Original Article

Household out-of-pocket expenditures on health care in Bangladesh according to Principal Component Analysis (PCA)

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Summary **In Bangladesh, illness results in large out-of-pocket health care expenditures for households. Identifying the components associated with health care expenditures should prove meaningful for future policy formulation in Bangladesh. Thus, the objective of the study was to investigate the overall influence of individual health care costs over data space in a probalistic way using Principal Component Analysis for expenditures incurred due to a recent illness. The study is based on secondary data of the Household Income and Expenditure Survey conducted in 2005 by the Bangladesh Bureau of Statistics. This survey is a nationally representative survey in Bangladesh and its sample includes 8,126 individuals who have incurred health care expenditures in the 30 days prior to the survey. Principal Component Analysis was used to analyze the influence of the factors of health care expenditures in Bangladesh. According to results, 58% of the information on the overall data space confirmed that the cost of medicine is greater than any other factor for health care expenditures. Drug-related health expenditures represented a large component and suggest the need for policies promoting the rational use of drugs. If such strategies are considered and implemented in operational stages, the quality of health care should improve and drug expenditures should substantially decrease.**

Keywords: Out of pocket expenditures, Medicine cost, Illness, Principal Component Analysis, Singular value decomposition

1. Introduction

Heavy reliance on out-of-pocket (OOP) financing of health care expenditures in most developing countries leaves households exposed to the risk of unforeseen expenditures that may absorb a large share of their budget. In many developing countries, governments are facing increasing pressure to improve the efficiency and financial viability of health service delivery systems (*1*). Millions of people around the world are prevented from seeking and obtaining needed care each year because they cannot afford to pay the fees for diagnosis and treatment. This can lead to financial hardship and even impoverishment because people are too ill to work. In addition, many of those who do seek care suffer financial catastrophe and impoverishment as a result of paying these fees in both rich and poor countries. A survey in eighty nine countries covering 89 percent of the world's population found that 150 million people worldwide suffer financial catastrophe annually because they must pay for health services (*2*). Ill health can have a significant economic impact on a household. Such an impact can trigger a spiral of asset depletion, indebtedness, and reductions in essential consumption (*3*). According to the World Health Organization (WHO), one-third of the global population lacks reliable access to needed medicines. The high price of medicines is a key factor in their

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inaccessibility. High prices are particularly burdensome to patients in developing countries, where most of the medicines are paid for OOP by individual patients (*4*). State health services may impose a heavy cost burden on households, especially in developing countries (*5,6*). A study financed by the Commonwealth Fund reported that OOP spending on health care services remains a major source of financial insecurity for people with inadequate health insurance coverage (*7*).

Like many other developing countries, Bangladesh has been exploring how scarce resources can be tapped to co-finance health services. Unequal and uneven geographical distribution of medical health care resources and insufficient health care coverage are two long-standing problems in Bangladesh. Although revenue generation is important for the vitality of health services, effects on utilization and on equity of access to health care must also be considered. The WHO report in 2000 highlighted the fact that the performance of a health system affects peoples' lives and livelihood (*7*). The challenge to a health care system is to make health care equitable and sustainable while efficiently using of resources (*7*). Increased access to health care according to need can promote equity and also achieve efficiency through a reduction in per capita health care costs (*8*). Increasing utilization of health services is the prime goal for Bangladesh, as is true for many developing countries. OOP expenditures constitute the single largest component of total health expenditures in Bangladesh. OOP expenditures particularly involve utilization of health services and purchase of drugs. However, expenditures for transportation to access health services are also part of OOP expenditures. Higher public expenditures and better risk pooling mechanisms have been identified to decrease the share of OOP expenditures. The WHO's Health and Millennium Development Goals indicate that OOP expenditures have a severe impact on increasing the poverty rate in India. The estimate for 1999-2000 was that 3.25% of the total population, or approximately 32.5 million people, plunged into poverty because of health care payments. This figure does not include those who were already poor and have plunged into deeper poverty and also confirms that high expenditures on drugs are one of the main reasons for high OOP payments (*9*). Various kinds of indirect costs such as days, wages, or income lost are not taken into account as part of OOP costs.

Any health expenditures that threaten a household's financial ability to sustain itself are termed "catastrophic" and do not necessarily equate to high health care costs. This definition was in response to the severe problems in financing health services in most developing countries. In the developing world, government health budgets declined in real terms in response to macroeconomic problems at the time while demand for health services increased, partly because of population growth and successful social mobilization (*10*). Households in developed countries were protected from catastrophic spending by adequate health insurance coverage or a tax-funded health system. In developing countries, however, high OOP expenditures, an absence of risk-pooling mechanisms in health financing systems, and high levels of poverty can result in catastrophic health care expenditures (HCE) (*7*). As per WHO estimates, families who spend 50% or more of their non-food expenditures on health care are likely to be impoverished (*11*). In a study on household expenditures in Nepal, the amount of HCE, choice of providers, and reported illness were determined at the same time (*12*). Using the HIES-2005 data, the current study analyzed different factors that affect the determinants of household expenditures and attempted to answer the following question: How much are households currently spending on health care to treat a recent illness?

The objective of the study is to investigate the overall influence of individual factors for health care costs over data space in a probalistic way using Principal Component Analysis (PCA) for expenditures incurred due to a recent illness (30 days prior to the survey).

2. Methods

2.1. *Setting: Study area*

Bangladesh, a South Asian country with a population of approximately 158.6 million, has more than 50% of its people living below the national poverty line (World Bank, statistics for 2007). Though a majority of the population lives in rural areas, the government health care system remains a very minor source of health care there. There is no risk-pooling mechanism in financing health care as of yet. According to the WHO, out of total GDP in 2005, 2.8% was spent on health care. A striking fact is that nearly 88.3% of private expenditures are OOP expenditures (*13,14*). The Directorate of Drug Administration (DDA) under the Ministry of Health & Family Welfare, Government of the People's Republic of Bangladesh, is the country's regulatory authority for drugs. The mission of the DDA is to ensure that the common people have easy access to useful, effective, safe, and good quality essential and other drugs at affordable prices. All matters related to drugs and medicines are regulated in Bangladesh by the Drugs Act of 1940 and subsequent regulations. In addition, the government adopted the National Drug Policy (NDP) in 1982, and the Drugs (Control) Ordinance was promulgated in 1982 to implement it. The ordinance controls the manufacture, import, distribution, sale, pricing, and advertisement of all allopathic drugs and medicines and prohibits the production, sale, and use of non-essentials and unnecessary or less necessary drugs and medicines in the country.

2.2. *Data source*

The data used in this study come from the Household Income & Expenditure Survey (HIES-2005) conducted by the Bangladesh Bureau of Statistics under the Planning Division, Ministry of Planning, Government Of the People's Republic of Bangladesh. The Bangladesh Bureau of Statistics (BBS) conducted the survey in all six divisions using a two-stage stratified random sampling approach under the framework of an Integrated Multipurpose Sample (IMPS). The IMPS design consists of 1,000 Primary Sampling Units (PSUs) throughout the country. There are 640 rural and 360 urban PSUs in the sample. A PSU is defined as two or more continuous enumeration areas (EAs) used in the 2001 Population and Housing Census. Each PSU consists of around 200 households. The current sample included 8,126 individuals who have had HCE 30 days prior to the survey. Using a recall period of 30 days prior to the interview, the survey collected information on past perceived illness (reported morbidity), its severity and treatment, and expenditures for that treatment. From this morbidity data, the current study extracted only OOP expenditures for consultations, Hospital/Clinic visits, Medicine, Tests/studies, Transportation, Tips for treatment, and other expenses (*15*). The data are accessible with the permission of the Bangladesh Bureau of Statistics, Ministry of Planning, Planning Division and the Government of Bangladesh.

2.3. *Principal Component Analysis*

PCA is a technique used to reduce multidimensional data sets to lower dimensions for analysis. It is mostly used as a tool in exploratory data analysis and to make predictive models. The analysis involves the calculation of the eigenvalue decomposition of a data covariance matrix or singular value decomposition (SVD) of a data matrix, usually after mean centering the data for each attribute (*16,17*). The results of a PCA are usually discussed in terms of component scores and loadings. PCA is mathematically defined as an orthogonal linear transformation that transforms the data to a new coordinate system such that the greatest variance by any projection of the data comes to lie on the first coordinate (called the first principal component), the second greatest variance on the second coordinate, and so on (*18*). PCA is theoretically the optimum transform for a given data point in least square terms. It can be used for dimension reduction in a data set by retaining the characteristics of the data set that contribute most to its variance, by keeping lower-order principal components and ignoring higher-order ones (*16*). Such low-order components often contain the "most important" aspects of the data. However, depending on the application this may not always be the case.

PCA is employed here to analyze the influence of the factors for HCE in Bangladesh. SVD is used to implement the PCA. A rigorous approach to HCE analysis must involve a weight characterization of the individual variables in the data. One of the challenges of such analysis is to develop effective ways to analyze global influence of the factors. In addition to a broader utility in analytical methods, SVD and PCA can help to provide such a characterization (*18*). SVD and PCA are common techniques for analysis of multivariate data, and health care cost data are well-suited to analysis using SVD. The HCE of thousands of individuals consist of different factors including medicine costs, hospital costs, and pathology costs. SVD analysis can detect the overall influence of individual cost factors over data space in a probabilistic manner. The intended analysis represents the HCE data with a smaller number of variables and detects the weighting pattern of the factors involved for individual variables.

2.4. *Mathematical formulation of SVD*

In linear algebra, the SVD is an important factorization of a rectangular real or complex matrix, with several applications in data processing and statistics (*4,18*). Two vectors x and y are orthogonal if $x^{\mathrm{T}}y = 0$, where T represents the transcript operation. In two or three-dimensional space this simply means that the vectors are perpendicular. Let X be a square matrix such that its columns are mutually orthogonal vectors of length 1, *i.e.* $x^{\mathrm{T}}x = 1$. Then X is an orthogonal matrix and $X^{\mathrm{T}}X = I$, the identity matrix. To simplify the notation, assume that a matrix $X_{m\times n}$ has at least as many rows as columns $m \geq n$. An SVD of an $m > n$ matrix X is any factorization of the form:

$$X_{m\times n} = (U_{m\times m})\,(S_{m\times n})\,(V^{\mathrm{T}}{}_{n\times n}) \qquad (1.1)$$

where U and V are square matrices, and S is a diagonal matrix. The columns of U are called the left singular vectors, $\{\mathbf{u}_k\}$, and form an orthonormal basis for the rows of the data vector X, so that $\mathbf{u}_i \bullet \mathbf{u}_j = 1$ for $i = j$, and $\mathbf{u}_i \bullet \mathbf{u}_j = 0$ otherwise. The rows of V^{T} contain the elements of the right singular vectors, $\{\mathbf{v}_k\}$, and form an orthonormal basis for the columns of the matrix X. The elements of S are only nonzero on the diagonal and are called the singular values (*18*). Thus, $S = \mathrm{diag}(s_1, s_2, \ldots, s_n)$ and $s_r > 0$ for $1 \leq r \leq n$. By convention, the ordering of the singular vectors is determined by high-to-low sorting of singular values, with the highest singular value in the upper left index of the S matrix (*19*). Note that for a square, symmetric matrix X, SVD is equivalent to diagonalization, or solution, of the eigenvalue problem.

The SVD defined thus has implicitly solved the problems inherent in the PCA definition. First, the SVD decomposes a non-square matrix, thus allowing

direct decomposition of the HCE data in either factors or individual orientation without the need for a covariance matrix. Furthermore, assuming a full SVD, the decomposition of a transposed data matrix can be derived from the SVD of its complimentary representative by the relation: $X^T = VSU^T$, which follows from the relation $S^T = S$. This means that the full SVD decomposition of a matrix in factor orientation can be used to specify an SVD decomposition in individual orientation and vice-versa. Thus, direct SVD decomposition keeps all of the relevant information about the null, row, and column spaces of a data matrix in a compact form (*20*). The major advantage of an SVD over a PCA is that of rank estimation and null-space identification can be identified for both the left and right singular vectors as the space spanned by vectors corresponding to the singular values for which $s_j = 0$, whereas if $s_j \neq 0$, then the corresponding singular vectors $\mathbf{u}_j$ and $\mathbf{v}_j$ are in the range of X which is spanned by the column space of the left and right singular vectors which, in turn, span the row space and column space of the data matrix X.

3. Results

HCE data is arranged as $X = \{x_1, x_2, \ldots, x_j, \ldots, x_n\}$ in an $m \times n$ matrix $X_{m \times n}$, where each vector x_j ($j = 1, 2, \ldots, 7$) represents the expenditures of individuals with respect to the j^{th} factor. Thus, each entry x_{ij} of the X matrix is the amount of expenditures for the i^{th} individual of the j^{th} factor affecting the HCE. The elements of the ith row of X form the n-dimensional vector $\mathbf{h}_i$, which is referred to here as the factor effects of HCE on the i^{th} individual. Alternatively, the elements of the j^{th} column of X form the m-dimensional vector x_j, which is referred to here as the expression profile of the j^{th} factor. Thus, the arrangement of data obviously suits SVD analysis. After SVD of X, the left singular vectors $\{\mathbf{u}_k\}$ represent the principal components for individual expenditures based on the factors. The right singular vectors $\{\mathbf{v}_r\}$ represent the principal components for factors over the whole data space and are termed here as *eigenfactors* $\mathbf{e}_r$. The main goal of this analysis is to investigate the characteristics of the eigenfactors.

As mentioned, HCE data is suited to analysis using SVD/PCA. What follows is some of the analytical results. An obvious question is 'what is the significance of using SVD to analyze HCE data?' The point is to investigate the effects of different factors of HCE over the data. The effects of individual HCE factors could also be measured by simply summing up costs factor-wise over the whole data length. There would be no statistical significance to basing a strong conclusion or recommendation on such analysis. Using SVD revealed clear effects of HCE factors on the available data in a probabilistic manner. The data are arranged in seven columns representing seven HCE factors (*doctor's fees, hospital fees, medicine, check-ups, communication, tips, and other expenses*) and 8,126 rows for individuals. After SVD of data matrix X, the elements of the diagonal of matrix $S_{m \times n}$ represent the relative information (variances), also termed as eigen values, corresponding to the principal components (PCs). The principal components representing the eigenvectors provide some significant information. The plots reveal interesting patterns in the data that may warrant further investigation. The eigen values and their cumulative sums are shown in Figure 1. The patterns of the seven eigenfactors are shown in Figure 2.

As is apparent, the first two eigenfactors represent the higher peak for the third factor (medicine). Also of note is the fact that the cumulative information (variance) corresponding to the first two eigenfactors is about 58% and hence provides the most information on the data space. The weights for the other factors are represented by the other eigenfactor or by a combination of several factors. As is apparent from the eigenfactor space, the most informative data space (corresponding to the first two eigenfactors) is influenced by the third factor (medicine).

The overall weight for the whole data space was computed by summing up the eigenfactor over the number of factors as:

$$\delta_{overall} = \sum_{r=1}^{7} e_r \qquad (2.1)$$

The normalized overall weight as shown in Figure 3 also confirms that the most influential factor over the data space was the third one, *i.e.* medicine costs.

Decomposition also revealed statistical significance.

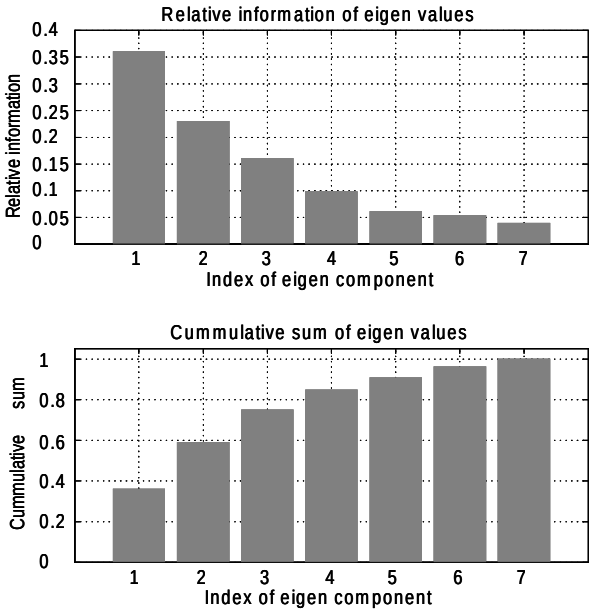

Figure 1. Relative information contained by the eigenvalues (upper) and their relative sum (lower).

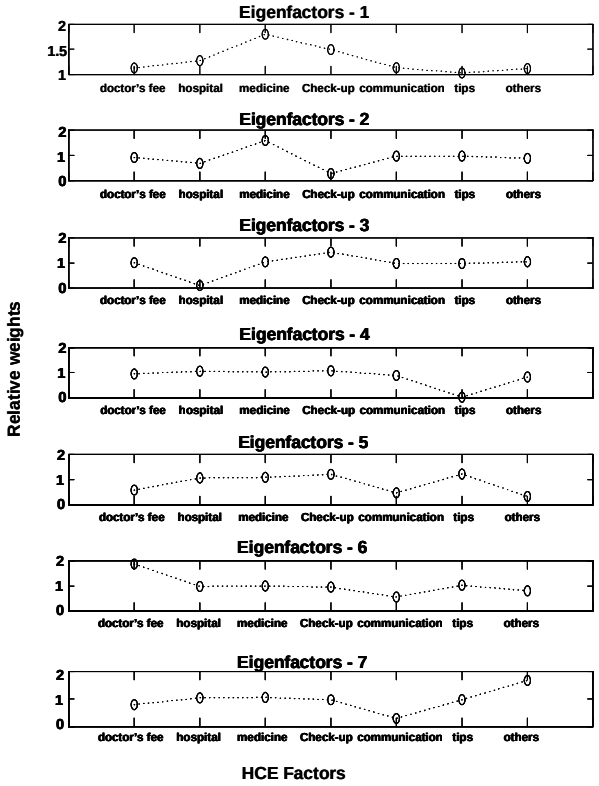

Figure 2. Relative weights of eigenfactors as a function of factors.

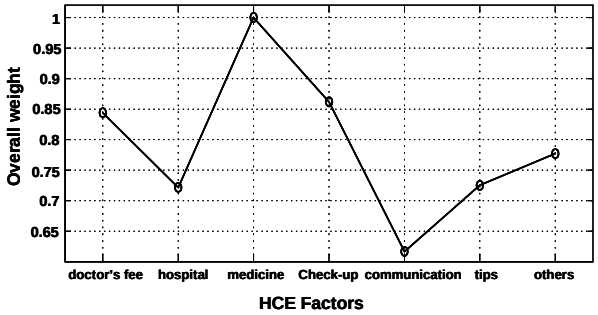

Figure 3. Normalized overall weight as a function of factors.

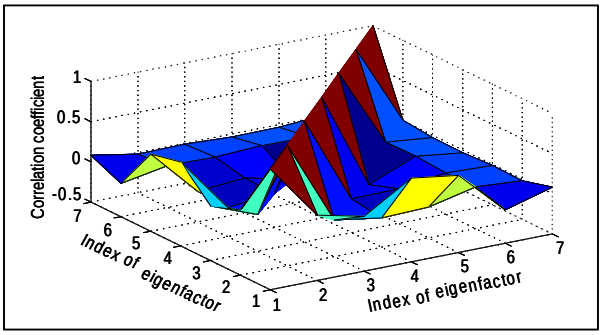

Figure 4. Correlation coefficients among the pairs of eigenfactors.

The correlation coefficient between two eigenfators $\mathbf{e}_a$ and $\mathbf{e}_b$ was defined as:

$$\rho_{ab} = \frac{E\{(e_a - \mu_a)(e_b - \mu_b)\}}{\sigma_a - \sigma_b} \qquad (3.1)$$

where E is the expectation operator, μ_a and μ_b are the expected values, and σ_a and σ_b are the standard deviations of the eigenfactors $\mathbf{e}_a$ and $\mathbf{e}_b$, respectively. The correlation coefficients of each pair of eigenfactors are shown in Figure 4.

As is apparent, the cross terms (correlation coefficients for different eigenfactors) are close to zero, indicating that the eigenfactors are weakly correlated. For many pairs, the coefficients are about zero, which means that both are linearly independent. Consideration of eigenfactors as a basic function with an independent effect on the data space is statistically significant.

4. Discussion

OOP expenditures account for a significant portion of the costs of health care throughout Bangladesh as the country has no risk-pooling mechanism. HCE analysis found that about 58% of the information on the overall data space revealed that the cost of medicine is greater than any other HCE factor. A previous study indicated that unqualified providers (drugstore salespersons and village doctors) and semi-qualified providers together are the major providers of allopathic health care to the poor and disadvantaged in rural Bangladesh, which confirms the present findings of medicine accounting for the highest expenditures. A previous study reported that irrational use of drugs such as over-prescribing, multi-drug prescribing, use of expensive but unnecessary drugs, and overuse of antibiotics and injections are the most common problems in Bangladesh; this also correlates with the present findings (*8,21,22*). However, aggressive marketing by pharmaceuticals companies as well as free availability of 'prescription only' drugs at unlicensed and unregulated drug retail outlets might play a role in the high expenditures on medicine. As these providers have no other channel of information from the formal sectors open to them, they fall easy prey to the marketing strategies of the pharmaceuticals companies (*23*). Because of the fatalistic attitude of the villagers/rural residents, unqualified providers are rarely blamed or held accountable for their poor practices. Due to excessive use of drugs, drug resistance is another problem in Bangladesh. The possible causes of drug resistance are indiscriminate use of drugs by quacks, unqualified personnel, and shopkeepers without training, free sale of drugs from commercial outlets, and a high degree of compliance (*1*). Spending on drugs constitutes the largest share of OOP expenditures on health, drug, and medical supplies and accounts for 79% of total costs in Ghana; similarly, medicine costs represent 64% of the total in Benin (*4*).

Many individuals or factors influence the irrational use of drugs such as patients, prescribers, the workplace

environment, the supply including industry influence, government regulation, and drug information and misinformation. Rational use of drugs in health centers is still a problem in Bangladesh. Reducing the irrational use of drugs at health centers in Bangladesh is not easy, however, since there are numerous constraints such as a lack of resources, lack of knowledge on the part of paramedics, lack of skilled health personnel, low levels of patient knowledge and habits, and demographic constraints. Health is regarded as a human right and the national drug policy promulgated in 1982 was aimed at simplifying the range of drugs available and at improving the logistics of drug distribution at reasonable prices. Given the shortage of qualified health care providers in rural Bangladesh, the importance of unqualified/semi-qualified practitioners as major providers of health care to the poor should be recognized by the public sector, and their capacity should be developed in a planned manner so as to ensure that the poor and the disadvantaged receive an acceptable level of care, at least in the sort term, until supply-side constraints can be alleviated. This will also promote rational use of drugs, improve the quality of health care, and reduce expenditures on drugs. A recent survey evaluating the performance of the latest Health and Population Sector Program (HPSP) in Bangladesh noted that the proportion of people utilizing public health services gradually declined from 13 to 10% and that the proportion seeking unqualified practitioners increased from 50 to 60% from 1999 to 2003 (*24*). The findings of the current analysis reveal greater irrational use of drugs at the household level.

The present study has a number of limitations. First, the study used a cross-sectional design; thus, causality cannot be established. A study using a longitudinal design is necessary to assess the significance and stability of predictors of utilization behavior over time. Second, the study is based on secondary and archival data, which presumably reflects the perspectives and purposes of the original investigators. Shaping the data to match the research questions was a challenge and required an intensive process of understanding the data set, recoding variables, and recasting research variables/questions to match data available. Third, OOP expenditures were recorded for a 30-day period in the surveys and health care spending was based on expenditures reported in that period of 30 days. Fourth, the survey method and the data used in this analysis only partially reveal the situation regarding OOP health care expenditures. Fifth, the HCE components of the survey only include item-specific questions on one broad type of health care services, *i.e.* care associated with a recent illness 30 days prior to the survey. For this type of service, questions were asked on the amounts spent for consultations, medicine, tests, and other expenses. Finally, the survey does not include questions on the types and quantity of medicines prescribed and used. Although the data in this study provides information on household consumption of health care, it only focuses on the collection of OOP health expenditures. Future studies should focus on these issues.

5. Conclusions and Recommendations

Through PCA the current study found that among factors for health care costs medicine costs are a dominant factor in OOP expenditures in Bangladesh. The outcomes of the analysis can be used in policy formulation to improve health system performance in Bangladesh. To promote rational drug use along with a reduction in OOP expenditures at the community level, a greater commitment from drug regulatory authorities, drug manufacturers, and health care professionals is required in order to ensure effective and sound mechanisms of drug management and utilization.

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