Intact Tombs Analysis Final Report

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Abstract

This study analyzes intact and nearly intact New Kingdom tombs from Thebes to assess whether burial assemblages can be placed into well-defined groupings based on the socioeconomic statuses of those within them. Building on Smith's (1992) "manually" established tomb groupings, we employ several multivariate statistical approaches, including PERMANOVA, PERMDISP, pairwise distance analysis, and K-Means clustering, to evaluate the consistency and distinctiveness of these groupings. While PERMANOVA suggests significant group differences, PERMDISP reveals high variance in group dispersions, debunking those results. Pairwise distance analysis supports Smith's classifications, showing lower within-group variability and higher between-group differences. In contrast, the K-Means algorithm produces alternative clusters driven less by total tomb valuation and social dynamics and more by the specific composition of burial goods, identifying distinct provisioning patterns related to fertility items, furniture, and vessels. Together, these approaches offer complementary perspectives on both systemic and individualized aspects of funerary behavior in the New Kingdom.

Data Overview

The dataset includes 134 New Kingdom tombs primarily excavated from Thebes, as documented in Smith (1992). These tombs span the 17th and 18th Dynasties and reflect a wide socioeconomic spectrum, from royal burials to modest graves. Smith's sample includes burials from key sites such as the Valley of the Kings, Deir el-Medineh, Sheikh Abd el-Qurna, Khokha, and several pit complexes excavated by the Metropolitan Museum of Art. The dataset we use in our analysis contains information for each tomb regarding the total tomb value, and the value of the different types of provisions contained within the tomb. Tomb valuations are based on the quality, quantity, and type of grave goods, including coffins, canopic equipment, professional tools, furniture, jewelry, provisions, vessels, and other personal or ritual objects.

Manual Tomb Groupings

Smith (1992) groups the 134 into five socioeconomic classes based on the valuation and scope of the tomb provisioning. The following classifications are provided:

Tutankhamen: The tomb of Tutankhamen, grouped on its own as by far the most luxurious tomb.

Elite Status: Yuya & Tuya, Kha & Merit, Mahirper

High Middle Status: Nakht, Khay, Hatnofer, Neferkhewet, Renofer, Ruyu, Boki, Amenemheb, Siamun, Hentut'u, Mahy, Bakiset, Taat, Tahuty, Ahotep, Hatiay, Setau, S&N, Petrie

Middle Status: Harmose, Mentuhotep, DeM 1389, DeM 1381, DeM 1380, DeM 1377, DeM 1375, # 78 f, # 53 m, # 18 ?, M+, SR+, Amenemhet, B+, Ramose, Maya, Nub

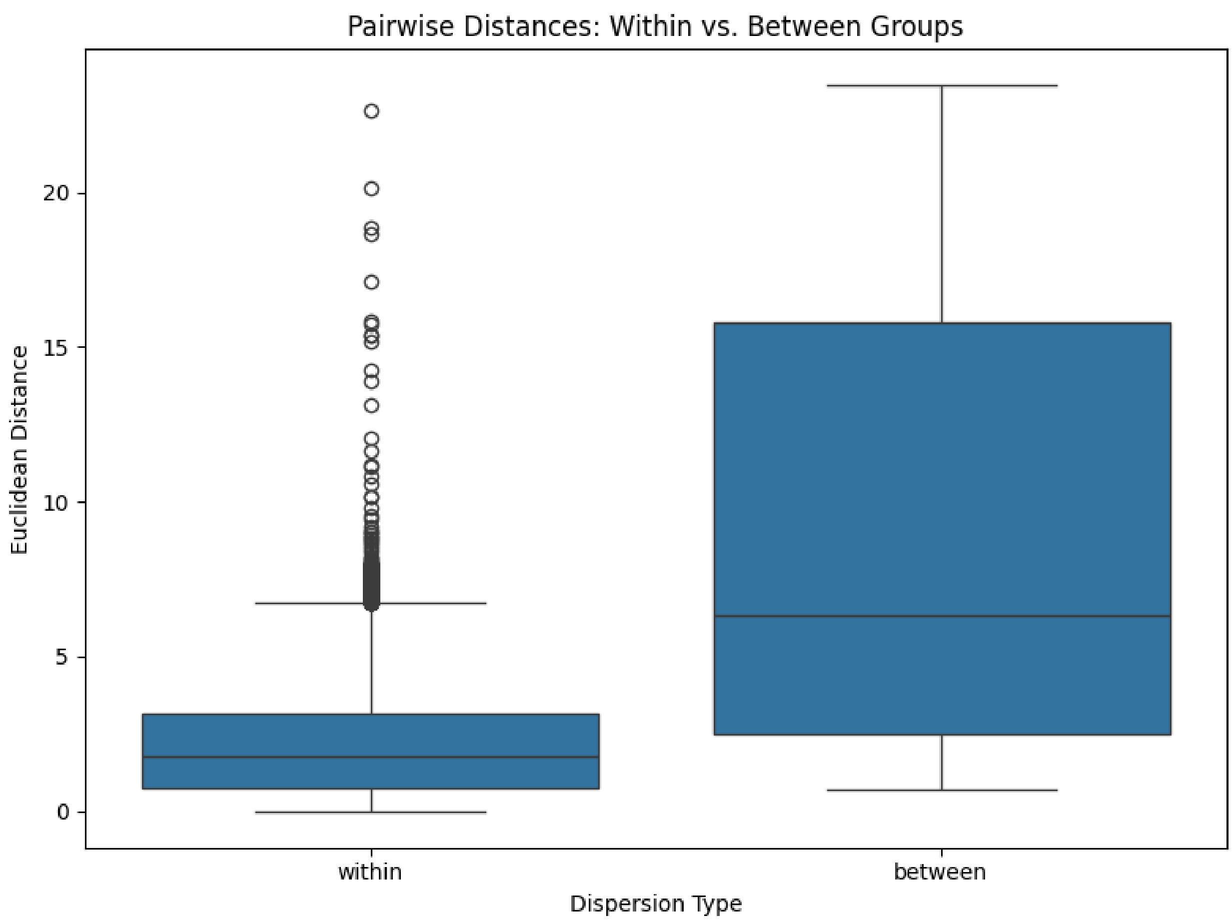
Low Status: All other tombs

This classification is based on the quality, quantity, and types of grave goods present. Higher status burials included multiple nested coffins, gilded masks, canopic jars, papyri, professional equipment, elaborate jewelry, and furniture, reflecting close ties to the royal court or high-ranking positions (Smith 1992). Mid-level burials had more modest provisioning, with some professional items and limited luxury goods, while low-status burials typically contained simple pottery, a few jewelry items, and shared or plain coffins (Smith 1992). One of the goals of this analysis is to determine whether there is statistical justification for these groupings. While a traditional MANOVA (Multivariate Analysis of Variance) could be used to test for differences in group means, it is not well-suited for this dataset due to the highly unbalanced group sizes and the skewed nature of the data.

To address these limitations, we employed PERMANOVA (Permutational Multivariate Analysis of Variance), a non-parametric, permutation-based technique that does not assume any particular data distribution or homogeneity of variances (Hébert). PERMANOVA tests whether group centroids (in this case, average spending profiles) differ significantly in multivariate space using a predetermined distance metric–here, we used Euclidean distance. The null hypothesis asserts that observations are exchangeable among groups. To test this, we permuted the group labels and calculated a pseudo F-statistic, the ratio of between-group to within-group variation, for each permutation (Hébert). The PERMANOVA test yielded a p-value of 0.001, suggesting significant group differences and allowing us to tentatively reject the null hypothesis.

However, PERMANOVA can be sensitive to differences in group dispersion, potentially leading to false positives when groups differ in their spread (Hébert). For example, a group with higher internal variability may artificially inflate between-group distances. To account for this, we conducted a follow-up PERMDISP (Permutational Analysis of Multivariate Dispersions) analysis (Hébert). PERMDISP assesses whether the groups differ in their dispersion by calculating the distance of each observation to its group centroid and comparing these distances across groups. This test yielded a p-value of 2.2e-16, indicating major differences in dispersion across groups and casting doubt on the validity of the PERMANOVA results.

Given the confounding effect of unequal dispersion, we shifted our focus to pairwise distance analysis, which allowed us to directly examine both within-group and between-group variability. Specifically, we computed within-group dispersion,the variability among members of the same group, and between-group dispersion, the variability between members of different groups.



On average, between-group dispersion exceeded within-group dispersion, suggesting that the groupings still capture meaningful separation overall. However, several within-group outlier distances were identified, each representing pairs of points that are unusually distant from one another within the same group.

Frequency of Outlier Distances by Tomb

Tomb	Number of Outlier Distance Instances
S+	96
Nu+	91
DeM 1381	85

The most prominent tombs involved in these outlier distances were S+ (96 instances), Nu+ (91 instances), and DeM 1381 (81 instances). Other tombs exhibited far fewer outlier distances (fewer than 18 occurrences), making these three the primary contributors. All three of these tombs are members of the low status group, and are among some of the higher spenders in this category, which may contribute to their outlier status.

K-Means Clustering

It is also valuable to explore inherent groupings of the tombs that emerge from the natural structures present in the data. In this way, we can attempt to discover which tombs are more similar to each other based solely on their quantitative characteristics. To do this, we use the K-Means clustering algorithm.

K-Means clustering is a popular unsupervised learning technique that groups similar data points into a specified number of clusters. It identifies patterns in the data and organizes points so that those within the same cluster are more similar to each other than to those in other clusters. The general approach is to divide data points into K clusters such that each point belongs to the cluster with the nearest mean (called the "centroid").

At a high level, the algorithm is as follows:

1. **Initialization**
   Choose the number of clusters (K) and randomly initialize K centroids.
2. **Assignment**
   Assign each data point to the nearest centroid based on distance (typically Euclidean).
3. **Update**
   Recalculate the centroids as the mean of all points assigned to each cluster.
4. **Repeat**
   Continue the assignment and update steps until the centroids stabilize or a maximum number of iterations is reached.

Principal Components Analysis (PCA)

As part of pre-processing, we perform Principal Components Analysis (PCA) on our features. PCA is a dimensionality reduction technique that transforms the original data into a new set of uncorrelated variables called principal components. These components are ordered so that the first few retain most of the variation present in the original dataset. We use PCA here for two main reasons:

1. **Visualization:** Since the original cost data table contains many features, plotting the data in two or three dimensions is difficult. We use PCA to reduce the number of features to two principal components, allowing us to visualize the data structure and clusters more clearly.
2. **Improved Clustering**
   K-Means performs better when features are uncorrelated and the dataset has reduced noise or redundancy. PCA helps achieve this by projecting the data into a lower-dimensional space that preserves the most important patterns, which can lead to more distinct and meaningful clusters.

Results

We set $K = 5$ to follow along with the original groupings established by Smith (1992) - Tutankhamen, Elite, High-Middle, Middle, and Low Status. This is partially to test whether the algorithmically determined clusters will align with the manual groups. The tomb were assigned as follows:

Cluster Assignments

Cluster 0	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**
All Other Tombs	Tutankhamen	Y&T (Yuya and Tuya)	Mahirper	K&M (Kha and Merit)
		Setau	M+	Hatnofer
			DeM 1381	S&N (Sennofer and Nefertiti)
			DeM 1389	
			DeM 1375	
			Neferkhewet	
			I+	
			SR+	

Out of the 134 tombs in this analysis, 120 of them are assigned to Cluster 0. All of these tombs had a grand total cost of less than 565 db, and therefore nearly all of these tombs would be considered to be of Low Status according to the typology established in Smith (1992). For the full list of tombs in Cluster 0, please see Appendix A. Cluster 1 is occupied by only King Tutankhamen. Given the extraordinarily high cost of Tutankhamen's burial, it is unsurprising that the algorithm isolates him into a cluster of his own, mirroring the distinction made in the original classification. It is in Cluster 2, Cluster 3, and Cluster 4 that we see major deviations from the original groupings. None of these clusters seem to reflect the socioeconomic differences that are highlighted by Smith (1992), and in fact have highly variable tomb valuations. We evaluate each of these three clusters in turn.

Cluster 2

Cluster 2 consists of the tomb of Setau and the tomb of Yuya and Tuya. What is most striking is the mismatch in expenditure between the two tombs–Yuya and Tuya's overall valuation is nearly 10 times that of Setau's. Going off of tomb worth alone, it would be reasonable to suggest that Setau should instead be grouped into Cluster 0, especially since he is actually being outspent by some of the individuals in this cluster. The question then becomes why is Setau tied to Yuya and Tuya's tomb despite this stark disparity. While we can never say for sure what the reasoning for the K-Means cluster assignments are due to the nature of the algorithm and the dimensionality reduction performed by PCA, we can make some educated guesses as to what the similarities that drive this cluster (and the ones that will follow) are.

Likely the connection between these two tombs lies in the pronounced provisioning of fertility products. Setau and Yuya and Tuya provisioned fertility products valued at 30 db and 14 db respectively, making them the two top spenders in fertility among all tombs, even Tutankhamen's. This elevated fertility spending appears to be a key distinguishing feature of

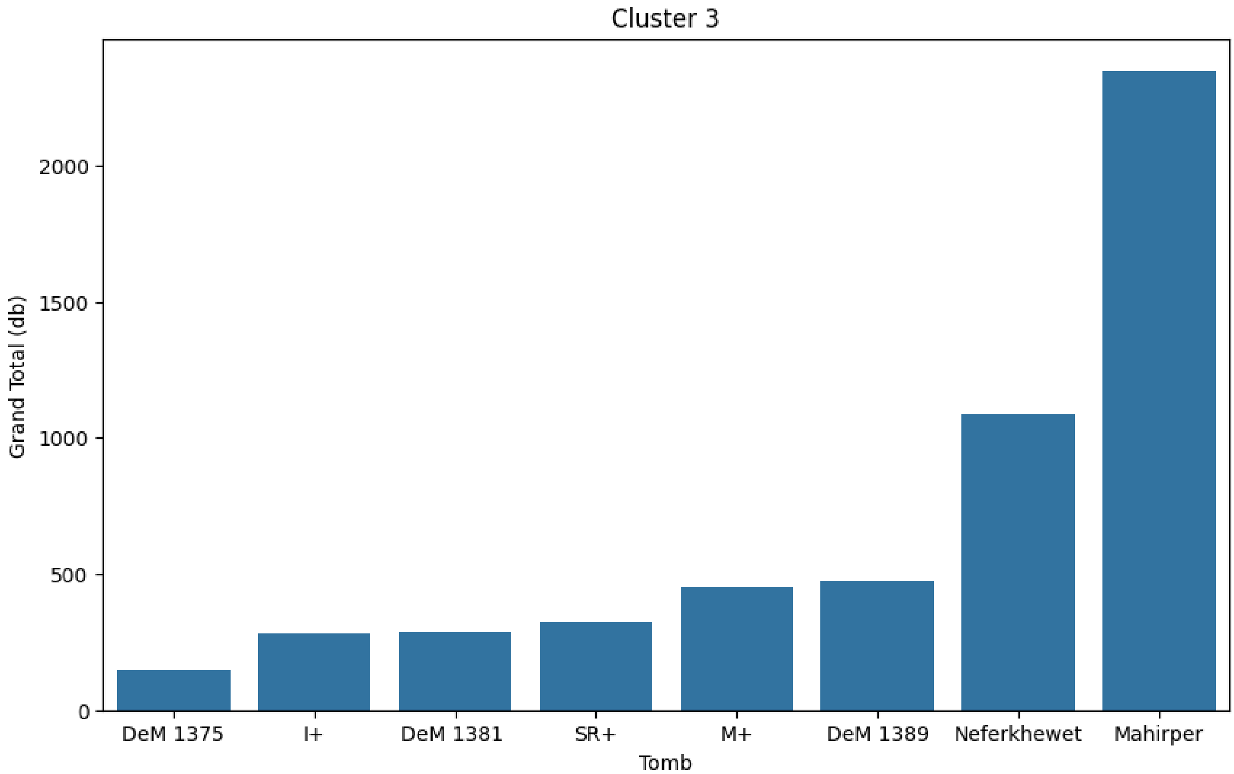
Cluster 2, as reflected in its much higher mean fertility expenditure (22.00 db) compared to all other clusters, which remain close to zero. The unusually high investment in fertility products may therefore play a significant role in why these tombs were grouped together by the algorithm.

Mean Fertility Spending Among Clusters (db)

Cluster 0	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**
0.07	2.00	22.00	2.50	0.00

In addition, Setau and Yuya and Tuya tombs both entirely lack provisioning in black bowls, bouquets, professional equipment, toiletries, and funerary equipment. While this would not be entirely unexpected for Setau given his low expenditure overall, it is more surprising for Yuya and Tuya. In addition, Setau and Yuya and Tuya tombs both entirely lack provisioning in black bowls, bouquets, professional equipment, toiletries, and funerary equipment. While this absence would not be entirely unexpected for Setau, given his relatively low overall expenditure, it is more surprising in the case of Yuya and Tuya. The combination of minimal provisioning across several key categories alongside a disproportionately high investment in fertility products may help explain why these tombs were grouped together by the algorithm.

Cluster 3



In Cluster 3, we again see many individual tombs that, based on the total expenditure, might be better off placed into Cluster 0. We also see the tombs of Neferkhewet and Mahirper, which respectively double and and quadruple the overall valuation of the other tombs in this cluster. We are once again prompted to question why such disparate tombs are placed within one cluster by the K-Means algorithm.

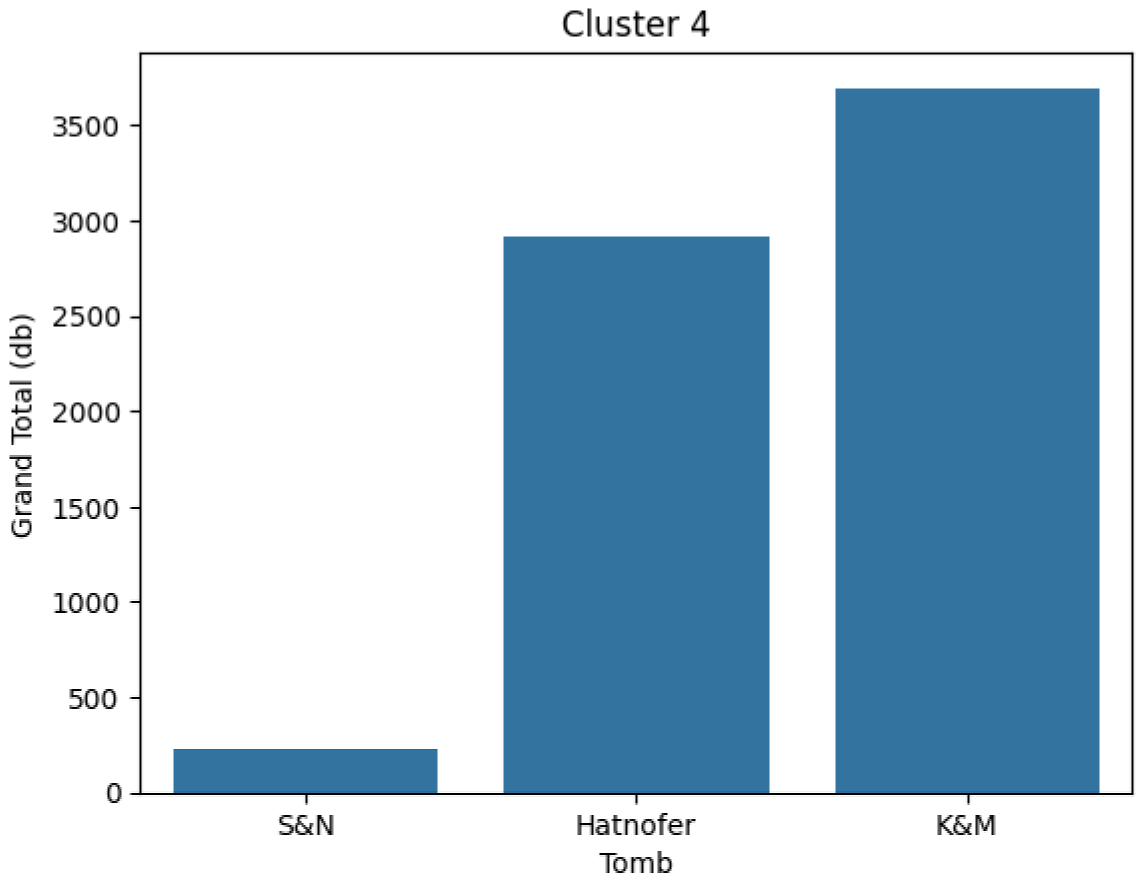
Despite these differences in overall expenditure, the tombs in Cluster 3 show notable consistency across several specific provisioning categories. Fertility products, toiletries, boxes and baskets, bouquets, and vessels all have standard deviations below 10 db within this cluster, suggesting that similarities in these areas may have contributed to the grouping of Mahirper, Neferkhewet, and the lower-cost tombs together.

Another factor that may help explain the cluster's structure is the level of investment in furniture. Mahirper had no furniture provisioned in her tomb, while Neferkhewet spent only 8 db on furniture. This stands in sharp contrast to other high-spending tombs: Kha and Merit's tomb included furniture valued at 262 db, while Yuya and Tuya's tomb contained 317 db worth of furniture. As furniture provisioning is often associated with higher wealth and elevated burial status, the absence or near-absence of furniture in these tombs may have influenced the algorithm to place Mahirper and Neferkhewet alongside tombs of lower cost rather than with other high-profile burials.

Additionally, the presence of lower-cost tombs in Cluster 3 may be explained by their investment in furniture, a category typically associated with higher-status burials. The lower-cost tombs in this cluster consistently include some level of furniture provisioning, with an average furniture cost of approximately 19 db. In contrast, most tombs in Cluster 0, which represent the majority of low-status burials, average only about 1 db in furniture valuation. This suggests that, although these tombs are lower in total cost, their inclusion of furniture distinguishes them from typical low-status burials and may contribute to their placement alongside Mahirper and Neferkhewet in Cluster 3.

At the same time, Mahirper and Neferkhewet, despite having much higher overall expenditures, have very little or no furniture provisioned which sets them apart from other high-cost elite tombs. Therefore, it may be this shared pattern–lower-cost tombs with elevated furniture spending, and higher-cost tombs with unusually limited furniture–that led the algorithm to group these tombs together in Cluster 3.

Cluster 4

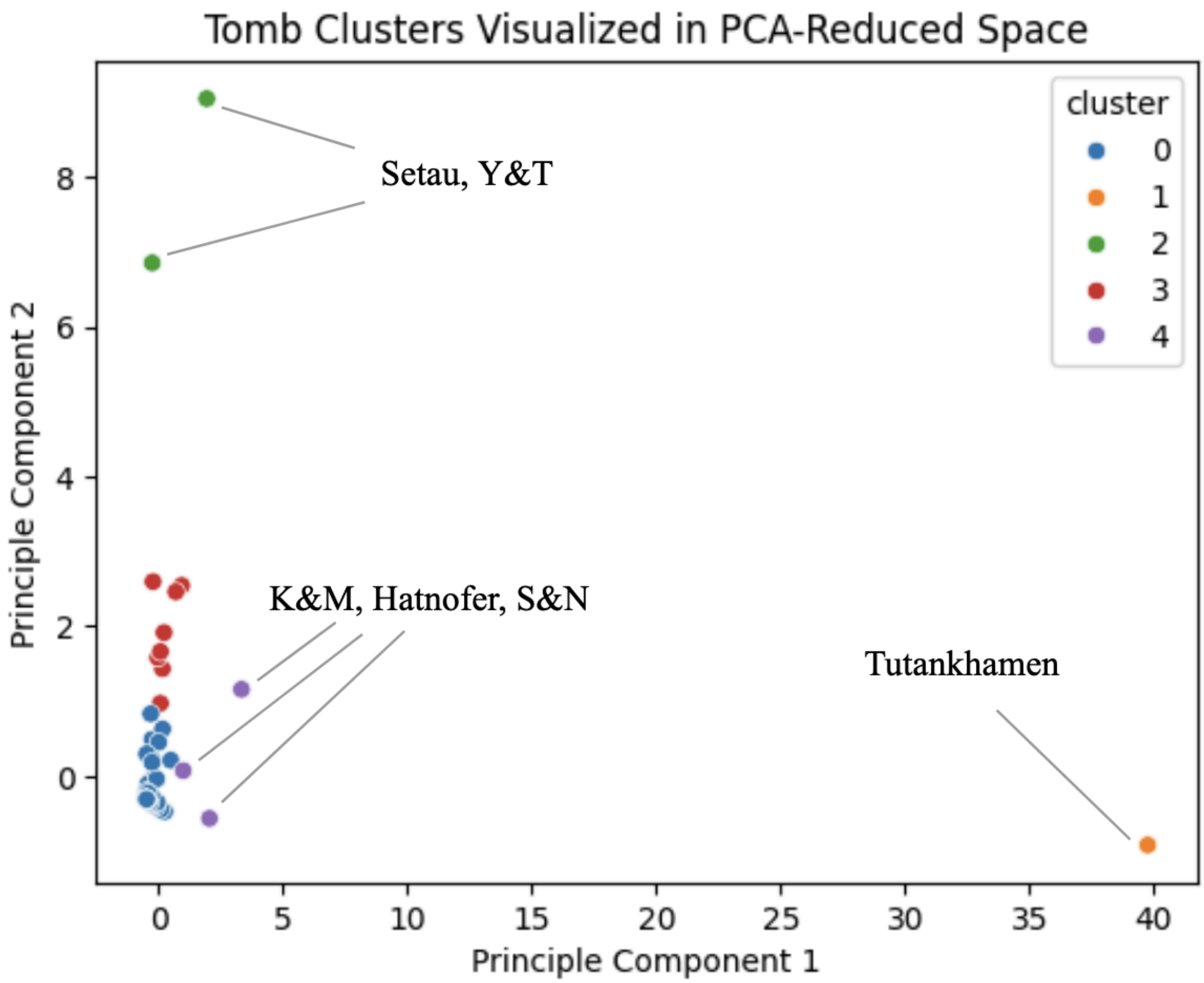


The final cluster continues the pattern of tombs with different economic statuses being assigned to the same group. In this case, Sennofer and Nefertiti's tomb stands out as much less equipped than those of Hatnofer and Kha and Merit. We can find an explanation for this cluster assignment in the vessel expenditures in these tombs.

Average Proportion of Total Tomb Value Allocated to Vessels (by Cluster)

Cluster 0	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**
0.2%	0.4%	2.6%	0.6%	36.6%

Tombs in Cluster 4 devoted a far greater share of their budgets to vessels compared to other clusters. On average, Cluster 4 tombs spent 36.6% of their total cost on vessels, whereas the other clusters allocated only a small fraction (ranging from 0.2% to 2.6%). This is especially pronounced in the tomb of Sennofer and Nefertiti, where 45% of their 233 db budget went toward vessels, more than double the highest percentage observed in Cluster 0. This distinctive emphasis on vessel provisioning likely links Sennofer and Nefertiti with the other two higher-profile tombs, separating them from lower-cost burials in Cluster 0.



Plotting all five clusters in the PCA-reduced space can help visualize the structure and separation of the groups. The placement of Tutankhamen far along Principal Component 1, and Setau along with Yuya and Tuya high on Principal Component 2, provides some insight into what these principal components may be capturing. Principal Component 1 may largely reflect overall tomb valuation, given Tutankhamen's exceptionally high total cost, while Principal Component 2 may be influenced by fertility spending, as Setau and Yuya and Tuya are the highest spenders in this category.

However, it is important to note that PCA creates linear combinations of all input features, and each principal component may reflect contributions from multiple factors simultaneously. While tomb valuation and fertility spending appear to be important drivers, other provisioning categories likely contribute as well, and the true interpretation of these components remains approximate. Nonetheless, this separation helps illustrate how varying provisioning patterns across different categories can contribute to the formation of distinct clusters.

Discussion

The tomb classifications established by Smith (1992) are based on a combination of several factors: the documented social status of the individuals interred, the specific provisions included within each tomb, the social significance of these provisions, and the overall valuation of the burial assemblage. Smith's grouping process considers both the quantity and the nature of provisioned items which serve as material indicators of status and access to economic or institutional resources. Higher-status tombs, for example, often include extensive investments in costly or symbolically significant categories like furniture and professional equipment, while lower-status tombs are typically characterized by more modest or limited provisioning across these categories.

We are able to offer quantitative support for these groupings: the pairwise distance analysis showed that tombs assigned to the same socioeconomic class by Smith tend to exhibit lower within-group distances and higher between-group distances, reflecting consistent patterns in the composition of burial assemblages. These patterns are not arbitrary but reflect the structured nature of New Kingdom society. Burial provisions served as expressions of social identity, encompassing individual wealth, professional roles, access to institutional resources, and broader socio-economic obligations.

By contrast, the K-Means algorithm places very less emphasis on the total tomb valuation except at the extremes of the very poor (the Low Status tomb) and the uniquely wealthy (Tutankhamen). This is partially because the algorithm is entirely agnostic to the nuances of New Kingdom social stratification and the wealth implications of certain items in comparison to others. Instead, it highlights the importance of the composition of tomb goods–that is, what was included in the burial rather than simply how much it is valued at. This approach offers a complementary perspective that captures distinctions that are more influenced by the types and combinations of objects present. The clusters determined by this algorithm can be seen to reflect the priorities of the individuals within them. For example, we can say that Setau and Yuya and Tuya of Cluster 2 both prioritised fertility products when provisioning for their afterlife, and this priority sets them apart from the other New Kingdom tombs. We can conclude something similar for Cluster 3 and 4 in regards to furniture and vessels, respectively.

Conclusion

Through both manual classification and multivariate statistical analysis, this study demonstrates that New Kingdom burial assemblages reflect both overarching patterns of social hierarchy and more individualized provisioning strategies. Smith's (1992) socioeconomic classifications are largely supported, with pairwise distance analysis revealing consistent clustering among tombs of similar status. At the same time, K-Means clustering exposes alternative dimensions of variation, emphasizing the role of provisioning priorities, such as fertility goods, furniture, or vessels that may cut across wealth statuses. These findings suggest that while socioeconomic rank played a central role in shaping burial assemblages, the specific configuration of tomb goods also reflected the diverse priorities, identities, and ritual choices of the tomb owners themselves.

References

Hébert, James. *Applied Multivariate Statistics: PERMANOVA*. University of Washington. Accessed June 3, 2025. https://uw.pressbooks.pub/appliedmultivariatestatistics/chapter/permanova/.

Hébert, James. *Applied Multivariate Statistics: PERMDISP*. University of Washington. Accessed June 3, 2025. https://uw.pressbooks.pub/appliedmultivariatestatistics/chapter/permdisp/.

Smith, Stuart Tyson. *Intact Tombs of the Seventeenth and Eighteenth Dynasties from Thebes and the New Kingdom Burial System.* MDAIK 48 (1992): 193–222.

Appendix A

0	1	2	3	4
Nakht	Tutankhamen	Y&T	Mahirper	K&M
Khay		Setau	M+	Hatnofer
Ramose			DeM 1381	S&N
Renofer			DeM 1389	
Boki			Neferkhewet	
Ruyu			I+	
Amenemhet			SR+	
Hatiay			DeM 1375	
Hentut'u				
Siamun				
Mahy				
Taat				
SetauAnon				
SetauInfant				
Sennofer				
Nefertiti				
Pit 3 Room B				
Nub				
Iabtina				
DeM 1380				
Nubeity				
Sat-Re■				
Petrie				
Amenhotep				
Sn Woman old				
HatnoferIII 2f 2c				
Mentuhotep				
# 83 3c				
Room C				
Tahuty				
Ahotep				
# 21 m				
# 22 f				
# 31 c				

# 34 ?				
# 36 ?				
# 37 f				
# 38 ?				
# 43 c				
# 47 f				
# 49 m f				
# 50 c				
# 51 c				
# 52 f				
# 53 m				
# 55 2? c				
# 57 3?				
# 59 f m c ?				
# 62 2? c				
# 63 f m				
# 64 m				
Maya				
Bakiset				
M Man				
H+				
S+				
Sanimay				
N Man				
NuMan				
NuWoman				
SRWoman				
N Woman				
B+				
Harmose				
Aahmes				
Sn Woman				
Nu+				
# 18 ?				
#68 m				

#69 f				
#70 f				
#71 f				
#75 f				
#76 f				
DeM 1372				
DeM 1372a				
DeM 1372b				
DeM 1372c				
DeM 1373				
DeM 1374				
DeM 1376				
DeM 1377				
DeM 1378				
DeM 1383				
DeM 1384				
DeM 1390				
Sn Man				
HatnoferIV f c				
NeferkhewetVIII				
NeferkhewetVII				
NeferkhewetIX				
NeferkhewetX				
# 77 m 2c				
# 77a m				
# 78 f				
# 79 f				
# 80 c				
# 29 c				
# 30 c				
# 35 ?				
# 40 c				
# 41 c				
# 42 c				
# 44 c				

# 45 c				
# 46 m				
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