, the algorithm copies this initial network and extends it. If initial_graph is not specified, the algorithm starts from a graph containing (m+1) nodes. First create a small-scale BA model, containing 52 nodes and 100 edges. Then use this small-scale BA model as the initial network, and continue to add nodes and edges based on it according to the growth rule, eventually reaching the same 438 nodes and 486 edges as the Tube network.

The growth rule of the BA model is: each time a new node is added, it is connected to m nodes in the existing network by m edges. m=1, each time a new node is added, it is only connected to 1 node in the existing network. when the number of nodes increases from 52 to 438, the number of edges will increase by 386. The final number of edges is the initial 100 edges + 386 new edges = 486 edges, which is consistent with the Tube network. **(netlogo)**

It is closer to the topology of a real network, because most real networks do not grow from a complete blank, but continue to expand based on an existing small-scale network.

The **average degree** reflects the average number of connections of nodes in the network. The average degrees of the 3 models are very close, the degree of connectivity of the three networks is similar, and the ER and BA models can better simulate real networks in this regard.

The clustering coefficient of the ER model is very low, which is consistent with its random connection characteristics, and nodes rarely form a tight triangle structure.
The clustering coefficient of the BA model is lower because newly added nodes tend to be connected to existing "hub nodes" during the growth process of the BA model and are unlikely to form local clusters.
The clustering coefficient of the London network is significantly higher than that of the

ER and BA models, indicating that in real networks, due to the influence of geographical location, functional areas and other factors, it is easier to form local clusters or community structures between nodes.

The ER model can be used as a "null model" to compare and measure the extent to which other network models or real networks deviate from a completely random state. In the London subway network, although it exhibits scale-free characteristics as a whole, in local areas, the connections between certain stations may be close to a random connection state, reflecting some characteristics of the ER model.

the BA model can better simulate the scale-free and "hub node" characteristics that exist in real networks such as the London Underground network. However, cannot fully reflect all topological properties of the real network. The BA model ignores the constraints on the spatial location of nodes, while the connections of nodes in tube networks are often restricted by geographical location.

It still obeys the power law distribution. the scale-free characteristics of the growth process of the BA model are determined by the preferential attachment mechanism. new nodes subsequently added according to the BA model will be more likely to be connected to existing height nodes (because the probability of height nodes being selected is greater).

Spatial scale-free network model: The spatial location information of nodes is introduced, making the connection probability of distant nodes lower.
Community scale-free network model: takes into account the tendency of nodes to form local communities or clusters.
Adaptive scale-free network model: allows the connection probability of nodes to dynamically change over time, which is closer to the evolution process of the real network.

Spatial scale-free network model:
In NetworkX, spatial scale-free networks can be simulated by storing the location information of nodes as attributes and taking the distance between nodes into account when generating the network. You can use the add_node method provided by NetworkX to add node attributes and then set the connection probability based on the distance between nodes.

Community scale-free network model:
Community scale-free network models take into account the tendency of nodes to form local communities or clusters. You can use the community discovery algorithm provided by NetworkX to detect community structure in a network and consider the influence of these communities when generating the network. For example, you can use the Louvain algorithm or the Girvan-Newman algorithm to detect community structure and set connection probabilities based on the community structure.