# The Topology of Opportunity: Measuring Stepping-Stone Potential in Bureaucratic Mobility Networks of Late Qing (1830–1905)

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**Abstract**

Career mobility is conventionally modeled using statutory rank or hierarchical level as the outcome variable. However, particularly in bureaucratic contexts, the most valuable positions may not be those with the highest statutory rank, but rather the "stepping-stones" that serve as fast-tracks to elite roles. Formal rank often obscures the underlying empirical topology of opportunity, conflating statutory outcomes with a position's structural capacity to generate further mobility. Building on recent network approaches to internal labor markets, we introduce a methodology to compute the structural potential of positions independently of their formal ranks. Applying a modified PageRank algorithm to a mobility network constructed from 2.7 million career records of 130,000 civil officials in the late Qing Dynasty (1830–1905), we extract the empirical stepping-stone potential of bureaucratic posts. Our findings demonstrate two primary mechanisms of bureaucratic stratification. First, at the position level, stepping-stone potential is heavily dictated by hard geographic constraints (monopolized by the central capital) and mid-to-low statutory ranks. These hubs derive their systemic value by functioning as high-turnover structural bottlenecks rather than the elite demographic composition of their occupants. Second, at the individual level, empirical exposure to these high-potential transit hubs independently predicts a significantly higher ultimate career achievement.

## 1 Introduction

A central problem in organizational sociology and social stratification is identifying how labor market structures and individual characteristics interact to shape careers (Spilerman, 1977; Brass, 1984). Conventionally, studies of bureaucratic mobility measure attainment by treating a position's "statutory rank" or hierarchical level as the dependent variable. However, this static metric conflates a position's *formal outcome* with its *structural potential*—its empirical utility as a transit hub to send individuals upward. In complex organizations, formal authority frequently diverges from informal structural power (Brass, 1984). Certain high-ranking posts might act as organizational "sinks" or dead-ends, while mid-to-low-ranking positions might function as

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critical structural stepping-stones that control access to elite endpoints. Relying exclusively on formal rank thus creates a blind spot that obscures the underlying topology of opportunity.

Recent advances in occupational mobility networks emphasize the need to distinguish between dead-end jobs and stepping-stone pathways (Mouw et al., 2024; Cheng and Park, 2020). Yet, current approaches largely focus on dyadic relationships between adjacent careers, neglecting the broader topological structure of the labor market. A true stepping-stone may not directly yield a high-status outcome, but rather route an individual into a sequence of subsequent fast-tracks. This topological chaining is especially pronounced in the Chinese bureaucratic system, which has historically relied on institutionalized fast-tracks—such as the Hanlin Academy in Imperial China (Elman, 1989) or early party membership in modern contexts (Li and Walder, 2001)—to accelerate elite advancement. To accurately map how a bureaucracy functions and how individuals advance, we must measure a position's systemic network *potential* independently of its formal rank.

This study addresses this methodological gap by formalizing a novel network framework to extract the structural potential of bureaucratic posts. We apply this method to the China Government Employee Database-Qing (CGED-Q JSL) (Chen et al., 2020), analyzing the longitudinal personnel mobility of roughly 130,000 civil officials in the late Qing Dynasty (1830–1905). By decoupling structural potential from nominal rank, we provide an empirical reassessment of bureaucratic stratification and elite mobility in late imperial China.

## 2 Methodological Framework: Formalizing Network Potential

To measure structural advantage, we conceptualize the bureaucracy as a directed mobility network. Let $V$ be the set of specific official posts (nodes). The directed edge weight $W_{i \to j}$ represents the observed frequency of transfers from post $i$ to post $j$ within a specific temporal window (see Figure 1). To focus exclusively on inter-positional transitions, self-loops are excluded ($W_{i \to i} = 0$). Our methodology decouples a node's topological centrality (total value) from its statutory attribute (nominal value) via four steps:[1]

[Figure 1 about here.]

**Step 1: Nominal Value ($NV$).** This represents the static baseline power assigned by the formal hierarchy. We construct a mass vector $M$ based on the statutory rank ($r_i$) of the position. For any node $i \in V$: $M_i = f(r_i)$. Normalizing $M$ yields the Nominal Value $NV_i = \frac{M_i}{\sum_{k \in V} M_k}$, such that $\sum NV_i = 1$. In our algorithm, $NV_i$ serves as the reset probability.

**Step 2: Reverse Transition Matrix ($R$).** To measure a position's capacity to supply personnel outward as a stepping-stone, we reverse the directed network (see Figure 2). In the forward network, the total influx to node $j$ is $I_j = \sum_k W_{k \to j}$. In the reverse network, the transition

[1] Our approach to isolating network potential builds upon an unpublished framework by (Wang, 2019), which similarly isolates a position's stepping-stone potential by subtracting its static nominal value from a recursively calculated network value. However, while the model by Wang (2019) iteratively computes this value using time-decayed, forward-looking transition probabilities to target positions, our methodology fundamentally diverges by reversing the directed mobility network to calculate "supply share," explicitly measuring a position's retrospective capacity as a structural bottleneck.

probability $R_{j \to i}$ is defined as:

$$R_{j \to i} = \frac{W_{i \to j}}{I_j} \tag{1}$$

$R_{j \to i}$ empirically measures node $i$'s "supply share" to node $j$. If $j$ is a highly valuable elite node and nearly all of its personnel originate from $i$, then $R_{j \to i} \approx 1$, indicating $i$'s structural monopoly over access to $j$.

**Step 3: Total Network Value ($TV$).** We utilize a Personalized PageRank algorithm (Page et al., 1999; Haveliwala, 2003) on the reverse network to calculate the dynamic topological value of nodes. Given a damping factor $\alpha$, which we set to be 0.7, the recursive equation for node $i$'s Total Value ($TV_i$) is:

$$TV_i = (1 - \alpha) \cdot NV_i + \alpha \sum_{j \in V} (TV_j \cdot R_{j \to i}) \tag{2}$$

A position's network power comprises its baseline statutory probability plus the discounted network power of all target positions $j$ that it supplies. Through recursive convergence, the value of all downstream chains is compressed into node $i$'s score.

**Step 4: Stepping-Stone Potential ($SP$).** To isolate pure structural advantage, we subtract the position's expected Nominal Value from its Total Network Value:

$$SP_i = TV_i - NV_i \tag{3}$$

If $SP_i > 0$, the post controls promotion pathways exceeding its static rank expectations; it is an empirical stepping-stone. We convert the absolute $SP$ scores into a network-wide percentile rank ($P \in [0, 1]$) as our standardized dependent variable, ensuring strict cross-temporal comparability.

## 3 Results

We utilize the methodology to analyze the CGED-Q JSL dataset (Chen et al., 2020) by treating each distinct bureaucratic office as a node and the volume of personnel transitioning between nodes as directed edge weights. In the Qing imperial system, statutory rank (*Pinji*) is assigned numerically from 1a (highest, coded 1.0) to 9b (lowest, coded 9.5). Marginal, unranked positions are coded as 10.0. To manage the high geographic dispersion of the data (over a thousand local counties) without losing structural fidelity, we aggregate local officials by combining the province and the core office type into a single node. For central officials, we combine the central department (e.g., specific Ministries, Grand Council) and the core office.

The analysis proceeds in three stages. First, we identify the empirical stepping-stones in the network. Second, we conduct a position-level analysis to determine the structural and compositional predictors of a high-potential node. Third, we conduct a person-level analysis to evaluate whether exposure to a high-potential position correlates with higher career achievement.

### 3.1 Identifying Empirical Stepping-Stones

To substantively ground the algorithmic outputs, Table 1 presents a selection of the highest-potential nodes identified in the global mobility network. The results empirically validate a complete structural decoupling of formal statutory rank and actual network potential. The absolute top nodes in the Qing bureaucracy are not the highest-ranking ministers (e.g., Ranks 1.0 to 3.0), but rather mid-level central government roles (Ranks 4.0 to 7.0), such as Compilers and Bachelors in the Hanlin Academy, Secretariat Drafters, and Investigating Censors. These findings align precisely with the historiography of the Qing civil service. The Hanlin Academy functioned as the supreme institutional incubator for the bureaucratic elite (Ho, 1962; Elman, 1989), although these positions themselves carried modest statutory ranks. The algorithmic identification of these specific positions demonstrates that the network metric successfully recovers the underlying administrative design.

Furthermore, Table 1 highlights the varied composition of local stepping-stones. High-potential non-central nodes include mid-ranking regional administrators in vital metropolitan or economic areas, such as Circuit Intendants (*Daoyuan*) in Zhili and Jiangsu. Intriguingly, the data also reveals the high structural potential of unranked, marginal local positions (coded 10.0), such as District Jailor (*Dianshi*) in peripheral provinces like Guizhou and Guangdong. This suggests these lowest-tier grassroots positions may also function as high-volume entry or flexible transit points.

[Table 1 about here.]

### 3.2 Position-Level Determinants: Geography over Composition

What makes a position a stepping-stone? To rule out the possibility that network potential is merely a proxy for the concentration of elite individuals who possess systematic educational or ethnic advantages, we aggregate the data to the position level ($N = 528$; filtered for positions with $\geq 20$ historical appointees). We regress a position's stepping-stone potential (percentile) on its static structural traits (geography and statutory rank) and its demographic composition (the standardized historical proportion of occupants holding specific credentials or ethnic identities).

The OLS results in Table 2 demonstrate that stepping-stone potential is heavily dictated by hard physical constraints rather than the elite traits of a position's occupants. Geographically, positions in the central capital (Beijing) possess a structural monopoly over mobility hubs. Provincial postings exhibit significant negative penalties relative to the capital (e.g., Zhejiang $\beta = -0.285$; Guizhou $\beta = -0.235$; $p < 0.001$). Furthermore, mid-to-low tier statutory ranks have strong positive effects on network potential relative to high ranks ($\beta = 0.226$ and 0.395, respectively), reinforcing the "transit" nature of mid-level administration.

Crucially, the personnel composition of a position does not positively predict its network utility. Positions with higher historical proportions of Manchu officials or elite *Jinshi* degree holders exhibit strict null correlations with stepping-stone percentiles ($\beta = -0.001$ and 0.010, respectively; $p > 0.5$). This indicates that a position's systemic value is derived fundamentally from its institutional placement in the bureaucratic flow, not simply because it was reserved for elites. Interestingly, a higher proportion of *Liyuan* (clerk) qualifications positively predicts a position's stepping-stone potential ($\beta = 0.047$, $p < 0.05$). While *Liyuan* represents a low-prestige background, this finding reinforces that a position's stepping-stone potential is driven by its structural functionality rather than the cultural or ethnic capital of its occupants. These nodes likely operated as high-volume administrative bottlenecks, allowing elite officials to rapidly accumulate essential governance experience before advancing.

[Table 2 about here.]

### 3.3 Individual Returns to Stepping-Stone Exposure

To determine whether exposure to these structural hubs actually translates to better career outcomes, we shift the analytical unit to the individual official ($N = 10,106$; filtered for officials with $\geq 2$ recorded jobs). Table 3 regresses an individual's ultimate career ceiling (their best, or numerically lowest, *Pinji* achieved) on whether they ever passed through a top 10% stepping-stone position.

Even after controlling for an individual's starting advantages (initial rank and geographic region of the position), mobility frequency (total jobs), and individual capital (qualification and ethnicity), having ever occupied a top 10% hub is significantly correlated with reaching a higher ultimate rank ($\beta = -0.585$, $p < 0.001$, meaning more than half level higher). Because bureaucratic assignments were rarely exogenous, we cannot interpret the stepping-stone coefficient as a strict causal treatment effect. However, the robust correlation affirms that empirical stepping-stones operate as genuine accelerators in the bureaucratic life course, independent of formal entry credentials.

[Table 3 about here.]

## 4 Future Works

While our findings demonstrate the analytical value of decoupling structural potential from statutory rank to map bureaucratic mobility, several avenues remain for ongoing development.

First, we are exploring the temporal dynamics of these high-potential positions. With the weakening of state capacity in the Late Qing period, particularly following the systemic crises of the 1860s, preliminary macro-historical evidence points toward increasing bureaucratic stagnation (Campbell and Gao, 2024). We intend to investigate how the structural properties of these stepping-stone positions evolved under such macro-level crises. Specifically, whether access to these critical mobility conduits contracted, exhibiting increased social closure along ethnic or educational lines as the organizational environment deteriorated. Second, we plan to systematically evaluate the robustness of our modified PageRank algorithm. This entails benchmarking our metric against alternative global network centrality measures (such as betweenness or eigenvector centrality), as well as conducting sensitivity analyses across varying hyperparameters and transition-weighting assumptions Third, we aim to address the methodological scope conditions of this approach, particularly regarding data scarcity. While our current dataset spans over seven decades, contemporary intra-organizational data is rarely as longitudinally rich. We will simulate data scarcity by artificially constraining our time windows (e.g., analyzing only five to ten years of mobility data) to test whether our network approach remains a robust proxy for structural potential. This will broaden the methodology's applicability to modern labor markets. In conclusion, we are continuing to refine these structural models, and we will present the full results at the SSHA in Atlanta.

## References


Brass, D. J. (1984). Being in the right place: A structural analysis of individual influence in an organization. *Administrative Science Quarterly 29*(4), 518–539.

Campbell, C. and S. Gao (2024, February). The organizational demography of the qing civil service, 1830-1911. *Social Science Research (Shehui Kexue Yanjiu) 1*, 157–169, 212.

Chen, B., C. Campbell, Y. Ren, and J. Lee (2020). Big data for the study of qing officialdom: The china government employee database-qing (cged-q). *Journal of Chinese History 4*(2), 431–460.

Cheng, S. and B. Park (2020). Flows and boundaries: A network approach to studying occupational mobility in the labor market. *American Journal of Sociology 126*(3), 577–631.

Elman, B. A. (1989). Imperial politics and confucian societies in late imperial china: The hanlin and donglin academies. *Modern China 15*(4), 379–418.

Haveliwala, T. (2003). Topic-sensitive pagerank: a context-sensitive ranking algorithm for web search. *IEEE Transactions on Knowledge and Data Engineering 15*(4), 784–796.

Ho, P.-T. (1962). *The Ladder of Success in Imperial China: Aspects of Social Mobility, 1368–1911.* New York: Columbia University Press.

Li, B. and A. Walder (2001). Career advancement as party patronage: Sponsored mobility into the chinese administrative elite, 1949–1996. *American Journal of Sociology 106*(5), 1371–1408.

Mouw, T., A. L. Kalleberg, and M. A. Schultz (2024). "stepping-stone" versus "dead-end" jobs: Occupational structure, work experience, and mobility out of low-wage jobs. *American Sociological Review 89*(2), 298–345.

Page, L., S. Brin, R. Motwani, and T. Winograd (1999, November). The pagerank citation ranking: Bringing order to the web. Technical Report 1999-66, Stanford InfoLab. Previous number = SIDL-WP-1999-0120.

Spilerman, S. (1977). Careers, labor market structure, and socioeconomic achievement. *American Journal of Sociology 83*(3), 551–593.

Wang, Y. (2019). Analyzing career trajectories of Qing dynasty civil servants with data mining and machine learning. Unpublished manuscript.

# List of Figures

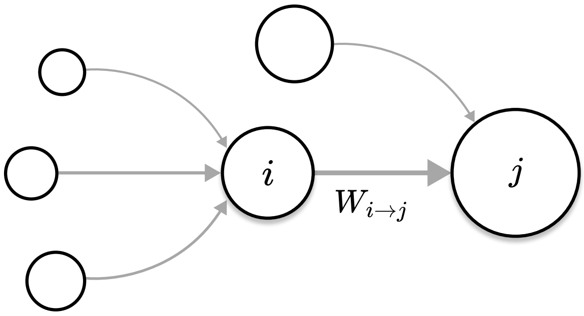


Figure 1: Forward mobility transitions. Edge weights ($W_{i \to j}$) represent the observed volume of personnel moving from position $i$ to $j$.

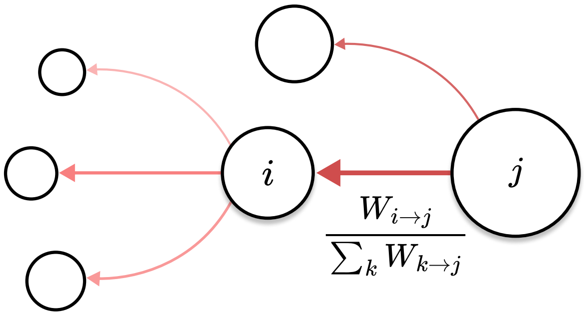


Figure 2: The reversed mobility network. Edges are inverted to calculate the supply share, identifying structural stepping-stones.

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Table 1: Selected High-Potential Stepping-Stone Nodes in the Global Network (1830–1905)

| **Node (Office / Department)** | **Statutory Rank (*Pinji*)** | **Potential Percentile** |
|---|---|---|
| *Top Central Stepping-Stones* | | |
| Compiler, Hanlin Academy (*Bianxiu*) | 7.0 | 100.0% |
| Bachelor, Hanlin Academy (*Shujishi*) | 7.0 | 99.9% |
| Secretariat Drafter, Grand Secretariat (*Zhongshu*) | 7.0 | 99.8% |
| Drafter, Grand Secretariat (*Zhongshu sheren*) | 7.0 | 99.7% |
| Investigating Censor, Censorate (*Jiancha yushi*) | 5.0 | 99.6% |
| *Top Local Stepping-Stones* | | |
| Circuit Intendant, Zhili Province (*Daoyuan*) | 4.0 | 97.4% |
| Circuit Intendant, Jiangsu Province (*Daoyuan*) | 4.0 | 96.5% |
| District Jailor, Guizhou Province (*Dianshi*) | 10.0 (unranked) | 95.9% |
| District Jailor, Guangdong Province (*Dianshi*) | 10.0 (unranked) | 95.2% |
| Director of Studies, Zhili Province (*Jiaoyu*) | 8.0 | 95.0% |

Note: Rank (*Pinji*) is numeric, where a lower number indicates a higher statuary rank. Unranked positions are coded as 10.0.

Table 2: Position-Level Predictors of Stepping-Stone Potential ($N = 528$)

| | **OLS Model** (DV: Network Percentile) | |
|---|---|---|
| **Variable** | **Coef.** | **(S.E.)** |
| *Personnel Composition (Z-Scored)* | | |
| Pct. Manchu | −0.001 | (0.018) |
| Pct. *Jinshi* | 0.010 | (0.016) |
| Pct. *Juren* | 0.019 | (0.015) |
| Pct. *Gongsheng* | 0.029* | (0.014) |
| Pct. *Jiansheng* | −0.009 | (0.020) |
| Pct. Clerk (*Liyuan*) | 0.047* | (0.019) |
| Pct. *Shengyuan* | −0.017 | (0.011) |
| *Static Position Traits* | | |
| Region: Shengjing (Ref: Beijing) | 0.007 | (0.062) |
| Region: Zhili | −0.173** | (0.054) |
| Region: Zhejiang | −0.285*** | (0.067) |
| Region: Guizhou | −0.235*** | (0.065) |
| ... | ... | ... |
| Stat. Rank: Low (Ref: High) | 0.395*** | (0.045) |
| Stat. Rank: Medium | 0.226*** | (0.034) |
| Intercept | 0.466*** | (0.040) |
| $R^2$ | 0.397 | |

Standard errors in parentheses. Regional controls include all provinces; selected provinces shown for brevity. Personnel composition variables are standardized (Z-scores).

$^{*}p < 0.05, ^{**}p < 0.01, ^{***}p < 0.001$

Table 3: Individual-Level OLS Model Predicting Career Ceiling ($N = 10,106$)

| | **Model 2: OLS** (DV: Best *Pinji* Attained) | |
|---|---|---|
| **Variable** | **Coef.** | **(S.E.)** |
| *High Potential Exposure* | | |
| Ever occupied Top 10% Positions | $-0.585^{***}$ | (0.050) |
| *Individual Capital* | | |
| Ethnicity: Manchu (Ref: Han) | $-0.354^{***}$ | (0.039) |
| Qualification: *Jinshi* (Ref: *Juren*) | $-0.657^{***}$ | (0.066) |
| Qualification: *Jiansheng* | $-0.419^{***}$ | (0.065) |
| Qualification: *Liyuan*) | $-0.484^{**}$ | (0.155) |
| ... | ... | ... |
| *Career Controls* | | |
| Total Jobs Held | $-0.063^{***}$ | (0.004) |
| Start Rank: Low (Ref: High) | $5.218^{***}$ | (0.100) |
| Start Rank: Medium | $2.972^{***}$ | (0.093) |
| Intercept | $2.770^{***}$ | (0.113) |
| Starting Region Fixed Effects | Included | |
| $R^2$ / Adjusted $R^2$ | 0.399 / 0.397 | |

*Notes:* Lower *Pinji* values indicate higher bureaucratic status.
Additional qualifications and regions are controlled but omitted for brevity.
$^{***}$ $p < 0.001$, $^{**}$ $p < 0.01$, $^{*}$ $p < 0.05$.