Enhancement of Human Development Assessment Model: An Insight from Bagmati Province, Nepal

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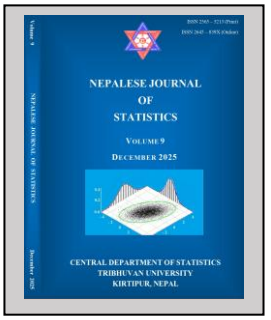

ABSTRACT

Background: Human development is a pivotal issue with Human Development Index (HDI) serving as a key indicator.

Objective: The study was conducted to enhance measurement of HDI by adding social governance and technological adaptation along with the existing dimensions, namely income, education and longevity.

Materials and Methods: Unequal weights were assigned to the components objectively through Principal Component Analysis and HDI was estimated as a weighted geometric mean. A sample household survey conducted in 2023 used three-stage stratified random sampling which covered 17 municipalities with 569 households of Bagmati Province, Nepal in order to construct the HDI dimensions.

Results: The estimated dimensions of income, education, health, social governance and technological adaptation were 0.341 (95% CI: 0.337, 0.345), 0.650 (95% CI: 0.645-0.655), 0.807 (95% CI: 0.80656-0.80664), 0.678 (95% CI: 0.674, 0.681), and 0.462 (95% CI: 0.454, 0.469), respectively. The estimated weights were maximum for income (0.248), followed by technological adaptation (0.247), education (0.241), social governance (0.168) and health (0.096). Finally, the estimated HDI for Bagmati province was 0.524 (95% CI: 0.519, 0.528) which is notably lower than the corresponding UNDP computed HDI (0.661).

Conclusion: The study demonstrates that UNDP adopted HDI is overestimated for Bagmati Province, Nepal.

Keywords: Human development, principal component analysis, social governance, technological adaptation, weighted geometric mean

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INTRODUCTION

The constitution of Nepal (2015) transitioned Nepal from a unitary to a federal system. Within the system, there exists three levels of government namely federal, provincial and local, developing in one federal government at the center, seven provincial state governments, and 753 local governments spread in 293 urban and 460 rural municipalities. Article 50 (3) of the constitution profiles the state's economic goal of sustainable development and rapid growth by maximizing resources (Nepal Law Commission, 2015). It purposes to create a socialist-oriented, self-reliant economy by reducing economic inequality through reasonable distribution. Human development is the core of federal and provincial development plans in Nepal. Since 1990, the Human Development Index (HDI) has been used globally to measure progresses of nations. Nepal has published Human Development Reports (HDRs) in 1998, 2002, 2004, 2009, 2014, and 2020 making human development a key focus in development planning and policy implications (UNDP, 1998; UNDP, 2002; UNDP, 2004; UNDP, 2009; Government of Nepal and UNDP, 2014; Government of Nepal and UNDP, 2020). Human Development is also central to the Sustainable Development Goals (SDGs), especially goals 3 (good health), 4 (quality education) and 8 (decent work). Achieving these goals requires addressing human development issues. The 2015 constitution of Nepal emphasizes human development in the context of fundamental rights, such as free primary and secondary education (Article 31) and basic health care (Article 35), highlighting its importance in political and economic spheres (Nepal Law Commission 2015). Provincial governments need HDI data for formulating better policies and strategies and allocating budgets based upon development indicators.

HDI is a summary measure used to assess advancement levels of countries through citizens' well-being related to income, education, and health. However, HDI has limitations in capturing the multi-dimensional complex phenomena of human development. Still human development assessment through HDI or IHDI fails comprehensively to capture important features in the present context despite being used as a tool by policymakers to identify areas for improvement in national and regional development strategies. Moreover, it fails to address many factors considered and included in the SDGs. Literature review related to human development shows that researchers have criticized the UNDP adopted HDI and proposed various alternative indexes and models (Noorbakhsh, 1998; Sagar & Najim, 1998; Lind 1992; Chakravarty, 2003; Despotis, 2005; Herrero et al., 2010; Kovacevic, 2010). They have suggested for the addition of components besides the existing components (income, longevity and education) for better quantification of HDI. Critics have highlighted that HDI has overlooked disparities in human development distribution within populations. They advocate for inequality adjustments or the development of better estimators (Hicks, 1997; Foster et al., 2005; Seth, 2009). In recent years, there has been a lively debate about the use of well-being indicators, with the HDI performing a significant role since its launch in 1990. The HDI's central evidence supports with the idea that progress should enhance people's choice and capabilities, representation heavily from the capability approach developed by Amartya Sen (Sen, 1999). However, critiques of the HDI continued, including concerns about its comparison across time and weighting of its dimensions. The methodology of assigning equal weight to the HDI dimensions has also been criticized by researchers (Mahlberg & Obersteiner, 2001; Chowdhury & Squire, 2006;

Louangrath, 2017) and is questionable since the components may not be equally important to assess the level of human development. For example, sustainable development addresses 17 SDGs. It is evident that the three HDI dimensions do not fairly, appropriately, or sufficiently represent the 17 SDGs when these goals are connected to the current dimensions. In contrast to representativeness, it appears that allocating equal weights to dimensions has been accepted for computational ease and simplicity. This may have also been done to prevent future discussions about the assignment of specific weights. However, the creation or application of appropriate methodology can support arguments resulting from the assignment of unequal weights. Moreover, if there exists correlation between the components as is present to some extent in HDI components, it creates the problem of redundancy if the components are weighted equally (Deb, 2015).

Inclusion of additional dimensions in the form of social governance and technological adaptation is likely to enhance the measurement of HDI as a more comprehensive and representative measure and thus increase its validity. The inclusion of these components would be even more suitable to least developed countries like Nepal where the components can play key roles in the assessment of human development. According to the UNDP, social governance is essential to ending poverty and promoting development. The organization supports the people and Government of Nepal to increase gender equality and social inclusion through various activities (UNDP, 2024). Institutions and procedures that allow citizens to exercise their rights and voice their interests are part of governance. Milotoy (2020) has defined social governance as the process of governing societies in a situation where no single actor can claim absolute dominance and referred along with processes of social organizations and social coordination. It is participatory, accountable, equitable, transparent, and also promotes the rule of law. It encourages interaction and decision making among participants for the purpose of solving problems collectively and fulfilling mutual interests which are essential components of development of a society. Moreover, social governance is associated with various issues like welfare of people, employment, sustainable lifestyles, community development, participation and decision making by local people, etc. Consequently, participation in social activities directly affects social governance and hence is an integral part of assessment of social governance. Human development and technological development has advanced side by side historically. Historical human development over various time periods is demonstrated by technological advancements and their adaptations to food, housing, transportation, communication, comfort, etc. People have been using technology to improve and manage livelihood processes as a result of the growth of various skills, ideas, and knowledge. Human development with the support of technology boosts economic growth and in turn is essential to generate further growth in human development (Gustav, 2011). As a result, technological adaptation and human development are closely related and should to be taken into account when assessing human development.

In the context as described, the present study has been carried out to enhance human development assessment model by

(a) accounting extra logical HDI components to evaluate human development,

(b) developing an appropriate methodology for assigning weights to each of the dimensions in order to capture variability in the dimensions and generate a sequential ordering of the units like districts, provinces, etc., and

(c) applying the enhanced methodological approach to compute HDI and weights for Bagmati province of Nepal based upon survey and mortality data.

MATERIALS AND METHODS

According to a review of the literature, the UNDP's HDI appears to be insufficient for measuring human development in the present context. The goal of the current study was to create a new and improved approach to measuring HDI by capturing the variation in HDI sub-indices that can be used to rank units (such as districts, provinces, etc.) and applying the approach specifically to sample survey data from Nepal's Bagmati province. In order to achieve the goal, we suggest a different and improved approach to HDI measurement that takes into account crucial elements that can capture the problems and elements of SDGs.

Methodological procedures for calculating the HDI

The methodological steps are stated as follows. Its diagrammatic representation is also shown (Figure 1).

- **Constructing HDI sub-index dimensions (components)**
  Inclusion of five essential and rational components namely Income, Education, Health, Social Governance and Technological Adaptation
- **Normalizing HDI components**
  The HDI components are normalized following the UNDP adopted method of normalizing.
- **Using weighted method**
  Weights of the sub-index dimensions are computed objectively through Principal Component Analysis (PCA) method.
- **Aggregating the individual components**
  Calculating the modified HDI by averaging the five distinct component sub-indices using a weighted geometric mean.

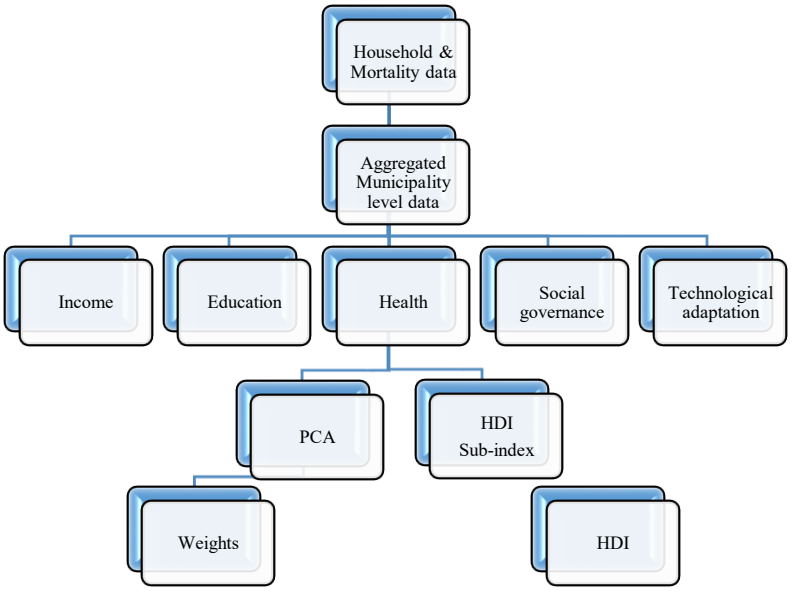

Fig. 1. Diagrammatic representation of methodology.

Computation of normalized HDI sub-index dimensions

The normalization process can be used to calculate the HDI dimension sub-indices. The UNDP approach, which is currently in practice, can be used to normalize the three aspects of income, education, and health. As stated below, other aspects of social governance and technological adaptation are also suggested to be normalized. The computational expressions for normalizing different dimensions are as follows.

Income dimension index

Gross National Income (GNI) per capita serves as the foundation for the income index (Government of Nepal and UNDP, 2020). The income dimension index is calculated as follows:

$$\text{HDI}_{\text{Income}} = \frac{\text{LN(Income Indicator)} - \text{LN}\left(\text{Min.}\left(\text{Income Indicator}\right)\right)}{\text{LN}\left(\text{Max.}\left(\text{Income Indicator}\right)\right) - \text{LN}\left(\text{Min.}\left(\text{Income Indicator}\right)\right)} \quad (1)$$

According to the UNDP, the minimum and maximum values of the income indicator (GNI per capita) are $100 and $75,000, respectively. Survey or National Accounts data can be used to estimate the income indicator.

Education dimension index

Education index as defined by UNDP for HDI calculation is computed taking account of mean years of schooling (MYS) and expected years of schooling (EYS). For MYS, the normalizing equation is:

$$\text{MYS}_{\text{Normalized}} = \frac{\text{MYS-Min.}(\text{MYS})}{\text{Range (MYS)}} \tag{2}$$

where minimum MYS and maximum MYS are taken as 0 and 15, respectively and Range (MYS) = Max. (MYS) – Min. (MYS). Similarly, for expected years of schooling, the normalizing equation is:

$$\text{EYS}_{\text{Normalized}} = \frac{\text{EYS-Min.}(\text{EYS})}{\text{Range (EYS)}} \tag{3}$$

where minimum EYS and maximum EYS are taken as 0 and 18, respectively and Range (EYS) = $\text{Max.}(\text{EYS}) - \text{Min.}(\text{EYS})$. The education index is the arithmetic average of mean years of schooling and expected years of schooling (Government of Nepal and UNDP, 2020).

$$\text{HDI}_{\text{Education}} = \frac{\text{MYS}_{\text{Normalized}} + \text{EYS}_{\text{Normalized}}}{2} \tag{4}$$

MYS can be calculated from household survey data and EYS from education statistics using enrollment percentage by level of education.

Health dimension index

The UNDP adopted health component index is based upon life expectancy at birth (e_x^0) which is as follows (Government of Nepal and UNDP, 2020).

$$\text{HDI}_{\text{Health}} = \frac{e_x^0 - \text{Min.}\left(e_x^0\right)}{\text{Range}\left(e_x^0\right)} \tag{5}$$

where minimum and maximum values of life expectancy at birth are considered as 20 and 85, respectively and $\text{Range}\left(e_x^0\right) = \text{Max.}\left(e_x^0\right) - \text{Min.}\left(e_x^0\right)$. Mortality data from national population censuses or surveys of the target population, such as the Nepal Demographic and Health Survey (NDHS) can be used to calculate life expectancy at birth.

Social governance dimension index

A new dimension that has been suggested for inclusion in the HDI construction is social governance. The following social governance-related indicators are taken into consideration when it is constructed.

- Engaging in socio-cultural activities or social and community-based organizations
- The degree of contentment and joy experienced when engaging in social activities
- Views on social organizations' governance and accountability obligations

Since social governance and these social activity metrics are closely related, they are regarded as indicators of the HDI's social governance component. Household survey data based on the aforementioned activities in a 5-point Likert scale variables can be used to gather information on social governance. Under social governance, the component index is defined and normalized as follows:

$$\text{SGCA}_{i(\text{Normalized})} = \frac{\text{SGCA}_i - \text{Min.}(\text{SGCA}_i)}{\text{Max.}(\text{SGCA}_i) - \text{Min.}(\text{SGCA}_i)} \quad (6)$$

where SGCA_i means social governance component average for the i^{th} component related to social governance, minimum and maximum value of a SGCA is 1 and 5, respectively. The social governance dimension index is computed as the arithmetic average of SGCAs.

Technological adaptation dimension index

Another new element of HDI construction is technological adaptation, which includes various technologically adapted amenities linked to people's everyday lives, such as those for cooking, lighting, electronics, the kitchen, restrooms, media, and transportation. Each sub-index is constructed using the following common normalizing expression.

$$\text{TA}_{i(\text{Normalized})} = \frac{\text{TA}_i - \text{Min.}(\text{TA}_i)}{\text{Max.}(\text{TA}_i) - \text{Min.}(\text{TA}_i)} \quad (7)$$

The minimum and maximum values for each ith component are dependent on particular TA-related components, like cooking and lighting. The following technological facilities' presence or absence is used to construct each sub-index.

- TA facilities related to lighting which includes adaptation of 8 facilities with its score ranging between 0-8,
- TA facilities related to cooking which includes adaptation of 6 facilities with its score ranging between 0-6,
- TA facilities related to media access which includes adaptation of 5 facilities with its score ranging between 0-5,
- TA facilities related to electronic devices which includes adaptation of 7 facilities with its score ranging between 0-7,
- TA facilities related to kitchen operation which includes adaptation of 2 facilities with its score ranging between 0-2,
- TA facilities related to washroom and toilet which includes adaptation of 5 facilities with its score ranging between 0-5,
- and TA facilities related to transportation which includes adaptation of 4 facilities with its score ranging between 0-4.

Lastly, the arithmetic average of the values of each TA-related component sub-index is used to create the technological adaptation index.

Method of weighting

Weighting for the construction of a composite index is a critical issue. In case of HDI, equal weighting has been adopted for the dimensions so far by the UNDP though inequality adjusted HDI adjusts HDI addressing inequality in the population distribution through computation of the geometric mean for each of the dimensions. Geometric mean essentially assigns relatively higher significance to lower values compared to higher values in the computation of the individual dimensions separately but gives equal importance and weight between the dimensions. However,

assigning equal weight to each of the dimensions of the HDI has been criticized by many researchers. Alternatively, assigning unequal weights to dimensions can be achieved through different methodologies. Among them subjective and objective assigning of weights exists. In the present context, we propose to follow the objective method of weighting through PCA. The purpose of PCA in the context of construction of composite index is to reduce dimensions to a single dimension as the composite index which explains the maximum variance (eigenvalue) of all the dimensions included. The first PCA is the linear combination of the dimensions with maximum eigenvalue and weights as the rescaled eigenvector. Weights in PCA are assigned based upon presence of variability in the individual dimensions with dimension having highest variability receives the maximum weights among the dimensions. This is particularly useful when ranking the entities or units through the method of PCA.

Survey methodology for computing individual HDI dimensions

Following stratified multistage sampling, a household survey was carried out to estimate the individual HDI dimensions. Furthermore, the estimation of life expectancy at birth needed to create the health dimension index was done specifically using secondary data from the National Population Census of Nepal, 2021. As indicated in Table 1, two analytical domains were created for the survey in order to capture the Bagmati province's heterogeneity with regard to the expected level of HDI. The types of municipalities in the province of Bagmati serve as the foundation for the domain construction.

Study area

The proposed methodology for the construction of HDI was applied specifically on Bagmati province of Nepal. The study area was chosen considering some major concerns such as its suitability within the Nepalese context, as it spreads from lowland to highland regions offering a comprehensive representativeness of Nepal's geographical diversity and also Kathmandu valley with the capital of Nepal lies in this province. Bagmati province is one of Nepal's seven provinces which is the second-most populous province with over 6 million population and the fifth largest by area (20,300 km^2). The province shares borders with Madhesh Province, the Indian state of Bihar to the south, Gandaki Province to the west, Koshi Province to the east, and the Tibet Autonomous Region of China to the north. Its provincial capital, Hetauda, encompasses the Kathmandu Valley. The province features hilly and mountainous terrain with peaks like Gaurishanker and Langtang. This province is diverse in culture, geography and climate, home to different cast and communities mainly Newar, Tamang, Madhesi, Sherpa and more. The province was named after the Bagmati River, significant in the Newar civilization. Bagmati's elevation ranges from 141m to 7,422m which includes plain Terai region to mountain region with 13 districts. Three metropolitan cities, one sub-metropolitan city, forty-one urban municipalities, and seventy-four rural municipalities make up the province's 119 local administrative units. Urban population share has reached 77.3% and rural population is around 22.7% as per the 2021 population census of Nepal. It has 33 major rivers, with the Sunkoshi being the longest. The province's climate varies from tundra in the High Himalayas to

subtropical in the Siwalik region, with temperature from 30°C to-10°C and annual precipitation from 150-3000 (Wikipedia contributors, 2024).

Analytic domains

Firstly, several districts were selected for sampling so as to represent ecological diversity in Bagmati province. Out of the total thirteen districts of the province, eight districts were chosen for the survey. Two districts were selected from mountain region namely Rasuwa and Sindhupalchowk. Similarly, five districts were chosen from hills namely Kavrepalanchowk, Kathmandu valley districts (Kathmandu, Lalitpur and Bhaktapur) and Makawanpur. From Terai region, one district namely Chitwan was chosen. There were two defined analytic domains (strata). The Bagmati province's rural (rural municipality) and semi-urban (urban municipality) areas were included in the first domain, while the sub-metropolitan and metropolitan city areas were included in the second. Prior to random sampling in both domains, districts were predetermined. The domain-wise distribution of households, population, allocated sample households and observed non-responses are shown in Table 1. The selected districts, municipalities (17 municipalities: 6 rural, 8 urban, 1 sub-metropolitan city and 2 metropolitan cities) and households in each domain is shown in Table 2.

Table 1. Domain-wise sample sizes.

Domain	Sub-domain	Units	HHs*	% of domain total HHs	Proportionally adjusted sample HHs	Actual sample HHs	Non-response %
Rural / Semi-urban	Rural municipality	74	347944	31.4	100	99	1.0
	Urban municipality	41	760691	68.6	194	192	1.0
	Total	115	1108635	100	294	291	1.0
Urban	Sub-metropolitan	1	46566	10.1	35	32	8.6
	Metropolitan	3	412716	89.9	259	246	5.0
	Total	4	459282	100	294	278	5.4
	Grand Total	119	1567917		588	569	3.2

* Data based upon Nepal Population Census, 2021

Table 2. Households for sample survey in the selected districts and municipalities.

Domain	District	Municipal	Sample households
Rural/Semi-urban	Rasuwa	Kalika, Uttargaya	32
	Sindhupalchowk	Bhotekoshi, Barahbise	41
	Kathmandu	Budhanilkantha, Kirtipur	48
	Bhaktapur	Changunarayan	24
	Lalitpur	Mahankal, Godawari	41
	Chitwan	Ichakamana, Khairhani, Madi	64
	Kavre	Chaurideurali, Panauti	41
	Total		291
Urban	Kathmandu	Kathmandu	118
	Lalitpur	Lalitpur	128
	Makawanpur	Hetauda	32
	Total		278

Sample size

Domain level sample size (Table 1) was calculated considering the important input variables. These are as follows.

- Type I error (α), $\alpha = 0.05$
- Power of test $(1-\beta)$, $1-\beta = 0.90$
- Relative margin of error (r), $r = 0.025$
- Coefficient of variation (CV) of the main variable under study (HDI), *CV* = 0.089
- Design effect (*Deff*), *Deff* = 2.0
- and expected non-response rate (*NR*), *NR* = 10%.

The required sample size per domain allowing 10% expected non-response rate is:

$$n = \frac{\left(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta}\right)^2 CV^2}{r^2} \times Deff \times (1+NR) = 294 \quad (8)$$

In total, 588 sample households are needed for the survey, allowing for 10% expected non-responses. The Nepal Multiple Indicator Cluster Survey (NMICS), 2019 was used to determine the value of Deff (1.5 for two-stage sampling, suggesting higher Deff for three-stage sampling and taken

as 2.0) (Central Bureau of Statistics and UNICEF Nepal, 2020). The HDI variation between Nepal's provincial states, which is 0.089 (Government of Nepal and UNDP, 2020), was used to calculate CV.

Study design

The cross-sectional study design was used to collect household and individual data necessary for the construction of the proposed HDI sub-indexes. Data on mortality to construct the health (longevity) index was obtained from the 2021 population census.

Sample design

A stratified multistage (three stage) sampling design was adopted and implemented for sample household survey. The province was stratified into two analytic domains namely rural/semi urban and metropolitan and sub-metropolitan areas within the province. Sampling was carried out independently between the two regions so that independent estimates can be computed for the two regions separately. In the first stage of selection, municipalities were selected randomly (simple random sampling) from the preselected districts for sampling. From the selected municipalities, wards (sub-wards in metropolitan cities) were selected randomly (simple random sampling) in the second stage of selection. In the final stage of selection, households were selected randomly.

Data collection tools and techniques

Field survey was implemented by visiting the respondent households and collecting data through personal interview of the household head (or representative of the household head with age at least 18 years of age wherever the household head was unavailable during data collection, frequency less than 5%). As per the sample size, 588 households were included for survey, out of which 569 households provided data with 3.2% non-response rate which was less than the assumed non-response rate (5%). Randomization of the final stage units (households) was done by pseudo randomization procedure since listing of units was practically unavailable. Pseudo-randomization was implemented through the technique of random walk procedure by choosing a centrally located reference point in a selected ward (or sub-ward) and choosing a direction randomly (N-S-E-W). In the selected direction, households were chosen systematically until a desired number of households per ward (or sub-ward) was attained by taking account of the total number of households in the area. Data was collected through structured questionnaire which contained information/questions regarding identification details, demographic characteristics, household features, information related to income, education, social governance, technological adaptation, health profiles, etc. Data was collected by maintaining reliability and validity to a high level as far as possible or practicable. In this regard, we designed the questionnaire with utmost care, maintained randomization procedure for the selection of sampling units at different stages of selection, interviewed respondents with their consent, cordial atmosphere and with adequate explanation. Data was collected through COBO toolbox. Collected data was screened for errors, managed data and analyzed with the support of appropriate software like R and SPSS.

Statistical analysis and estimation

Descriptive analysis of household survey data was performed. Individual dimension indexes regarding income, education, health (longevity), social governance, technological adaptation were estimated following the method as discussed earlier. Weights to the individual dimensions were estimated through objectively assigning weights by PCA.

PCA

Principal components (Johnson & Wichern, 2007) were estimated from the correlation matrix. The first principal component which explained the highest variance (eigenvalue) was considered for obtaining the weights (eigenvector) supported by Bartletts test for sphericity, Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Cronbatch Alpha. The first principal component is the linear combination of the HDI sub-indexes with maximum variance. It is given by:

$$w_1 \times \text{Income} + w_2 \times \text{Education} + w_3 \times \text{Health} + w_4 \times \text{Social governance} + w_5 \times \text{Technological adaptation} \quad (9)$$

Its variance is given by the eigenvalue.

HDI

HDI is obtained by the weighted geometric mean of the individual HDI dimensions along with their 95% confidence intervals. The computational expression for the calculation of the HDI is as follows.

$$\text{HDI} = EXP\left(\frac{1}{\sum_{i=1}^{k} w_i} \sum_{i=1}^{k} w_i \log_e(x_i) \right), k=5 \quad (10)$$

HDI is computed as the weighted geometric mean of the 5 individual HDI component sub-indexes (x_i) and w_is are the survey data weights. The individual sub-indexes are computed as the arithmetic averages from the survey and mortality data.

IHDI

Based on the Atkinson family of inequalities (Atkinson, 1970), the inequality-adjusted human development index (IHDI) corrects for the disparity in the individual dimension indices in the population (Foster et al., 2005). The geometric mean of the geometric means of each HDI dimension is used to compute the measure. Inequalities pertaining to each HDI dimension are taken into account by the IHDI, which is helpful in addressing population-level inequality. Although the sub-indices are computed as geometric means rather than arithmetic means, the computational expression of IHDI is identical to that of expression (9). Additionally, the IHDI measure is based on the Atkinson inequality measure, which is expressed using the following formula that accounts for survey weights.

$$A_i = 1 - \frac{GM_{y_i}}{AM_{y_i}} = 1 - \frac{\left(\prod_{i=1}^{n} y_i^{w_i}\right)^{\frac{1}{\sum_{i=1}^{n} w_i}}}{\frac{\sum_{i=1}^{n} w_i y_i}{\sum_{i=1}^{n} w_i}} = 1 - \frac{e^{\left(\frac{\sum_{i=1}^{n} w_i Ln(y_i)}{\sum_{i=1}^{n} w_i}\right)}}{\frac{\sum_{i=1}^{n} w_i y_i}{\sum_{i=1}^{n} w_i}} \quad (11)$$

The IHDI sub-index for the ith HDI component is: $(1 - A_i) HDI(i)$ where A_i is obtained for each dimension component of HDI and HDI(i) is the HDI of the ith component index.

Software for numerical computations and data analysis

R software was used to perform numerical calculations pertaining to the estimation of HDI and IHDI with their confidence intervals and the estimation of sub-index dimensions with their standard error (Windows R-4.4.0). SPSS version 27 was used for the initial construction of each sub-index variable from survey data.

RESULTS AND DISCUSSION

General household and individual characteristics

Sample household survey of Bagmati province was undertaken primarily to estimate sub-index dimensions of HDI. Data collected through personal interviews of household heads (or representatives) yielded information on demographic characteristics including general characteristics, household features, information related to income, education, health, socio-cultural dynamics and technology adoption. A descriptive analysis was performed to study about the main household and individual characteristics.

Demographic and general characteristics

Among the interviewed respondents (household heads or representatives in very few cases), majority of them were males (63.6%) compared to females (36.4%). Among them, 90.3% were currently married whereas very few (6.3% were unmarried and others were only around 3.4% (widow, widower, divorced, separated). The average age of the respondents was 44.4 years (minimum: 18 and maximum 84 years) with a standard deviation of 12.9 years. The average household size was 3.9 persons per household. Regarding occupation, most of the respondents were service holders (37.1%), followed by persons engaged in business (24.4%), workers relying in wages (16.3%), self-employed (10.7%), and others (11.5%) (agriculture, livestock, etc.). Majority of the sample respondents were Janjati (57.3%), followed by Brahmin (24.4%), Chhetry and Thakuree (12.3%) and rest were Dalit, Madhesi, and others (6%). Considering religion of the respondents, most of them were Hindu (71.5%) followed by Buddhist (23.2%), Christian (4.6%) and others (0.7%).

Information regarding HDI dimensions

As per the proposed HDI dimensions, data was collected on income, education, health (mortality), social governance and technological adaptation. Since sample size was only 569 households, data on mortality was very few and could not be used for sub-index construction. For the estimation of death rates required for the calculation of life expectancy at birth, mortality data of population census (2021) of Bagmati province was used instead. Household income was estimated considering all the possible income sources such as income from salary, wages, agriculture and livestock, business, remittance, others (if any). The average monthly income of the respondents was found to be around NRs. 58678.5 per households (or equivalently NRs. 14802.1 per month per person which includes all the persons in the households). Among the persons aged 25 and above, the percent of literate people were 78.3% which included people educated with non-formal education (7.4%), educated up to lower secondary education (31.3%), educated with higher secondary (15.9%), and educated with bachelor and above (23.7%). The mean years of schooling of sample individuals aged 25 and above was found to be 7.96 years. We also calculated life expectancy at birth for the population of Bagmati province from Nepal population census, 2021 data using age group specific death rates. It is found to be 72.4 years.

Data collected on social governance related variables showed that majority (or substantial proportion) of the respondents expressed that they frequently participated in social organization activities (57.3%) and organizations such as community based organizations (CBOs) or NGOs or GOs (46.1%). Majority (or substantial proportion) of the participants were highly satisfied with the social organization related activities (52.4%), community based organizations (CBOs) or NGOs or GOs (47.5%). 47.1% of the respondents were satisfied with the social governance related activities by social organizations and 48.6% were happy about their involvement in social activities. Technological adaptation is another sub-indexed proposed to be included in HDI calculation. Accordingly, there were many questions related to this context and asked in household survey. The questionnaire included questions on adaptation of technologies related to lighting, cooking, sanitation, kitchen appliances, electronic devices, media access, and transportation means used by people. Results revealed that 99% households used electricity, 16.8% used solar energy for the purpose of lighting. Similarly, 97.4% of households used LPG for cooking. However, there were households which also used traditional and environmentally harmful fuels like firewood (27.9%), crop residue and dung (3.5%) and others (8.9%). The results implied that households used multiple fuels for cooking. Considering kitchen equipments like oven and refrigerators, around 63-68% households used the appliances. Sanitation related adaptation of technologies revealed that 64.3% of people used flushed (or piped sewer system), 14% used geyser or solar powered heating system, 3.8% used exhaust fan, and 24.4% used water lifting motors. Mass media related adopted technologies revealed that 2.8% used daily newspaper, 27.8% used radio, 65.7% used internet and 77.3% used cable TV. Moreover, 58.6% used telephone and mobile, 11.9% used computer, and 5.7% used sound system. Regarding use of transportation facilities, 61.1% used bus, 55.3% used motorbike, 10.9% used car or van and 18.5% used bicycle. The usage were mostly multiple means of transportation.

Principal component analysis

PCA was used to determine the weights that can be attached to the individual HDI dimensions. The results regarding the extracted eigenvalues, percent of variance explained are shown in Table 3. The first principal component explains 58.5% of the total variance with eigenvalue, 2.925, the second component explains 20.5% of the total variance with eigenvalue, 1.023, and so on as shown in the Scree plot (Fig. 2). Generally, an eigenvalue above unity is considered substantial in the construction of reduced dimension using PCA. However, for the construction of the composite index of human development, we require only the first component with highest variance explained. The suitability of use of PCA from the sub-index dimensions of HDI was assessed by several statistical means as mentioned below.

- **Bartlett's test for sphericity**
  Bartlett's test for sphericity shows that the hypothesis of identity correlation matrix with zero correlations between the variables under consideration would be rejected at 5% level of significance (Chi-square value = 46.76, degrees of freedom = 10, p value < 0.0001). This implies that the non-zero correlations between dimension indexes are statistically significant at 95% confidence level.
- **KMO statistic**
  The KMO value is equal to 0.57 which is higher than the minimum cut-off point of 0.50. A KMO value below 0.50 is considered unacceptable in order to use PCA for a given set of data (Kaiser & Rice, 1974).
- **Cronbatch Alpha**
  The Cronbatch alpha value is equal to 0.80 computed considering the dimensions as the items. A high value generally greater or equal to 0.70 can be regarded as large enough to justify the use of PCA (Nguefack-Tsague et al., 2010).
- **Anti-image covariance matrix**
  The anti-image covariance matrix shows nearly zero values (<0.1) for 5 covariances and < 0.2 for rest of 10 possible covariances the (Table 4).

Consequently, the test results imply that application of PCA to HDI components is statistically justified. The components weights and corresponding rescaled weights estimated from running PCA are shown in Table 5. The highest weight is estimated for the income dimension (0.5305) followed by technological adaptation (0.5283), education (0.5166), social governance (0.3607) and health (0.2061). The estimated values of the weights suggest that among the five considered dimensions, income, education and technological adaptation were the most varied components with weights greater than 0.50. On the contrary, health index accounted by life expectancy at birth showed the least variation among the people of Bagmati province which resulted in the least weight attached with the component.

Table 3. PCA estimates.

	Eigenvalue	Percent of variance	Cumulative %
1	2.925	58.502	58.502
2	1.023	20.467	78.969
3	0.808	16.165	95.134
4	0.165	3.296	98.429
5	0.0785	1.571	100.000

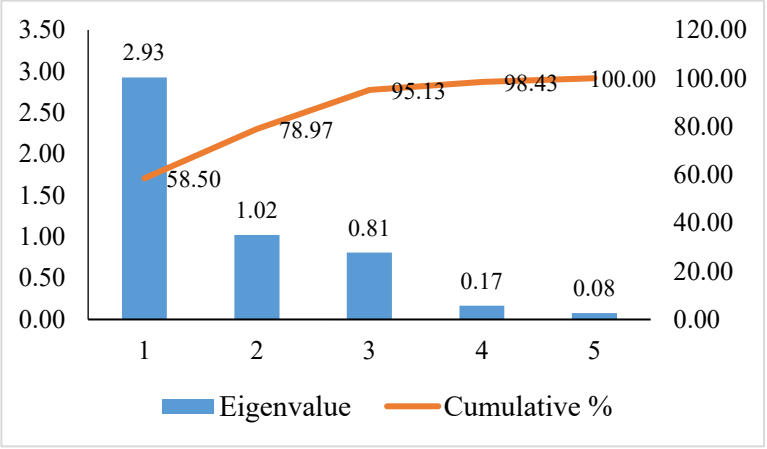

Fig. 2. Scree plot.

Table 4. Anti-image covariance matrix.

Dimension	Income	Education	Health	Social governance	Technological adaptation
Income	0.240	-0.028	0.040	-0.189	-0.079
Education	-0.028	0.156	-0.193	0.092	-0.111
Health	0.040	-0.193	0.489	-0.178	0.134
Social governance	-0.189	0.092	-0.178	0.556	-0.029
Technological adaptation	-0.079	-0.111	0.134	-0.029	0.144

Estimation of HDI

HDI components were estimated as the weighted arithmetic mean from municipal level data obtained from household survey data and mortality data from population census data. Rescaled weights (total weight = 1) were used for the estimation of the sub-indexes. Estimated sub-index values along with their standard errors and 95% confidence intervals are shown in Table 5. Highest value of the sub-index corresponded to the health index (0.8066; 95% CI: 0.80656-0.80664) followed by social governance (0.6775; 85% CI: 0.6736-0.6814), education (0.6496; 95% CI: 0.6445-

0.6547), technological adaptation (0.4615; 95% CI: 0.4544-0.4686) and income (0.3412; 95% CI: 0.3373-0.3415). The income index (0.3412) is found to be much lower than UNDP HDI income index (0.598). On the contrary, education index (0.6496) is found to be higher than the UNDP HDI education index (0.603), and health index (0.8066) is found to be approximately same as the corresponding HDI health index (0.800). The observed differences in the sub-index values obtained from the present analysis compared to UNDP HDI sub-index values could be due to many factors. For instance, the factors could be differences in the number of dimensions, weighting of components, post COVID economic effects, etc.

Bagmati province residents appear to be socially conscious and engaged, as evidenced by the social governance index being higher (0.6775) than the overall HDI value (0.5235). However, the technological adaptation index is significantly lower (0.4615) than the overall HDI value, indicating that households in Bagmati province lag behind in terms of technological adaptation and are comparatively underequipped with technologically sound goods and appliances to raise the level of human development. Finally, the estimated HDI value computed through weighted geometric mean is found to be 0.5235 (Equivalent 95% CI: 0.5185, 0.5284). The value is notably lower compared to UNDP adopted HDI value of Bagmati province (0.661) (Government of Nepal and UNDP, 2020). The results demonstrate that the UNDP adopted HDI value of Bagmati province is indeed overestimated which could substantially affect the policy decisions which have been planned considering UNDP adopted HDI and actually required more efforts than assumed.

Table 5. Estimates of HDI dimension sub-indices and related statistics.

Sub-index	PCA weight	Rescaled Weight	Estimate	Standard Error	Lower limit of 95% CI	Upper limit of 95% CI
Income	0.5305	0.2477	0.3412	0.00197	0.3373	0.3451
Education	0.5166	0.2412	0.6496	0.00262	0.6445	0.6547
Health	0.2061	0.0962	0.8066	0.00002	0.80656	0.80664
Social Governance	0.3607	0.1684	0.6775	0.00197	0.6736	0.6814
Technological Adaptation	0.5283	0.2466	0.4615	0.00363	0.4544	0.4686
HDI			0.5235		0.5185	0.5284

Estimation of IHDI

The IHDI was also estimated using weights assigned using PCA methodology, individual dimension indices derived from the sample household survey data and Nepal population census, and 2021 mortality data in order to evaluate the presence of inequalities in the Bagmati province's population. As indicated in Table 6, the IHDIs of the sub-indices are significantly lower than the corresponding HDI individual dimension indices. The income IHDI dimension is estimated as 0.2899 (95% CI: 0.2848, 0.295) which is found to be around 15% lower than the corresponding income

HDI sub-index. Similarly, the education, health, social governance and technological adaptation IHDI sub-indexes are found to be 0.5380 (95% CI: 0.5320, 0.5441), 0.6292 (95% CI: 0.62912, 0.62918), 0.6621 (95% CI: 0.6578, 0.6642) and 0.4389 (95% CI: 0.4319, 0.4460). The estimated IHDI sub-indexes are found to be 17.2%, 22%, 2.3% and 4.9% less than the corresponding IHDI sub-index values of education, health, social governance and technological adaptation, respectively. Because of this, the Atkinson measure of inequality for each sub-index was significantly higher than zero, suggesting that there are significant levels of inequality in Bagmati province across all IHDI components. Furthermore, estimates derived from survey data showed that social governance had the lowest Atkinson measure (0.0228) among the five individual dimensions, while estimates derived from survey data showed the highest for education (0.1718) and the health sub-index (0.22) from the Nepal Population Census, 2021 mortality data. The IHDI value of Bagmati province is approximately 11.9% lower than the HDI value, according to the overall Atkinson measure, which took into account all five of the IHDI's components, and was found to be 0.1185.

Table 6. Estimates of IHDI dimension sub-indices and related statistics.

Sub-index	Weight	Estimate	Geometric Standard Error	Lower limit of 95% CI	Upper limit of 95% CI	Atkinson Inequality (A_i)
Income	0.2477	0.2899	1.0091	0.2848	0.2951	0.1503
Education	0.2412	0.5380	1.0058	0.5320	0.5441	0.1718
Health	0.0962	0.6292	1.00002	0.62912	0.62918	0.2200
Social Governance	0.1684	0.6621	1.0033	0.6578	0.6642	0.0228
Technological Adaptation	0.2466	0.4389	1.0082	0.4319	0.4460	0.0490
IHDI		0.4615		0.4559	0.4669	0.1185
HDI		0.5235		0.5185	0.5284	
IHDI/HDI		0.8815		0.8793	0.8836	

CONCLUSION

Methodology for human development assessment was enhanced though taking account of five rational dimensions namely income, education, health, social governance and technological adaptation. The inclusion of additional components, namely social governance and technological adaptation is expected to increase representativeness and validity of human development assessment and could be relatively more suitable to least developed countries of the world like Nepal. The dimensions were unequally weighted by assigning weights objectively through PCA. Assigning weights by PCA would capture observed variability in HDI sub-indexes and suitable to rank units in view of human development levels. HDI and IHDI were estimated based upon the enhanced methodology and household sample survey data and mortality data of Bagmati province.

Sample household survey was conducted following three stage stratified sampling with a sample size of 569 representative households. Results of PCA yielded weights which were 0.2477 for income, 0.2412 for education, 0.0962 for health, 0.1684 for social governance and 0.2466 for technological adaptation. Highest weight was estimated for income and least weight was estimated for health which implied that income variation was highest and health (life expectancy) variation was lowest among the people of Bagmati province. The estimated dimension measures of income, education, health, social governance and technological adaptation were 0.3412 (95% CI: 0.3373, 0.3451), 0.6496 (95% CI: 0.6445-0.6547), 0.8066 (95% CI: 0.80656-0.80664), 0.6775 (95% CI: 0.6736, 0.6814), and 0.4615 (95% CI: 0.4544, 0.4686), respectively. Finally, the estimated HDI for Bagmati province was 0.5235 (95% CI: 0.5185, 0.5284) which is substantially lower than the corresponding UNDP computed HDI (0.661). The estimated income and education sub-index dimensions were quite different from the corresponding UNDP computed dimensions whereas approximately same considering health sub-index dimensions. The observed differences could be due to differences in methodology for computation, differences arising from post COVID context, etc.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the paper.

AUTHOR CONTRIBUTION

IPB contributed in conceptualization, methodology, data collection and management, analysis and draft manuscript writing. SLS contributed in methodology, data management and analysis, draft writing, editing, finalizing the manuscript and overall supervision of the study. Both authors read and approved the manuscript.

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DATA AVAILABILITY

The municipality level data can be made available upon request.

ETHICAL STATEMENT

The study is a partial research output of an approved (registered) Ph. D. research by the Dean's Office, Institute of Science and Technology, Tribhuvan University. The primary data was collected from respondents in household survey after taking their consent along with the commitment of maintaining the confidentiality of their identity and results will be published only at group levels but not at individual level.

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