Identifying High-Potential Work Areas in Engineering for Global Development: Linking Industry Sectors to the Human Development Index

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Those working in Engineering for Global Development seek to improve the conditions in developing countries. A common metric for understanding the development state of a given country is the Human Development Index (HDI), which focuses on three dimensions: health, education, and income. An engineer's expertise does not always align with any of those dimensions directly, while they still hope to perform impactful work for human development. To discover other areas of expertise that are highly associated with the HDI, correlations and variable selection were performed between all World Development Indicators and the HDI. The resultant associations are presented according to industry sector for a straightforward connection to engineering expertise. The associated areas of expertise can be used during opportunity development as surrogates for focusing on the HDI dimensions themselves. The data analysis shows that work related to "Trade, Transportation, and Utilities," such as electricity distribution, and exports or imports, "Natural Resources and Mining," such as energy resources, agriculture, or access to clean water, and "Manufacturing," in general, are most commonly associated with improvements in the HDI in developing countries. Also, because the associations were discovered at country-level, they direct where geographically particular areas of expertise have been historically associated with improving HDI. [DOI: 10.1115/1.4048746]

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1 Introduction

Although there has been significant improvement in general health, economic, and other conditions throughout the world in the past few decades, there remains a striking difference in conditions between developed and developing countries. For example, the UN recently reported that 3 billion people lack clean cooking fuels and technology [1]. Manufacturing value added per capita in developing countries was 2.3% of that in Europe and Northern America in 2018 [1]. And yet, some technologies have spread into developing countries with relative ease, as is evident by the fact that more people have access to a cell phone than a functioning toilet in many developing countries [2]. These compelling circumstances and others have inspired the action of local non-profit and non-governmental organizations in addition to international humanitarian efforts, creation of the United Nations Development Goals, and rallied individuals to causes such as Engineering for Global Development (EGD) [3,4]. Although EGD applies to countries from low- to high-development, the focus of this paper is on low- and lower middle-income economies classified by the World Bank [5], which will be hereafter referred to as developing countries.

Individuals interested in EGD face unique challenges, particularly when they are geographically removed from where their work is implemented, such as differences in language, culture and context that can lead to incorrectly assumed user needs and lack of product adoption [6,7]. At the same time, opportunity in EGD is replete and covers a number of disciplines, such as agriculture, sanitation, electricity, water, product design, and manufacturing [8–13]. Regarding EGD, two important and often difficult questions considered are *what* project or product should our organization work on? and (more particularly for those geographically removed from developing countries) *where* should we implement our work [14–16]?

Those working towards improving conditions in developing countries currently focus on a variety of areas, such as poverty alleviation, human development, and gender equality [17–20]. The United Nations Development Programme (UNDP) has published measurements or indices in some of these areas, including the Human Development Index (HDI). The HDI summarizes the development state of a country using measures in three dimensions: "a long and healthy life, access to knowledge, and a decent standard of living" [21]. More succinctly, the HDI is quantified using data that captures the state of health, education, and income of individuals in a given country and its calculation is shown in Eq. (1).

$$HDI = (I_{\text{Health}} \cdot I_{\text{Education}} \cdot I_{\text{Income}})^{1/3} \tag{1}$$

where I_{Health} represents the Health index, $I_{\text{Education}}$ is the Education index, and I_{Income} the Income index. The indicators for each index are "Life expectancy (years)" for Health, "Expected years of schooling (years)" and "Mean years of schooling (years)" for Education, and "Gross national income per capita (2011 PPP $)" for Income. Each dimension index is calculated according to Eq. (2). Additional

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HDI details can be found in the UNDP Technical Notes for Calculating the HDI [21].

$$\text{Dimension index} = \frac{\text{actual value} - \text{minimum value}}{\text{maximum value} - \text{minimum value}} \quad (2)$$

The HDI has been referenced in a number of different disciplines and applications. For example, Ray et al. [22] used the HDI to measure the impact of switching from kerosene lamps to solar lights, Dufo-López et al. [23] used the HDI as an optimization objective for off-grid electrical supply, others have examined how electricity consumption [24,25] and the sustainable water use index [26] are correlated with the HDI. Early social science research on the country-level factors that are associated with the HDI have focused on economic predictors such as GDP per capita [27] and per capita real income [28]. More recent efforts have compared and contrasted the HDI and environmental sustainability, which scholars argue is related to and should be included in an index of human well-being [29]. Jain and Nagpal find that the HDI is positively associated with environmental sustainability, measured as environmental health and ecosystem vitality [30].

The HDI provides a more well-rounded approach to quantifying the development of a country than solely focusing on gross national product growth [31]. This said, the HDI provides only a summary of human development in a given country, and as such, cannot communicate many of the details related to development [32].

While the HDI can provide a useful basis for what to work on and where to work, not every EGD practitioner has expertise in health, education, or income directly, yet they still hope to perform work that will improve human development. To put the research in this paper into perspective, consider the intersection of passion, expertise, and market needs presented in Fig. 1(*a*). Focusing energy and resources on work that falls in the intersection of these three categories, Nucor Steel became a distinguished steel fabrication and Fortune 500 company [33]. Nucor's Circles is suggested by Mattson and Sorensen as a tool for thoughtfully converging on high-potential opportunities during the opportunity development stage of product development [34]. According to the Nucor's Circles approach, high-potential opportunities fall in the intersection of an individual's or group's passion, expertise, and the needs of the market.

Under the assumption that EGD is the passion of the individual or group, two important considerations need to be made: what does the market need, and what are the individual's or group's expertise. This paper seeks to inform those considerations by (i) discovering what type of work is related to improvements in HDI by correlating the HDI to all World Development Indicators (published by the World Bank) and (ii) representing expertise by industry sector and linking them to the World Development Indicators (WDIs) and thus helping to clarify engineering expertise with high potential for EGD impact. With a clearer picture of what the market needs and a clarification of engineering expertise with high potential for EGD impact, the intersection between market needs and expertise is virtually expanded, as shown in Fig. 1(*b*).

In short, this research seeks to discover what areas of expertise—other than only health, education, and income—are commonly associated with improvements in HDI in developing countries.

We theorize that by examining historical correlations and performing variable selection between all WDI and the HDI for developing countries from 1990 to 2017, associated industry sectors will be found that can act as surrogates for focusing only on the three dimensions of the HDI (health, education, and income). Historical patterns from developing countries can help guide the choice of what to work on that has high-potential to improve human development in developing countries. For example, an engineer may seek to improve the Educational dimension of the HDI, but have no expertise related to educational products. Through the results provided in this paper, the engineer could recognize that work related to utilities, such as water distribution, is associated with improving HDI and infer that providing access to water can relieve water collection burdens children—particularly girls—may face, allowing them to attend school more consistently [35].

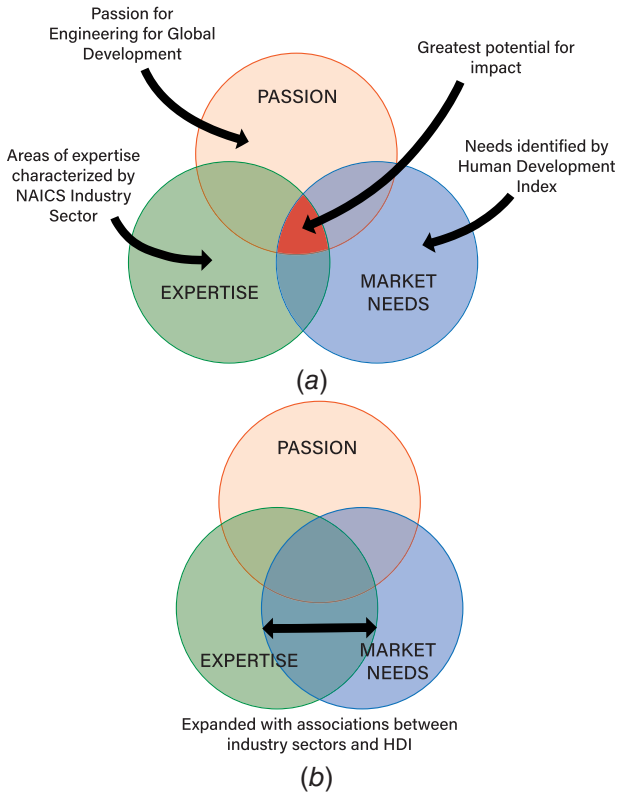

Fig. 1 Opportunities with high-potential are at the intersection of an individual's or group's expertise, their passion, and what the market needs. In EGD, market needs can be broadly determined from HDI, but HDI is only focused on three areas: health, education, and income. This research seeks to virtually expand the intersection of market needs and expertise by observing other areas of expertise commonly associated with improving HDI. Figure adapted from Ref. [33]. (*a*) Referencing HDI for market needs, opportunity is falsely limited to work in just health, education, and income and (*b*) virtual expansion by increased understanding of how industry sectors relate to HDI.

1.1 Assumptions and Limitations of Research Approach.

In performing this worldwide data analysis, there were some inherent limitations in addition to some assumptions and approximations that were made to enable a tractable approach. The assumptions and limitations are as follows:

(1) **Research was performed with historical observational data.** Because these data are observational, and historical patterns do not always repeat in different areas of the world, the results presented herein cannot claim a causal relationship between WDIs and HDI, and results from one country cannot be inferred to another country. While historical patterns can be insightful, they will not flawlessly transfer to modern circumstances. The patterns discovered may carry forward for one year, five years, or more, but there is no basis for determining how long they may be applicable. Also, some patterns discovered in this data analysis may be coincidental; thus, the results are presented for all developing countries, by region, and by country, where patterns repeated regionally or worldwide may be more indicative of true relationships. Finally, historical patterns cannot fully represent current needs: current needs and where to work are discussed in more detail by Mabey et al. [36].

(2) **We assume HDI represents market needs.** The HDI is an insightful metric that captures the general development state

of a given country and thus can provide insight into market needs. Because it is reported at country level and is a general measure, it does not capture the detailed needs of a community, family, or individual. Further investigation will need to be performed to validate more detailed and localized needs.

(3) **World Development Indicators data are not comprehensive and are aggregated at a national level.** There are many advantages of using the WDI data published by the World Bank, such as the qualitative nature of many of the survey data, the yearly publications for many data for many countries, and the sheer quantity of publicly available raw data. It is important to recognize, however, that the breadth of WDI data is not comprehensive and thus cannot capture every aspect of what causes changes in HDI. More specifically, WDI data is not always engineering or industry specific, so the results presented herein focus on those WDIs that are connected to an industry sector.

(4) **Limited number of terms were used in regression models.** A multiple linear regression model was fit for each country with a maximum of eight terms. Too many terms can cause overfitting, but limiting the number of model terms could exclude some lesser, yet insightful, associations between WDIs and HDI. Therefore, the results focus on areas of expertise related to the eight best fitting WDIs for each country; there are other less associated areas of expertise not captured by this analysis. A more detailed discussion of why eight was chosen as the number of regressors is included in Sec. 2.3.2.

(5) **Developing Countries Classification.** Various country classifications exist including those used in this paper by the World Bank [5]. The results of this study are influenced by the classification chosen, and will change somewhat if different country classifications were used. Different classifications that may be worth considering include UN DESA and IMF classifications.

The remainder of this paper is laid out as follows. In Sec. 2, the approach for discovering historical associations between WDIs and the HDI is detailed. Section 3 summarizes patterns of which industry sectors are related to increasing HDI in developing countries. Section 4 presents scenarios of how the results presented might be utilized by different individuals and groups. Finally, Sec. 5 discusses how the observed associations expand understanding of the intersection between expertise and market needs.

2 Method

The goal of this data analysis is to discover historical associations between WDIs and the HDI such that highly associated WDIs point toward areas of expertise related to increasing HDI. The process followed to discover these associations was as follows:

(1) Acquire HDI and WDI data
(2) Perform a keyword filter as well as a correlation filter on WDI data to reduce to a tractable dataset for variable selection
(3) Perform variable selection on filtered and normalized WDI data to identify the WDIs that best fit the change in the HDI
(4) Categorize the best fitting WDIs by NAICS Industry Sector for a more direct connection to areas of expertise

As illustrated in Fig. 2, this approach offers the ability to filter through the many WDIs using correlation and variable selection to determine which WDIs best fit the change in the HDI in a given country [37]. When categorized by industry sector, the selected WDIs will suggest areas of expertise that have been commonly associated with increasing HDI in developing countries. Each step of this data analysis is discussed in detail below.

2.1 Acquire Data. HDI data, published by the United Nations Development Programme, was available from 1990-2017 for 76 developing countries and was acquired for this study [21,38]. Additionally, the World Bank publishes WDI data that captures national development data in categories such as agriculture, education, gender, trade, and population dynamics [39]. Typically collected through censuses and surveys, some examples of WDIs include "Electric power consumption (kWh per capita)," "Manufacturing value added (current LCU)," and "Rural population growth (annual %)." Up to 1599 WDIs were available for the same 76 developing countries as HDI, and these data, also between 1990 and 2017, were acquired and included for this study.

2.1.1 Handling Incomplete Data. Many countries had incomplete HDI or WDI data between 1990 and 2017. For the HDI, it was typical that once the HDI began to be reported, it was reported for every year thereafter. For example, HDI data were not available from Ethiopia from 1990 to 1999, then was reported from 2000 to 2017. To avoid extrapolating into the past, the correlations and variable selection were only performed for years; the HDI was reported.

For the WDIs, if only those WDIs that had complete data between 1990 and 2017 were used, this exclusion would reduce the number of WDIs in each country (depending on the country) from up to 1599 down to approximately 500, so the missing data were imputed. WDIs with missing data were often reported for a few years and then failed to report for a few years. The strategy used to handle missing data was to impute the missing data by carrying the last observation forward [40]. For example, in El Salvador the "Government expenditure on education, total (% of GDP)" was

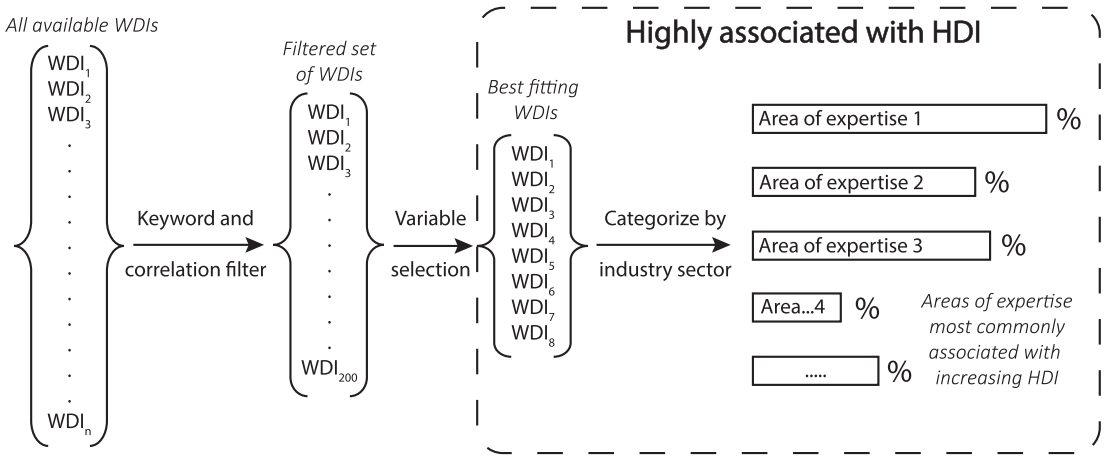

Fig. 2 Summary of historical data analysis for discovering areas of expertise associated with improving HDI in each country

reported in 1998–2000, 2002–2003, and 2005–2017. Because no data was reported until 1998, data were not extrapolated to 1990–1997; data from 2000 were carried forward into 2001, and data from 2003 were carried forward into 2004. Thus, percent change (discussed in detail in Sec. 2.3) calculated for 2000–2001 and 2003–2004 was zero. About 30.6% of the WDIs had missing data for at least 1 year. The effect of using last observation carried forward to impute the missing WDI data cannot be precisely known since the actual data for those years is missing. We can know, however, that the last observation carried forward method provides a reasonable estimate because it does not assume an increase or a decrease in that indicator. The change in a WDI could be positive or negative, so assuming there was no change can be conservative or nonconservative depending on the trend of the data.

2.2 Rank-Transform Data, Correlate World Development Indicator to Human Development Index and Filter. As a first step in analyzing which WDIs are highly associated with HDI, a bivariate correlation that measures the strength and direction of association was calculated for each WDI and the HDI. Common correlation statistics, including the Pearson r correlation, assume that the data is normal [41]. After performing the Anderson-Darling test on a subset of WDI data, it was apparent that much of the data was not normally distributed [42]. Others, such as the Spearman and Kendall correlations, eliminate the importance of population distributions by accepting rank-transformed data [41,43]. Therefore, the non-normal WDI and HDI data were transformed to ranks prior to calculating the correlation: the value of each WDI for each year was replaced by its rank relative to the values from other years of the same indicator [37].

For an initial screening of the many potentially associated WDIs, the WDI values from each country were correlated with the HDI values. The correlation was quantified using the Kendall's τ correlation coefficient. Quantifying Kendall's τ is a non-parametric test that calculates how many ranked values are concordant or discordant between two groups [43,44]. For example, if the values of a WDI increase year-to-year over a given time period and the values of the HDI also increase year-to-year over the same time period (no matter if the relationship is linear or non-linear), Kendall's τ will equal 1. Also, performed in MATLAB® R2019b, the calculation of Kendall's τ correlation coefficient included an adjustment for tied rank values [45].

As mentioned in Sec. 2.1.1, the correlation coefficient was calculated only for years the HDI was reported in each country. Regarding the example of Ethiopia from Sec. 2.1.1, the HDI was only reported from 2000 to 2017; so, the HDI and WDI values were correlated for only those years in Ethiopia.

2.2.1 Filter the Dataset. As the aim of this analysis was to expand the intersection between market needs and expertise (Fig. 1(*a*)), the WDIs that were directly related to the calculation of each HDI dimension—Health, Education, and Income—were filtered out of the dataset because they were assumed associated and would eliminate opportunities for associated indicators in other areas of expertise to be captured in each country's linear regression model. Also, this was done because this research aimed to discover *other* areas of expertise that have been related to increasing HDI in developing countries. Finally, those filtered out were often colinear with the metrics used to calculate the HDI and could thus adversely affect the regression model selected with stepwise variable selection [37].

After removing the directly related WDIs, the top 100 positively correlated WDIs and the top 100 negatively correlated WDIs were saved for variable selection. This reduced the likelihood of selecting coincidental associations during variable selection due to a large number of potential explanatory variables [46]. Also, it focused the variable selection on those WDIs that had strong correlations with the HDI (for most countries and WDIs, |Kendall's τ|>0.6), while maintaining a consistent number of WDIs for each country's variable selection.

2.3 Perform Stepwise Variable Selection on Percent Change of World Development Indicator and Human Development Index. Following the initial filtering of WDIs according to Kendall's τ, the WDIs that best fit change in the HDI in each country were identified using variable selection [37]. The values of the WDIs range in magnitude and vary in their configuration—some are percent values, others are raw counts, and some are ratios. Thus, to scale the WDIs in relation to the HDI, the percent change per year was calculated for each WDI and HDI specific to each country. Using the percent change also captured the direction of change in the indicator or index over time, thus allowing for simple interpretation.

2.3.1 Calculate Percent Change. The percent change in each HDI for each year from 1990 to 2017 was calculated as follows:

$$\delta_{I_t} = \frac{I_t - I_{t-1}}{\bar{I}} \tag{3}$$

where t represents the t-th year, δ_{I_t} represents the percent change in the index value from the past year to the current (or t-th) year, I_t represents the HDI value for the t-th year, and the average, $\bar{I}$, is calculated from available data between 1990 and 2017. This calculation was made for each country individually.

The calculation of percent change for each of the 1599 WDI values was of the same form as for the HDI data:

$$\delta_{w_t} = \frac{w_t - w_{t-1}}{\bar{w}} \tag{4}$$

where t represents the t-th year, δ_{w_t} represents the percent change in each WDI value from the past year to the current (or t-th) year, w_t represents the value of one of the WDIs for the t-th year, and the average, $\bar{w}$, is calculated from available data between 1990 and 2017, each country specific.

It is common to calculate percent change in relation to the past data point, but there were some WDI data whose change year to year was quite drastic. This led to influential outliers that biased the linear regression models that are not robust to outliers. Using the average of the data for each indicator helped attenuate the extremes in percent change per year.

2.3.2 Stepwise Variable Selection. The final step in discovering associations between WDIs and HDI was to perform a stepwise variable selection that created a multiple linear regression model for each country that denoted those WDIs that best fit change in the HDI. *To be clear, the purpose of the variable selection was to identify up to 8 WDIs in each country that have been highly associated with increasing HDI*, rather than to make quantitative predictions of the HDI given WDI input; thus, the results will not focus on the regression models (regression coefficients, p-values, etc.), rather the WDI terms included and their associated industry sectors. Given percent change per year (from Sec. 2.3) of the 200 most correlated WDIs (from Sec. 2.2), forward selection was performed using multiple linear regression [47]. The criterion used for adding or excluding terms to each country's model—to find the best fitting WDIs—was the adjusted R-squared metric [48].

It was desirable to exclude interaction terms to increase the diversity of WDIs included in each country's regression model. When interaction terms are included, it is appropriate to also include each of the explanatory variables in the interaction as individual regressors [37]. With a limited number of regressors per model, interactions would produce repeated WDI regressors. To determine if excluding interactions would adversely affect the accuracy of which WDIs are most associated with increasing HDI, multiple linear regression models were created for each country with and without interaction terms, and the models without interaction terms performed equally as well as those with interaction terms.

Therefore, the results presented herein are based on a variable selection of only first-order terms.

Regarding the number of regressors in the model, Peduzzi et al. suggest that a minimum of 10 years of data per regressor will help avoid overfitting and other issues, while Vittinghoff et al. and Austin and Steyerberg show that this may be too conservative and show that a minimum of 2–3 years of data per regressor is appropriate [49–51]. Specific to the analysis in this paper, each country reported the HDI and WDIs for up to 27 years, with an average of approximately 24 years for HDI and 20 years for WDIs. It was desirable to maximize the number of included WDI regressors to potentially increase their variety, while also avoiding overfitting so the models created would be informative of historical patterns that may be more applicable moving forward. In line with the goal of this research, the number of WDI regressors was maximized to eight regressors for a nonconservative 2.5 years of data per regressor.

In summary, forward selection was performed (terms were added to the model) for the HDI in each country until either (1) the adjusted R-squared criteria stopped increasing, or (2) the model fit eight WDI regressors.

2.4 Serial Correlation Effects. One potential issue when creating regression models using data that is reported year to year is serial correlation (also known as autocorrelation), where the residuals from year to year are correlated. The effect of serial correlations is that the regression coefficients will be imprecise, suggesting more or less statistical significance than is true [52,53]. In other words, the p-values for the regression coefficients will be estimated too high or too low and the confidence intervals will be too wide or too narrow.

A common test to discover the presence of serial correlations is the Durbin–Watson test that reports a statistic, d, between 0 and 4, where $d = 2$ suggests no serial correlation [54,55]. Critical values, d_L and d_U, for the Durbin–Watson statistics tabulated by Savin and White report that for a model with eight regressors and a sample size of 20, $d_L = 0.50$ and $d_U = 2.52$ [56]. Performing the Durbin–Watson test on the regression models created for each country showed that 0% of models predicted regression coefficients with exaggerated (p-value too low) statistical significance (when $d_L < 0.50$), and 18.3% of models predicted regression coefficients with underestimated (p-value too high) statistical significance (when $d_U > 2.52$). With the presence of some serial correlation effects, a Newey–West robust covariance matrix was used when fitting each country's regression that adjusted for or mitigated the serial correlations [57].

2.5 Categorizing World Development Indicators by NAICS Industry Sector. The previous steps in this data analysis filtered through up to 1599 WDIs per country down to approximately eight WDIs per country that best fit increasing HDI. With the goal of understanding which areas of expertise are commonly associated with increasing HDI, the WDIs selected for each country's model were categorized according the North American Industry Classification System (NAICS) Industry Sectors [58], and the results are presented according to how frequently each industry sector was connected to a WDI that best fit the change in HDI. The categorization process was performed by the synthesized judgment of four researchers [59] whose knowledge-base was used to make informed categorization judgments [60].

To perform the categorizations, four researchers, working in teams of two, examined each remaining unique WDI to determine if there was a connection to one or more industry sectors. By working in teams of two, each researcher was forced to justify, to a teammate, the reasoning for connecting a WDI to an industry sector. Recognizing that we cannot fully eliminate research bias, a brief description of the individuals included as well as a motivation for including them in this part of the study are as follows. The four researchers included a professor and three graduate students all in mechanical engineering. All four researchers were males whose home country is the United States. The professor and one of the graduate students were chosen because of their 11 and 5 years, respectively, working with EGD groups and implementing projects in a variety of locations including Uganda, Tanzania, Rwanda, Peru, Brazil, Mongolia, India, and Cambodia. Their familiarity with EGD, various cultures, as well as exposure to WDI data provided relevant context to the WDI data that were categorized. The other two graduate students both became thoroughly familiar with the NAICS Industry Sectors by studying the descriptions of each super-sector, sector, and subsector and accompanying examples for over 8 hours each and their expertise guided the discussions of how each WDI was connected or not connected to industry sectors.

First, each researcher completed a 30-min training to familiarize himself with the NAICS industry sectors. A Qualtrics online survey platform was used to rate each of the 329 unique WDIs according to its connection to industry sectors. The survey was created by referencing guidelines for survey research published by Rea and Parker [61]. The order in which the WDIs were presented to each team was randomized to reduce bias. The teams first rated each WDI's connected-ness to the NAICS industry super-sectors, then by industry sectors (if there was a "Moderate" or "Fundamental" super-sector connection), and lastly by industry sub-sectors (if there was a sector connection). A detailed description of each WDI was available during the survey for the teams to refer to as needed.

The level of connected-ness was determined according to the definitions in Table 1, similar to a Likert scale with no neutral option [61]. The results presented in this paper focus on those WDIs that are "Moderately" or "Fundamentally connected" to at least one industry sector. The "No specific connection" option was included because there are a number of WDIs that reflect a measure of industry as a whole while not referring to any specific sector of industry (see Table 5 for examples).

In general, the WDIs are metrics in a number of areas, such as economics, climate change, gender, health, poverty, among others; thus, how they connect to industry sectors is not always

Table 1 Rubric for categorizing WDIs by NAICS Industry Sector

Strength of connection	Description of the strength of connection
Fundamentally connected	The WDI is a **direct measure** of an aspect of the Industry Sector
Moderately connected	The WDI is the **result of work** in the Industry Sector, is **made possible by work** in the Industry Sector, or **offers motivation to work** in the Industry Sector
Insufficiently connected	The WDI pertains to measurements **outside of the Industry Sector being considered** or requires two or more logical steps to connect the WDI to the Industry Sector
No specific connection	The WDI measures employment, profit, activities, goods, or other metrics of **industry as a whole** with **no reference to a specific sector or sectors**
Unknown	**Insufficient WDI detail** to categorize by Industry Sector or researchers do not understand the WDI and thus cannot determine if it is connected to an Industry Sector

Table 2 Intraclass correlation coefficient reliability chart

ICC value	Reliability
0–0.5	Poor
0.5–0.75	Moderate
0.75–0.9	Good
0.9–1	Excellent

apparent and it was expected that the teams would differ in some of the categorizations. After both teams categorized all the unique WDIs, they met to discuss disagreements within teams and discrepancies between the teams' categorizations. Each discrepancy in categorization was seriously considered. About 37.8% of all WDIs were categorized as having a connection by one team when the other determined there was an "insufficient connection." An analysis of the discrepants showed five themes that explained 24.3% of the discrepancies and another nine themes that accounted for the remaining 13.5%. These themes centered on monetary authorities, social assistance, retail/wholesale trade, legal services, and others that teams would benefit from debating together. These themes were discussed, after which each researcher anonymously re-categorized the WDI. If there were at least three out of four researchers in agreement, the WDI was categorized as agreed upon and included in the results.

3 Results and Discussion

The analysis detailed in Sec. 2 produced a regression model for each developing country with up to eight WDIs that best fit the change in HDI data for each country according to the adjusted R-squared metric. The results of this paper focus on areas of expertise connected to the WDIs that best fit increasing HDI; thus, the WDIs selected for each country's regression model were categorized by NAICS Industry Sector. The results of the categorization and agreement between researchers is included in Sec. 3.1. Table 5 provides an example of the WDIs that best fit the change in the HDI in Zambia and their corresponding industry connections. The culmination of this research is discussed in Sec. 3.2 that primarily presents the frequency of industry sector connections to increasing HDI in developing countries. Resultant associations between industry sector and HDI are summarized across all developing countries in Table 3, by region in Table 4, and by country in Table 7. Because of the EGD motivation for this research, these results focus on areas of expertise commonly related to increasing HDI in developing countries. Added understanding of which industry sectors have historically been related to increasing HDI virtually expands the intersection between areas of expertise and market needs, as illustrated in Fig. 1(*b*).

3.1 Categorization Agreement Analysis. The categorization results presented below were calculated after the two teams discussed discrepancies between teams and voted to decide which of the discrepant WDIs were or were not connected to industry sectors. Out of the 579 total WDIs selected for regression models in 76 developing countries, it was determined that 52 WDIs were insufficiently connected to industry, 68 had no specific industry sector connection, and the remaining 459 had a moderate to fundamental connection to at least one industry sector, and thereby an area of expertise. The majority of the categorized WDIs were connected to multiple industry sectors.

To assess the reliability of these categorizations, an intraclass correlation coefficient (ICC) was calculated that quantifies the agreement of responses between the two teams of researchers [62]. The ICC was calculated according to super-sector and sector connections, where each data point was represented by a 0 if the WDI was "Insufficiently connected", had "No specific connection," or was "Unknown" and by a 1 if the WDI was "Moderately" or "Fundamentally connected". Calculated with the Pingouin statistical package in PYTHON [63], the two-way mixed-effects ICC was found to be 0.91 with a significance value <0.0001 and a 95% confidence interval from 0.90 to 0.91 indicating an excellent level of agreement between the respondents [64]. The scale of ICC and the reliability of the results according to Koo et al. is found in Table 2 [64]. Because of the excellent level of agreement between teams, we are confident that the categorizations were performed thoroughly and reliably.

3.2 Areas of Expertise Associated with Increasing Human Development Index. In practice, the results presented in Tables 3, 4, and 7 could be used during opportunity development in two ways:

(1) To determine *what* to work on by referencing areas of expertise strongly associated with improving HDI, or
(2) To determine *where* geographically to implement a product or project for highest-potential impact.

The areas of expertise presented are those associated with increasing HDI, on average, between 1990 and 2017. To be consistent with the previous statement, adjustments for South Sudan and the Syrian Arab Republic were made. South Sudan has only been reporting HDI data since 2010 and its HDI has only improved twice since that time; thus, there was not sufficient data to fit a model that relates WDI to increasing HDI. HDI in the Syrian Arab Republic decreased from 2010 to 2015, so the results for the Syrian Arab Republic are from an analysis between 1990 and 2009 where, on average, HDI increased year-to-year.

Regarding what to work on (point (1) above), engineers commonly begin the design process by developing a clear understanding of market and engineering requirements for a project or product; in other words, working through opportunity development [34]. While an individual or group is brainstorming potential opportunities, under the assumption that EGD is the passion of the individual or group, a high-potential opportunity may be identified by examining Table 3 and noting those areas of expertise that have been closely related to an increase in HDI.

The left two columns of Table 3 show how frequently an industry super-sector has historically been associated with increasing HDI across all developing countries. For example, out of all the WDIs selected for each of the developing countries' regression models, the WDI was connected to "Trade, Transportation, and Utilities" an impressive 36.4% of the time. Considering that eight WDIs were selected for each country, 36.4% means that, on average, approximately three WDIs in each country's model were related to "Trade, Transportation, and Utilities." The right two columns offer more detail: of the industry sub-sectors related to "Trade, Transportation, and Utilities," an indicator related to "Utilities" has been connected to 15.5% of the WDIs, more than nearly any other industry sector or sub-sector. In short, these industry sectors with a higher relative % connection to WDIs have been more commonly associated with an increase in HDI and may prove to be high-potential areas for improving human development.

Additionally, the high-potential work areas identified can offer direction regarding *who* to partner with to implement the work. More detail regarding the need for effective partnerships is discussed by Wood and Mattson [6] and Mabey et al. [36].

For reference, any value above 13% means that, on average, at least one WDI per developing country was connected to that industry sector, suggesting at least a moderate connection between that industry sector and increasing HDI in developing countries. That said, a percentage lower than 13% does not mean that area of expertise is inconsequential; rather, that area of expertise may not be impactful across *all* developing countries, but may be impactful in specific countries or regions; so, Tables 4 and 7 should be referenced for additional detail.

Table 3 Detail regarding areas of expertise that have been commonly related to increasing human development by reporting how frequently the WDI developing countries regressors were connected to NAICS Industry super-sectors, sectors, and sub-sectors

NAICS industry super-sector	Frequency of industry sector connection to increasing HDI in developing countries (%)	NAICS industry sector or sub-sectors	Frequency of industry sector connection to increasing HDI in developing countries (%)
Trade, Transportation and Utilities	36.4	Utilities (NAICS 22)	15.5
		Wholesale Trade (NAICS 42)	8.6
		Transportation and Warehousing (NAICS 48-49)	7.1
		Retail Trade (NAICS 44-45)	5.2
Education and Health Services	26.4	Health Care and Social Assistance (NAICS 62)	20.0
		Social Assistance (NAICS 624)	13.3
		Ambulatory Health Care Services (NAICS 621)	8.8
		Educational Services (NAICS 61)	6.0
Natural Resources and Mining	19.3	Agriculture, Forestry, Fishing and Hunting (NAICS 11)	8.3
		Mining, Quarrying, and Oil and Gas Extraction (NAICS 21)	3.8
		Crop Production (NAICS 111)	2.9
		Forestry and Logging (NAICS 113)	3.1
		Animal Production (NAICS 112)	1.2
Financial Activities	18.3	Finance and Insurance (NAICS 52)	16.4
		Monetary Authorities - Central Bank (NAICS 521)	11.4
Manufacturing	16.8	Manufacturing (no specific sub-sector)(NAICS 31-33)	14.2
		Computer and Electronic Product Manufacturing (NAICS 334)	1.9
		Chemical Manufacturing (NAICS 325)	1.7
		Machinery Manufacturing (NAICS 333)	1.2
Construction	15.7	Construction of Buildings (NAICS 236)	8.5
		Heavy and Civil Engineering Construction (NAICS 237)	6.2
Information	12.6	Broadcasting (except Internet) (NAICS 515)	8.6
		Internet Publishing and Broadcasting (NAICS 516)	9.3
		Publishing Industries (except Internet) (NAICS 511)	8.1
		Telecommunications (NAICS 517)	1.9
Professional and Business Services	9.5	Professional, Scientific, and Technical Services (NAICS 54)	5.7
		Management of Companies and Enterprises (NAICS 55)	1.0
		Administrative and Support and Waste Management and Remediation Services (NAICS 56)	0.9
Other Services (except Public Administration)	3.5	Repair and Maintenance (NAICS 811)	1.2
		Grantmaking, Civic, Professional, and Similar Organizations (NAICS 813)	1.0
Leisure and Hospitality	3.3	Arts, Entertainment, and Recreation (NAICS 71)	1.4
		Accommodation and Food Services (NAICS 72)	1.4

Note: Notice that NAICS sector and sub-sector code is provided for reference.

It is insightful that in developing countries, industry sectors and sub-sectors, or areas of expertise, which are most commonly associated with increasing HDI include

- "Trade, Transportation, and Utilities," such as merchandise exports and imports, electricity distribution, access to clean fuels and technologies for cooking, and basic drinking water and sanitation services.
- "Health Care and Social Assistance," such as access to contraceptives, immunizations, and social assistance programs such as Social Security in the US.
- "Natural Resources and Mining," such as energy resources, agriculture, or access to clean water.
- "Financial Activities," especially influencing monetary policies such as distribution of aid, international trade agreements and tariff rates.
- "Manufacturing," in general.
- "Construction," such as residential building construction and utility systems construction.

Additional comments related to the application of these results are found in Sec. 4.

Regarding where to work (point (2) above), a group may have specialized expertise and be interested in where geographically their expertise would have highest-potential impact. The results relating areas of expertise to increasing HDI are presented by region in Table 4 and by country in Table 7. The regional summary results in Table 4 show how frequently an industry sector has historically been associated with increasing HDI in a particular region. Industry sectors with higher % appearance in a particular region may prove to be high-potential areas of expertise for improving human development in that region. It is worth noting that while one area of expertise may not have been historically related to increasing HDI in one region, it may have proven otherwise in another region. For example, while work in "Information" has only been moderately related to increasing HDI across all developing countries (12.6%), it has been commonly associated with increasing HDI in Europe and Central Asia (25.0%). As a note, the majority of developing countries included in these results are from the Sub-Saharan Africa region, and thus the worldwide results presented in Table 3 are quite similar to an average of the Eastern, Middle, Southern, and Western Africa regions as shown in Table 4.

Table 4 The data analysis is summarized with how frequently the WDI developing countries regressors were connected to NAICS Industry super-sectors by region

	Frequency of industry sector connection to increasing HDI in developing countries by region (%)				
NAICS industry super-sector	East Asia and Pacific (12)	Europe and Central Asia (2)	Latin America and Caribbean (7)	Middle East and North Africa (6)	South Asia (6)
Trade, Transportation, and Utilities	38.5	25.0	39.6	37.8	39.1
Education and Health Services	26.4	31.3	20.8	4.4	17.4
Natural Resources and Mining	17.6	0.0	20.8	22.2	21.7
Financial Activities	23.1	12.5	13.2	26.7	26.1
Manufacturing	18.7	0.0	22.6	13.3	17.4
Construction	15.4	18.8	18.9	15.6	17.4
Information	11.0	25.0	7.5	15.6	10.9
Professional and Business Services	4.4	0.0	13.2	8.9	6.5
Other Services (except Public Administration)	4.4	0.0	1.9	4.4	4.3
Leisure and Hospitality	3.3	6.3	1.9	4.4	6.5

	Eastern Africa (14)	Middle Africa (8)	Southern Africa (4)	Western Africa (16)
Trade, Transportation, and Utilities	44.8	38.2	25.8	29.8
Education and Health Services	28.4	36.4	32.3	33.3
Natural Resources and Mining	25.0	21.8	6.5	19.3
Financial Activities	18.1	14.5	16.1	14.9
Manufacturing	16.4	25.5	12.9	14.9
Construction	15.5	21.8	12.9	13.2
Information	15.5	20.0	9.7	8.8
Professional and Business Services	11.2	12.7	19.4	9.6
Other Services (except Public Administration)	4.3	1.8	3.2	3.5
Leisure and Hospitality	1.7	3.6	6.5	2.6

Note: If every WDI regressor in a particular region was connected to an industry super-sector, the super-sector would be connected 100% of the time. Regional patterns offer more detail in illustrating which areas of expertise have been historically associated with an increase in HDI in developing countries in different regions of the world. The regions were classified by the World Bank analytical group [65] and the Sub-Saharan Africa region was divided geographically according to the UN Statistics Division [66]. As a note, the number of developing countries in each region is included in parentheses next to the region's name.

Table 5 Example of the WDIs selected for the multiple linear regression model during stepwise variable selection for Zambia

	Zambia	
World Development Indicator	Industry Super-Sector Connection(s)	Industry Sector and Sub-Sector Connections(s)
Access to clean fuels and technologies for cooking (% of population)	Natural Resources and Mining	Oil and Gas Extraction (NAICS 211); Utilities (NAICS 22)
Demand for family planning satisfied by modern methods	Trade, Transportation, and Utilities; Education and Health Services; Information	Health and Personal Care Stores (NAICS 446); Health Care and Social Assistance (NAICS 62); Merchant Wholesalers, Nondurable Goods (NAICS 424); Publishing Industries (except Internet) (NAICS 511); Broadcasting (except Internet) (NAICS 515); Internet Publishing and Broadcasting (NAICS 516)
GDP per unit of energy use	Trade, Transportation, and Utilities	Utilities (NAICS 22)
Goods and services expense	No specific super-sector connection	No specific sector/sub-sector connection
Information and communication technology service exports	Trade, Transportation, and Utilities; Information; Professional and Business Services	Information (NAICS 51); Professional, Scientific, and Technical Services (NAICS 54); Postal Service (NAICS 491); Couriers and Messengers (NAICS 492)
Imports of goods and services	Trade, Transportation, and Utilities	No specific sector/sub-sector connection
Population in urban agglomerations of more than 1 million	Construction; Trade, Transportation, and Utilities	Utilities (NAICS 22); Construction of Buildings (NAICS 236); Heavy and Civil Engineering Construction (NAICS 236)
Women who believe a husband is justified in beating his wife (any of five reasons)(%)	Information; Education and Health Services	Social Assistance (NAICS 624); Publishing Industries (except Internet) (NAICS 511); Broadcasting (except Internet) (NAICS 515); Internet Publishing and Broadcasting (NAICS 516)

Note: The WDIs from each country's model were categorized according to industry sector, as shown in the right column, and the average for all developing countries summary is found in Table 3.

More details can be found in Table 7 in the Appendix that captures how many times an industry sector was connected to WDIs in each country's regression model. Table 7 can be used as a step beyond the regional summary to guide an individual or group with particular expertise toward more specific geographical options for implementing their work. For example, while work in "Construction" has been moderately related to increasing HDI in East Asia and Pacific, we can see from Table 7 that of the eight WDIs selected in Indonesia, four are connected to "Construction"—more than any of the other countries in the East Asia and

Pacific region; thus, this can provide some justification for implementing a project or product in Indonesia that may improve capabilities or increase work in residential building construction or construction of utility systems or other facet of the "Construction" sector. A visualization of the historical association of "Manufacturing" and "Trade, Transportation, and Utilities" work is provided in Figs. 4 and 5 in the Appendix. Because of the many potential ways for visualizing these results geographically, tabulated data have been published.[1] Again, additional insights for how these results might be utilized by various individuals and groups are found in Sec. 4.

3.3 Exploration of Using Historical Associations to Guide Future Work Choices. This research presents patterns describing areas of expertise that have historically been associated with increasing HDI in developing countries. We are suggesting that these patterns may give direction to an individual or organization working in EGD to determine and/or justify their future choice of work. We cannot extrapolate and claim that these associations will continue into the future, but the exploration in this section can offer confidence for using the historical patterns from this research to guide future work.

To explore the use of historical patterns to guide future work, the following was performed. The analysis from Sec. 2 was followed for 10 randomly selected developing countries during the years 1990–2003 that had at least 10 years of HDI data that, on average, increased between 1990 and 2003. The best fitting WDI regressors were again categorized by industry sector to determine those most commonly associated with improving HDI. Then, the analysis from Sec. 2 was followed for the same 10 countries between 2004 and 2017. Four regressors were used in each country's model,to stay consistent with ratio of 2.5 years per regressor (see Sec. 2.3.2). Also, splitting the dataset at year 2003 was chosen to allow both the first and second set of years to fit the same number of regressors while following the said ratio of 2.5 years of data per regressor. The associated industry sectors from the second time period (2004–2017) were compared to the associated industry sectors from the first time period (1990–2003) to see how well the results of the first time period would have informed work in the second time period. This comparison is shown in Table 6.

Essentially, if we had performed this same study for the first time period, and followed its results to determine what to work on, would that work have been associated with improving HDI for the second time period? The following was used to calculate this comparison for n included countries where $n = 10$ for the first row and $n = 1$ for all other rows in Table 6.

$$M_n = 100\left(\frac{1}{10}\sum_{i=1}^{10}\begin{cases}\frac{C_{2_{i,n}}}{C_{1_{i,n}}}, & \text{if } C_{2_{i,n}} - C_{1_{i,n}} < 0\\ 1, & \text{otherwise}\end{cases}\right)$$

where M_n represents the percent maintained associations for all industry super-sectors for the n included country or countries, $C_{1_{i,n}} = \sum_{j=1}^{n} C_{1_{i,j}}$ and represents the number of connections during the first time period for the ith industry super-sector for n country or countries. So, for one country, $C_{1_{i,1}}$ includes all the ith industry super-sector connections for only that country during the first time period. Likewise, $C_{2_{i,n}}$ is for the second time period. In other words, this calculation identifies when the number of industry connections that were present during the first time period decreased during the second time period and finds the percentage of connections still present during the second time period as an average over the 10 industry super-sectors.

Table 6 shows that for 10 randomly selected developing countries, 81.7% of the associated industry sectors discovered from the first time period were as commonly associated for the following time period. Conversely, if an EGD practitioner were to have used these results after the first time period, there would have been an 18.3% likelihood they were misled to work in an area of expertise that would not have been as commonly associated with improving HDI for the second time period. It is interesting that for all developing countries, 81.7% of all WDI connections to each of the 10 industry super-sectors during the first time period carried over into the next time period. Whereas, the presence of the 18.3% of associations that did *not* carry forward into the second time period is in some ways evidence that the method used to find associations between WDI and HDI, as well as categorizations of WDI into industry sectors, works. It makes sense that while much of what is impactful will may continue to be impactful—some general needs will be fulfilled and others in demand. In general, this exploration indicates that using historical patterns to guide future work is a meaningful approach to finding work that is associated with improvements in HDI.

Also shown in Table 6, out of the 10 randomly selected countries, five of the countries had half or more of their industry sector associations maintained from the first to the second time period. The other five countries had few maintained industry sector associations, which could be due to a number of reasons. For example, Burundi was ravaged by civil war between 1993 and 2003 and then made some remarkable economic progress in addition to infrastructure improvements between 2003 and 2010 [67]; thus, it is logical that industry sectors associated with HDI improvements for the a time of war (the first time period) were quite different than those associated during a time of relative peace (the second time period).

This exploration shows that historical patterns may persist more commonly across all developing countries, but not necessarily within each country individually. Therefore, a combination of the patterns presented in this paper, the current HDI values of a nation, and seeking to understand the current and localized circumstances should be considered in tandem when narrowing the work focus to a particular country or community. Also, because only four regressors were used for this exploration, it is expected that the historical associations presented as the results of this paper, with additional data and eight regressors used in the analysis, are even more likely to maintain their associations into the future.

4 Application Scenarios

The activities of engineering design are based on the requirement selection and concept selection, both of which are centered on the selected opportunity. The process of selecting an opportunity when based on Nucor's Circles is facilitated by Tables 3, 4, and 7 as shown in Fig. 3. To illustrate opportunity selection in practice, scenarios are provided for individual as well as business cases. Although this paper—-including the following scenarios—has largely been directed toward individuals and small groups seeking to use their engineering for global good, the results have the potential to be equally valuable to large organizations that set the development agendas of smaller groups.

University Research Group: *This scenario follows the process (a), (b), (c) as shown in Fig. 3.* Individual A is the leader of a university research group whose work includes EGD. The research group has performed a number of projects, some more impactful than others, and Individual A is continually seeking to improve the impact of the projects they engage in. While updating the group's rolling 5-year plan, Individual A references this paper to find what types of work have been historically associated with improvements in HDI. From the left column of Table 3, he finds that on average across all developing countries, work related to "Trade, Transportation, and Utilities" has been the most commonly related to improvements in HDI, and from the right column of Table 3, work in "Utilities" has been most frequently connected to improving HDI.

Although his research group has performed work related to irrigation and drinking water, Individual A recognizes from this research that there may be potential to improve HDI by working

[1] design.byu.edu

Table 6 The data analysis from Sec. 2 was performed on data from 1990 to 2003 and then from 2004 to 2017 on 10 randomly selected countries

Country	Maintained associations, M_n, from 1990–2003 to 2004–2017 (%)
Combined 10 Country Sample	81.6
Bangladesh	33.3
Bolivia	66.7
Burundi	33.3
Ghana	75.0
Guinea	33.3
Kyrgyzstan	50.0
Mauritania	33.3
Morocco	100
Niger	11.1
Rwanda	71.4

Note: This table reports which industry sectors were associated with improvements in HDI for the first 14 years and continued to be as commonly associated during the following 13 years, suggesting the likelihood that an EGD practitioner would have been led to work in an area that maintained its association with improving HDI.

in energy, such as in off-grid electricity systems. With this information, Individual A and his research group can begin working with their local connections in developing communities to further explore these opportunities and determine if and where it would be best to implement energy-related projects.

EGD Leadership: *This scenario follows the process (a), (b), (e), (c), (d) as shown in Fig. 3.* Individual B is a manager of a team whose professional work is in EGD. Her company has recently received funding for the next 5 years to aid refugees in Pakistan who have fled conflict in Afghanistan. With the new focus and funding, Individual B seeks to establish a team that possesses the expertise that will best serve to improve the development state in Pakistan. She first needs to identify the areas of expertise most in demand. In addition to working with local officials and visiting refugee camps to identify immediate needs, Individual B examines the results presented in this paper to identify long-term patterns of which areas of expertise have been related to increasing HDI in Pakistan and the surrounding area.

She first references Table 7 and finds that four WDIs related to increasing HDI in Pakistan are connected to "Natural Resources and Mining" Examining Table 3 exhibits that sub-sectors of "Natural Resources and Mining" include work in agriculture, forestry, mining, oil and gas extraction, among others. For a perspective of impactful work in the surrounding region, she references Table 4 and is encouraged to find that work in the "Natural Resources and Mining" sector has been commonly related to an increase in HDI across the South Asia region when compared to the other industry sectors. Individual B can seek additional team members with skills related to agriculture, mining, etc. with an understanding that work in these areas of expertise has been related to increasing HDI in Pakistan and the South Asia region.

EGD Practitioner Local to a Developing Community: *This scenario follows the process (a), (b), (e) as shown in Fig. 3.* Individual C is a practicing engineer in Ghana whose work is focused in providing irrigation systems to rural farmers. He is considering other opportunities to utilize his expertise and resources to help the communities he lives and works in. For a perspective of what has historically been impactful in Ghana as a whole, Individual C references Table 7 and notices that work in "Trade, Transportation, and Utilities" has been frequently connected to increasing HDI in Ghana. With expertise related to utilities, he determines that expanding his work to improving sanitation systems would have a high potential for impacting the communities in which he works.

Large Businesses: *This scenario follows the process (a), (b), (c), (d), (e) as shown in Fig. 3.* Company A is a large company with an established product line. Company A is seeking to expand its manufacturing facilities to other locations throughout the world and is motivated to utilize inexpensive labor in addition to improving the quality of life of underserved communities. From the summary in left two columns of Table 3, Company A is encouraged that improving manufacturing has been commonly related to an increase in HDI. As they consider potential locations, starting regionally, Table 4 shows that work in the "Manufacturing" sector has been most closely related to increasing HDI in the Latin America region, second in the East Asia and Pacific region and Caribbean following. Company A can use this information, coupled with other factors, to focus its location decision. If multiple options within these regions are reasonable, Table 7 offers more detail regarding which countries have had multiple WDIs–suggesting a closer association–in the "Manufacturing" sector related to an increase in HDI.

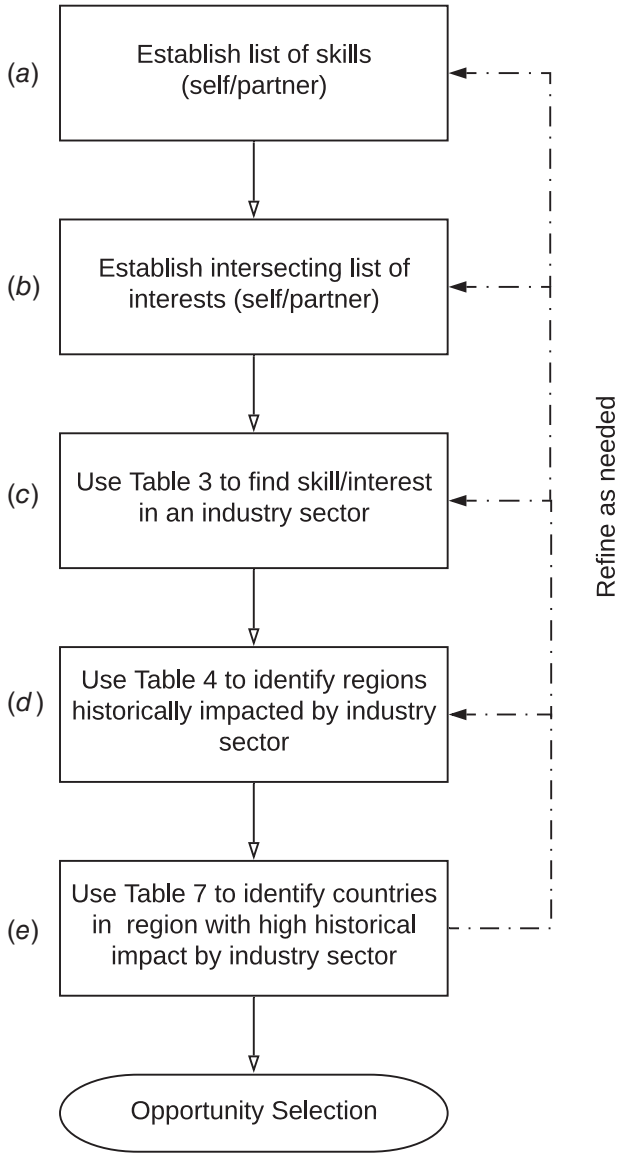

Fig. 3 Recommended process for effectively utilizing the results in this paper for opportunity development, although the particular order of steps is not fixed

Small Businesses: *This scenario follows the process (a), (b), (c), (d) as shown in Fig. 3.* Company B is a startup that leads humanitarian trips to build schools and orphanages in Sub-Saharan Africa. Company B is seeking to expand its team and type of projects offered; specifically, improving the communities' access to electricity. The investors of Company B are asking for justification for this

choice of work and want to know what will be most impactful in their target communities. The results presented in this paper offer some justification.

First, Company B references the right two columns in Table 3 that suggest that on average for developing countries, work related to "Utilities" has been commonly related to an increase in HDI. A quick reference to the NAICS Industry Sectors online page shows that "Electric Power Generation, Transmission and Distribution" is one of the three main utilities included in the "Utilities" sector. Also, of the industry sectors related to an increase in HDI in Eastern and Southern Africa, work in "Trade, Transportation, and Utilities" is the most common (see Table 4). With these data, in addition to an analysis of current local needs, Company B can better justify to its investors its choice to expand its work to providing access to electricity.

5 Conclusions and Future Work

From an examination of historical correlations and using variable selection to identify those WDIs, and their corresponding industry sectors, that have been highly associated with increasing HDI in developing countries, areas of expertise are identified that have been related to increasing HDI. The added understanding of which areas of expertise are commonly associated with increasing HDI virtually expands the intersection of market needs and expertise, as shown in Fig. 1(*b*). When exploring EGD opportunities, areas of expertise with strong historical associations with increasing HDI may be used as surrogates for focusing on the main categories of the HDI (health, education, and income) only. The results presented can aid EGD practitioners in identifying *what* to work on and *where* to work for high-potential impact. Details regarding what to work on is informed by patterns in developing countries summarized in Table 3, while where to work can be identified by referencing Tables 4 and 7 to examine regional and country specific patterns.

Due to the EGD motivation for this research, the results presented herein focus on associations between areas of expertise and HDI in developing countries. Rather than focusing on the three dimensions of the HDI only (health, education, and income), the data analysis shows that work related to "Trade, Transportation, and Utilities", such as exports and imports of goods and services, electricity production and distribution, and basic sanitation services, "Natural Resources and Mining", such as energy resources, agriculture or access to clean water, "Manufacturing", in general, "Construction", such as residential building construction as well as utilities construction, and "Professional and Business Services," such as the engineering of communications technologies are commonly associated with improvements in the HDI in developing countries. Additionally, the results of this paper are broadly consistent with the analyses found in the social science literature [68,69].

It is interesting to note that manufacturing work has been 1.3% *more* commonly associated with increasing HDI than work in "Utilities" That said, it is encouraging that work in "Utilities" has been commonly associated with increasing HDI, especially for groups involved in electricity production and distribution such as providing micro- and off-grid electricity solutions. Also, work in "Financial Activities" especially work that influences monetary policies, including trade agreements and aid money decisions, has been commonly associated with increasing HDI. Finally, although improvements in agriculture have been commonly associated with human development improvements, this analysis shows that work related to improving "Trade, Transportation, and Utilities" is nearly 1.5 times more commonly associated with increasing HDI than work in "Natural Resources and Mining".

This study determined WDI that have been associated with the HDI. It was not analyzed, however, which of these changed first and affected the other. For example, consider a country whose manufacturing capability is associated with increasing HDI: does the health, education, or income increase first, which in turn causes the manufacturing capability to increase, or vise versa? An investigative study into these interactions, and other interactions identified in the literature, could be insightful future work to further inform practitioners regarding high-potential skill areas and where to implement their work.

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Conflict of Interest

There are no conflicts of interest.

Data Availability Statement

The datasets generated and supporting the findings of this article are obtainable from the corresponding author upon reasonable request. The data and information that support the findings of this article are freely available online.[2] The authors attest that all data for this study are included in the paper. Data provided by a third party are listed in Acknowledgment.

Nomenclature

$\bar{w}$ = Average of a World Development Indicator's values for available data between 1990 and 2017
$\bar{I}$ = Average Human Development Index value for available data between 1990 and 2017
d = Durbin–Watson statistic
d_L = Durbin–Watson lower critical value
d_U = Durbin-Watson upper critical value
w_t = Value of one of the World Development Indicators for the t-th year
M_n = Maintained associations for n country or countries
$C_{1_{i,n}}$ = Number of connections for the first time period for the i-th industry super-sector for n country or countries
I_t = Human Development Index value for the t-th year
δ_{w_t} = Percent change in a World Development Indicator value from the past year to the current (or t-th) year
δ_{I_t} = Percent change in the Human Development Index value from the past year to the current (or t-th) year
$[\,]_i$ = [ ] for the i-th industry super-sector
$[\,]_n$ = [ ] for n country or countries
$[\,]_t$ = [ ] for the t-th year

[2]See Note 1.

Appendix

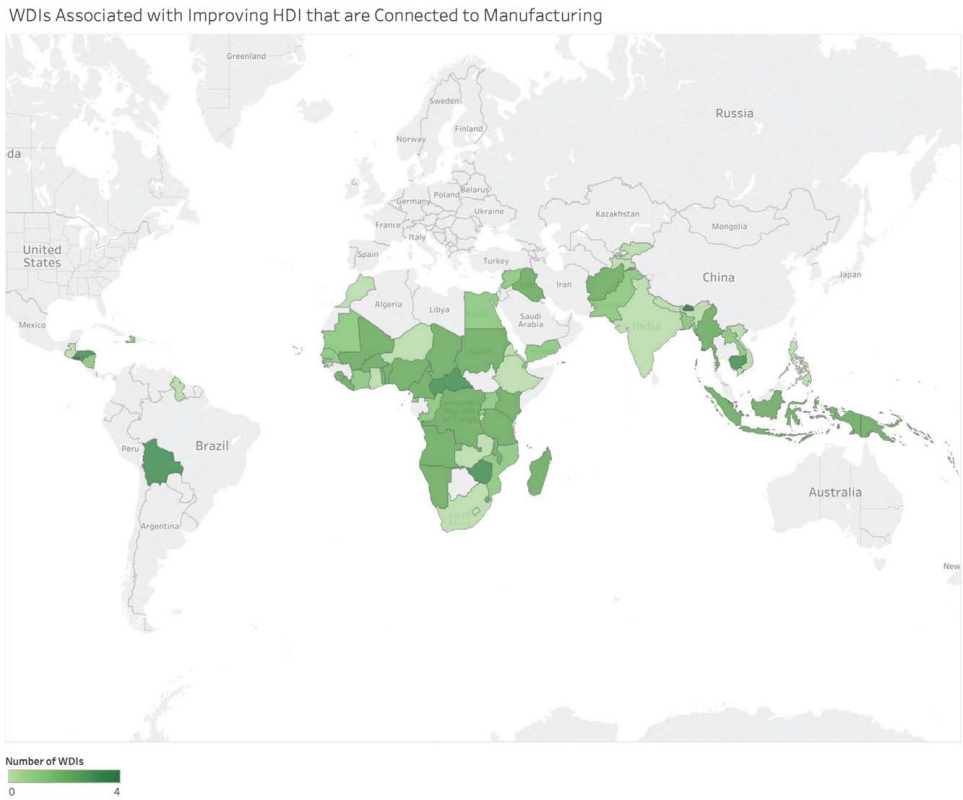

Fig. 4 A visualization of the number of WDIs related to increasing HDI and connected to the "Manufacturing" super-sector in developing countries. Darker shade suggests manufacturing work has been more impactful in that country over the past few decades.

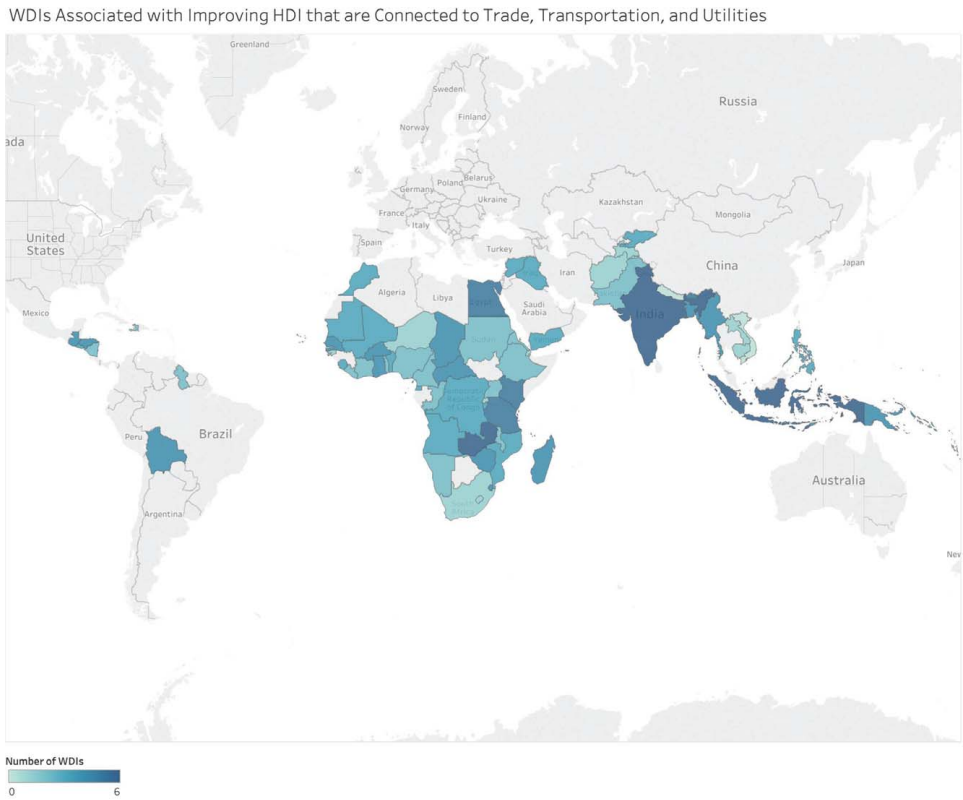

Fig. 5 A visualization of the number of WDIs related to increasing HDI and connected to the "Trade, Transportation, and Utilities" super-sector in developing countries.

Table 7 Presented at country level, the more frequently a WDI regressor is related to an industry sector suggests that work in that industry sector has historically been a good predictor of an increase in HDI

	Trade, Transportation, and Utilities	Education and Health Services	Natural Resources and Mining	Financial Activities	Manufacturing	Construction	Professional and Business Services	Information	Leisure and Hospitality	Other Services
Country or Territory	Number of Regression Model Indicators Related to Industry Sector									
East Asia and Pacific Region										
Cambodia	1	4	1	1	3	1	1	2	0	1
Indonesia	6	2	2	1	2	4	0	0	0	0
Kiribati	5	4	0	2	1	1	1	1	1	1
Lao People's Dem. Republic	1	3	0	1	1	0	0	3	0	0
Micronesia	2	1	2	2	2	2	0	1	0	0
Myanmar	4	2	3	0	2	2	1	0	0	0
Papua New Guinea	4	0	2	2	2	0	0	0	0	0
Philippines	3	2	3	3	0	1	1	1	1	0
Solomon Islands	3	1	0	3	1	0	0	0	0	0
Timor-Leste	4	2	1	2	2	1	0	1	1	0
Vanuatu	2	3	0	2	1	0	0	0	0	0
Viet Nam	0	0	2	2	0	1	0	0	0	2
Europe and Central Asia Region										
Krygyzstan	3	3	0	1	0	2	0	2	1	0
Tajikistan	1	2	0	1	0	1	0	2	0	0
Latin America and Caribbean Region										
Bolivia	4	3	2	1	3	1	2	1	0	1
El Salvador	3	1	1	0	4	2	0	1	1	0
Guatemala	4	1	0	2	0	2	1	0	0	0
Guyana	2	1	2	0	0	0	0	0	0	0
Haiti	2	1	2	1	1	1	1	1	0	0
Honduras	4	2	3	3	3	3	2	1	0	0
Nicaragua	2	2	1	0	1	1	1	0	0	0
Middle East and North Africa Region										
Djibouti	1	1	0	2	1	2	0	2	0	0
Egypt	5	0	2	2	1	1	1	1	1	1
Iraq	3	0	5	1	2	1	0	1	0	0
Morocco	3	0	1	0	0	1	2	1	0	0
Syrian Arab Republic	3	0	2	2	1	0	1	1	1	1
Yemen	3	1	1	4	1	1	0	1	0	0
South Asia Region										
Afghanistan	1	1	2	3	2	2	0	0	0	1
Bangladesh	4	1	2	3	1	2	0	0	0	0
Bhutan	5	0	1	1	4	1	1	3	1	1
India	6	3	0	3	0	2	1	1	1	0
Nepal	0	3	1	1	0	0	0	1	0	0
Pakistan	2	0	4	1	1	1	1	0	1	0
Sub-Saharan Africa Regions										
Eastern Africa Region										
Burundi	3	2	0	2	0	0	1	1	0	0
Comoros	5	2	0	2	2	0	1	1	1	1

Table 7 *Continued*

	Trade, Transportation, and Utilities	Education and Health Services	Natural Resources and Mining	Financial Activities	Manufacturing	Construction	Professional and Business Services	Information	Leisure and Hospitality	Other Services
Eritrea	2	4	0	3	0	0	3	1	0	0
Ethiopia	2	1	4	1	0	0	0	0	0	0
Ghana	4	3	0	3	0	2	1	0	1	0
Kenya	5	2	4	1	2	3	1	2	0	1
Madagascar	4	1	3	1	2	1	1	1	0	0
Malawi	2	3	1	1	2	1	0	1	0	0
Mozambique	3	3	4	0	1	1	0	0	0	0
Rwanda	1	2	1	1	1	1	0	1	0	0
Sudan	2	2	2	4	2	1	1	0	0	1
Tanzania	5	1	3	1	2	3	1	1	0	1
Uganda	2	3	2	0	1	2	0	1	0	0
Zambia	6	2	1	0	0	1	1	3	0	0
Zimbabwe	4	1	3	1	3	2	1	1	0	1
				Middle Africa Region						
Angola	3	2	1	0	2	3	0	1	0	0
Cameroon	2	4	2	0	2	1	1	1	0	0
Central African Republic	4	2	2	1	3	2	0	1	0	0
Chad	4	1	2	1	2	1	1	1	0	0
Congo	2	3	2	2	1	0	2	4	1	0
Dem. Rep. of the Congo	3	3	3	2	2	3	0	2	0	0
Equatorial Guinea	3	5	0	3	1	1	2	2	1	1
São Tomé and Príncipe	2	1	2	0	1	2	1	0	0	0
				Southern Africa Region						
Eswatini	4	2	1	1	2	1	1	0	1	0
Lesotho	1	5	0	1	0	1	1	0	0	0
Namibia	2	0	0	2	2	2	3	2	1	1
South Africa	1	3	1	1	0	0	1	1	0	0
				Western Africa Region						
Benin	3	2	1	1	2	2	2	1	0	1
Burkina Faso	4	5	1	0	2	2	0	2	0	0
Cabo Verde	1	2	2	1	0	0	0	0	0	0
Côte d'Ivoire	2	3	1	0	1	2	0	1	0	0
Gambia	0	4	0	0	0	0	0	2	0	0
Guinea	0	3	2	2	0	0	0	0	0	0
Guinea-Bissau	1	1	1	4	0	0	1	0	1	0
Liberia	2	2	2	1	2	1	0	0	0	0
Mali	3	1	2	3	2	1	2	0	1	3
Mauritania	3	4	3	1	1	1	3	1	0	0
Niger	1	1	1	1	0	1	1	1	0	0
Senegal	4	2	1	0	1	2	1	1	0	0
Sierra Leone	3	2	2	0	2	1	0	1	0	0
Togo	2	4	2	0	2	2	0	0	0	0

Note: Although there is a maximum of 8 WDI regressors per country (row), each WDI may be connected to none, one, or more than one industry sector, so the values in each row may not sum to 8.

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