Judges' Commentary: Is it Sustainable?

Kristin Arney
Dept. of Industrial Engineering
University of Washington
Seattle, WA 98195
arney@uw.edu

Jessica Libertini
Network Science Institute
Virginia Military Institute
Lexington, VA 24450
libertinijm@vmi.edu

Introduction

The ICM continues to challenge students to address real-world problems in a team setting. Due to the 96-hour time limit, students must work efficiently to research new fields, develop models, perform analysis, and reflect on how their model results are relevant in the real world. Given the interdisciplinary nature of the problems, teams can leverage the diverse strengths and skills of their individual members as they navigate this challenge. Teams must work together to communicate their concepts and models clearly and effectively in a one-page executive summary followed by a 20-page report.

For the first time since its inception in 1999, the 2015 ICM featured a choice of two questions. As promised, the 2015 environmental problem encouraged students to explore human-environment interactions in the areas of environmental science. With a focus on sustainability, national policies and programs, and international support, this year's question was truly interdisciplinary, spanning a wide range of academic subjects while addressing important global concerns.

The Problem Statement

One of the largest challenges of our time is how to manage increasing population and consumption with the Earth's finite resources. How can we do this while at the same time increasing equity and eradicating poverty? Since the beginning of the modern environmental movement in the 1960s, balancing human needs with the Earth's health has been a topic of considerable debate. Are economic development and ecosystem health at odds? To reconcile this difficult balance, the concept of sustainable development was introduced in the 1980s.

Sustainable development is defined by the 1987 Brundtland Report as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [World Commission on Environment and Development 1987, 8]. Since its conception, sustainable development has become a goal for international aid agencies, planners, governments, and non-profit organizations. Despite this, striving towards a sustainable future has never been more imperative. The United Nations (UN) predicts that the world's population will level off at 9 billion people by 2050. This, coupled with increased consumption, places a significant strain on the Earth's resources. Understanding that the Earth is a system that connects both time and space is critical to sustainable development. Development must focus on needs (e.g., reducing the vulnerability of the world's poor) and limitations (e.g., the environment's ability to detoxify wastes). In 2012, the UN Conference on Sustainable Development recognized that:

> that poverty eradication, changing unsustainable and promoting sustainable patterns of consumption and production and protecting and managing the natural resource base of economic and social development are the overarching objectives of and essential requirements for sustainable development.

Decreasing personal poverty and vulnerability, encouraging economic development, and maintaining ecosystem health are the pillars of sustainable development [United Nations 2012].

The International Conglomerate of Money (ICM) has hired you to help them use their extensive financial resources and influence to create a more sustainable world. They are particularly interested in developing countries, where they believe they can see the greatest results of their investments.

Task 1: Develop a model for the sustainability of a country. This model should provide a measure to distinguish more sustainable countries and policies from less sustainable ones. It can also serve to inform the ICM on those countries that need the most support and intervention. Some factors may include human health, food security, access to clean water, local environmental quality, energy access, livelihoods, community vulnerability, and equitable sustainable development. Your model should clearly define when and how a country is sustainable or unsustainable.

Task 2: Select a country from the United Nations list of the 48 Least Developed Countries (LDC) list [UNCTAD 2013]. Using your model and research from Task 1, create a 20-year sustainable development plan for your selected LDC country to move towards a more sustainable future. This plan should consist of programs, policies, and aid that can be provided by the ICM within a country based on their demographic, natural resources, economic, social and political conditions.

Task 3: Evaluate the effect your 20-year sustainability plan has on your country's sustainability measure created in Task 1. Predict the change that will occur over the 20 years in the future by implementing your plan in your evaluation. Based on the selected country, you may need to consider additional environmental factors such as climate change, development aid, foreign investment, natural disasters, and government instability. The ICM would like to get the "most bang for their buck," so determine which programs or policies produce the greatest effect on the sustainability measure for your country. Identifying highly effective strategies to be implemented is the ultimate goal of the ICM to create a more sustainable world.

Judges' Criteria

The judging panel included representatives from a diverse set of fields including sustainability, biology, behavioral science, geography, applied mathematics, statistics, and engineering.

The judges were looking for papers that clearly communicated each of these elements:

- an understanding of the complexity and the factors that can define sustainability;
- the development and use of a meaningful model to determine the sustainability of a country both now and in the future;
- an implementable and effective set of plans, strategies, or programs for improved sustainability tailored to one of the least developed countries in the world.

Each paper was evaluated using a common assessment guide. In the sections below, we offer commentary on the components of the problem and offer strong examples from this year's submissions.

Executive Summary

It remained critical that the summary succinctly and clearly explain the highlights of the submission. The executive summary should always contain a brief description of the problem that the team is trying to solve, the methods used, and their bottom-line results.

Researching the Key Factors

It was critical that teams distinguish between human development factors such as the economy, health, and education, vs. environmental factors such as ecosystem health and resources. Some teams chose to align factors into these two categories and others chose three categories, distinguishing the human development aspects into those related specifically to society and those related to the economy. Regardless, strong submissions discussed, and even included in their model, the interdependency of the factors chosen.

Most importantly, the judges were looking for the interpretation that drove the selection of input factors. The explanations of why a factor was included weighed more heavily with the judges than the actual factor itself or even the number of factors chosen for inclusion. We wanted to gain insight into the team's motivation for selecting and utilizing the particular factors within their model. Better papers used multiple inputs to define a single category within their metric, and some of the strongest papers understood the fact that one input could contribute to multiple categories.

Additionally, it was important for teams to distinguish between positive and negative impacts for a particular factor when creating their metric on sustainability. The judges sought to understand the resources that teams used to obtain what they considered to be the relevant factors.

Developing the Model

Assumptions

The inclusion of assumptions for the team's models was important in evaluating the quality of the presented solution. The better submissions explicitly discussed why key assumptions were made and how these assumptions affected the model development or the proposed 20-year plan.

One common assumption across strong papers was that the inputs used were the right ones to capture the complexity of the real situation concerning a nation's sustainability. Outstanding submissions realized that their initial model included assumptions that could then be changed to add some complexity or address some weakness in the initial model based on initial results. These teams revisited their assumptions and then revised their models for the inclusion of additional environmental factors such as climate change, development aid, foreign investment, natural disasters, or government instability as indicated within Task 3.

Defining and Measuring Sustainability

Task 1 asked teams to clearly explain the methods used to combine the chosen key factors into a model for the sustainability of country. Judges were impressed by the variety of ways that teams chose to create their metric. We saw the combination of factors into a single metric, as well as the creation of multiple metrics along the human and environmental lines, which lead to excellent visualization. Some teams combined their factors without weights, treating all equally, while other teams chose mathematically rigorous weighting methods or even a hierarchical approach.

The judges read papers from teams that developed completely original models for sustainability, while other teams leveraged and improved upon models available in the literature. Regardless, the expectation remains that the teams cite any work that is not theirs because proper documentation is essential.

Many models included the rescaling of inputs and the use of odd roots to allow for negative values. Judges praise teams that really took real-world considerations into account in their model.

The use of training sets to determine sustainability of nations was beneficial in ensuring that models clearly defined when and how a country is sustainable or unsustainable.

Additionally, when teams used cut-offs to differentiate between a sustainable nation and an unsustainable one, judges sought the justification for the creation of that mark.

Finally, strong papers compared the output of their model for some nations with known and reputable characterization from other published sources, as a type of validation of their model.

Predicting the Future

To predict the future for the chosen nation, some teams developed regressions for the input parameters based on historical data. Other teams propagated their output into the future, for example, by advancing state equations. Both approaches are reasonable, with advantages to each. In general, teams that used regressions on their inputs could test their regression models with past data, whereas propagating the model output was faster and may have afforded teams more time to explore alternative scenarios.

Quite a few teams used a fuzzy learning algorithm to develop a sustainability cut-off; doing that prevented predictive work without the development of an additional model, which caused many of these papers to be eliminated from further consideration.

Testing and Using the Model

After working hard to develop their models, teams validated their models and used them to develop a 20-year plan to move one of the least-developed nations onto a path towards improved sustainability. Since there was such large diversity in the models used, it is not surprising that the submissions offered a wide variety of approaches to validation. Although the models offered mathematical insights that led to the development of the national sustainability plan, it was only through the unique interpretations of these results that meaningful and actionable plans could be developed.

Data/Validity/Sensitivity

Even a well-developed model will not produce useful results unless the inputs are reasonable. Judges were impressed with teams that discriminated between objective and subjective input parameters, especially when teams proposed and implemented methods to address the subjective nature of certain parameters.

As an added challenge, even with the most reputable Web resources, teams encountered the problem of missing data. Some teams sidestepped this issue by simply not analyzing nations with incomplete datasets, but this approach clearly limited the utility of their models. As mathematical alternatives, some teams used very simple yet effective methods for filling in missing data points, while other teams devoted a disproportionate amount of effort and space to this task by creating complex interpolation techniques.

Validation is an important part of the modeling process, since it can instill confidence in results or help identify weaknesses in the model. This phase of the modeling process can aid in model selection; several papers presented a range of models from simple to complex and used a validation approach to justify the selection of one of those choices, considering the trade-off between speed and accuracy.

Most models had two elements requiring validation—that which measured sustainability levels and that which predicted the future.

- Most teams chose to validate their sustainability-measuring models either over a large set of nations spanning the sustainability spectrum or by using a small selection of nations representative of different levels of sustainability. For teams that used a learning algorithm, it was important that their validation sets be disjoint from the training sets. While many teams relied on commonly-accepted understandings of national levels of sustainability, some teams compared their results and rankings against other published results.
- For the predictive models, a few strong papers used national data from 20 years ago as inputs and compared their models' results with those nations' current measures of sustainability.

A thorough sensitivity analysis often sets a great paper apart from a good paper. Sensitivity analyses can be done in a variety of ways, so judges looked closely at the rationale behind each team's approach. Some teams revisited early simplifying assumptions; for example, if the team initially assumed no war, they later applied a shock to their model to see how the more steady solution was impacted by the eruption of a conflict. Other teams explored the stability of their models by perturbing the input parameters, either through complex stochastics or the use of a Monte Carlo method. Still other teams assessed the relative impacts of different types of improvements, such as education level or reforestation, by running their model over a large number of cases developed through parameter variation experimental design.

Strengths/Weaknesses

The ability to step back and assess the strengths and weaknesses of a model demonstrates a team's level of understanding of their work. Knowing the strengths of a model allows modelers to market their work, while knowing the model's limitations insures that model will be used and interpreted appropriately.

Strengths and weaknesses are relevant to the entire model, from the accuracy and availability of the input data, to the level of confidence and detail in the output. In addition to listing strengths and weaknesses, some strong papers not only identified weaknesses, but also outlined ideas for model refinements or modifications that would address those weaknesses.

Development of a 20-Year Plan

Teams were asked to analyze the sustainability of one of the world's least developed countries and provide a country-specific targeted 20-year plan towards improved sustainability. The judges appreciated papers that shared the rationale for selecting a particular country.

While quite a few strong submissions presented strong mathematical models for the development of a 20-year plan, the judges were most impressed with the teams that took the mathematical output and not only developed an actionable plan, but also made sure that the proposed plan was viable and sensible in the context of the selected nation. This element of contextual relevance allowed teams to showcase their individual strengths in areas such as ecology, geography, business, economics, health, education, government, and policy.

With a time constraint of 96 hours, the judges were pleased to see teams research the policies and programs that had worked in other nations. For example, many teams discovered that effective plans often had shorter durations, such as 4- or 5-year bursts. However, strong papers not only presented the research on these countries, but also emphasized the importance that these policies/programs be adapted to fit the specific national needs of the chosen LDC.

Strong papers provided plans that were actionable, meaning they gave decision-makers clear steps towards sustainability. For example, instead of simply proposing that the population growth rate decrease by 5%, an actionable plan may propose funding for family-planning classes for women with further analysis on whether to target cities or rural areas based on current demographic data. For another example, instead of telling countries they need to increase economic development, an actionable plan may provide some targeted programs for that nation to meets its economic goals, such as offering tax incentives for foreign industry.

In addition to the factors already presented, many strong papers addressed the economic cost of the plan, particularly when those costs were reasonable and broken down by individual programs and/or policies. A few teams even divided the costs into those which should be funded by the nation versus those which were best funded through international aid.

Lastly, in order to measure the efficacy of the plan, it was important that teams present predictions for the sustainability level of the nation both with and without implementing their plan. Several strong teams also used their predictive models to explore how the nation's sustainability level would be impacted by a wide range of factors including incremental modifications to the original plan, political unrest, short term natural disasters, and long-term climate change effects.

Presenting the Results

Regardless of the question or the year, the judges are always looking for papers that offer a healthy balance of mathematics and written explanations. The judges never want to see pages of equations that lack sufficient explanation of their origin, nor do they want to see expository prose presenting numerical results without any explanation of the analysis behind those results. Strong papers have a clear organizational structure. When appropriate, they should use graphics to help convey complicated ideas.

Paper Organization

Strong papers are presented clearly. New ideas are introduced in logical and natural sequence as if they were characters in a story, and there is a seamless narrative arc that runs throughout the paper. The spelling and grammar are correct, so as to not hinder the reader's understanding of the concepts. In addition to presenting the equations and steps of a model, it is just as important that papers present the justification for making these selections. Many teams include a glossary of variables early in their paper; while this can be helpful, it is important to keep reminding the readers of these definitions as those variables are introduced into the model and throughout the paper.

References and Citations

An important part of any submission is the list of references. Many papers included a strong set of references, but the judges were disappointed that many teams failed to use citations appropriately. The reference list should include in a single location all of the resources—with complete information for the reader to access each source. *Citations* to the references allow a team to credit specific portions of their paper to indicate the source for a quote or the support for an assertion. A citation should include a specific page number or URL. Plagiarism goes against both the contest rules and the spirit of the competition, including failure to use some form of quotation notation (quotation marks or indentation with citation) for statements taken directly from another source.

Visualization: Graphs, Charts, Figures

It can be challenging to convey the results of a weekend of intense modeling in a 20-page paper. The effective use of diagrams, graphs, charts, and other figures helped many teams to overcome this part of the challenge.

The decision on whether to include a figure, and the which type of figure to use, can be guided by the story one wishes to convey with that figure. Text is often sufficient to explain straightforward molding processes, but the understanding of a more intricate process can be aided by a flowchart. Some data is more clearly grasped in a table, while a bar graph, a line graph, or a pie graph may be more appropriate for other data.

This year, the Outstanding papers offered a nice range of means for visualizing the data, including radar plots, multidimensional plots, trajectory plots, and a creative angle-based plot.

Discussion of the Outstanding Papers

Every year, the judging panel is enthused by the diversity of the submissions, and this year was even more exciting than usual. Not only did teams tackle this challenge using a wide range of modeling tactics, but teams also selected different target nations and focused on different aspects of sustainability.

Most papers offered sound models, but there were several common reasons that teams did not reach the final judging:

- Some teams were not able to communicate clearly the models and/or the rationale behind them.
- Other teams offered models that were not sufficiently structured to address the question.
- Still others offered solutions that either did not provide an actionable 20-year plan or provided a plan that was not directly relevant to the country selected.
- Lastly, papers that did not draw meaningful connections between the model inputs, the model outputs, and their significance in the context of the real world— specifically that of the target nation—did not reach the final round of judging.

Each of the four Outstanding papers used different methodologies but addressed the problem in a comprehensive way. These papers were generally well-written and presented clear explanations of their modeling procedures. Several had a unique or innovative approach that distinguished them from the rest of the finalists. Others were noteworthy for either the thoroughness of their modeling or the significance of their results. The different modeling approaches, unique target nations, and the diverse individual factors chosen for inclusion in their 20-year plans made these papers interesting and exciting to read. The summaries of the four Outstanding papers follow.

Humboldt State University, Arcata, California, USA: "Is It Sustainable?"

Often students do not feel that they have a sophisticated-enough mathematical background to develop an outstanding model. The winning paper from Humboldt State challenges that viewpoint by offering a relatively straightforward mathematical model. To assess the sustainability of each country, separate sustainability metrics are developed and calculated in each of six domains: economics; risk; social; environmental; political; institutional. The equation for each of these metrics is thoroughly justified and grounded in a solid real-world understanding of how the chosen inputs could influence domain stability. Rather than integrate these six domain-specific results into a single number, this team proposes the use of radar plots, as shown in **Figure 1**, as a means of visualizing the results, allowing for simultaneous quantitative and qualitative comparisons across nations. Note that the lower values indicate increased sustainability, versus the high values indicating less sustainability or more instability.

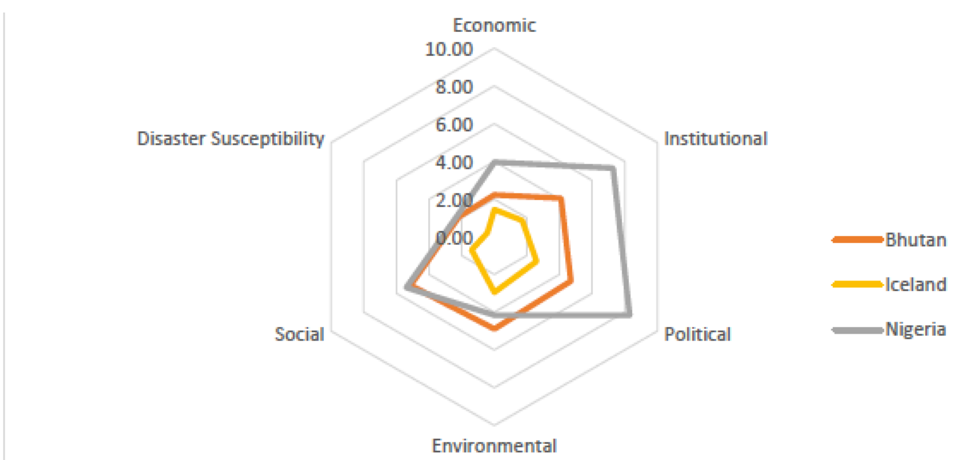

Figure 1. A radar plot used by the winning Humboldt State team to show "differences and main problem areas of the three countries."

After applying their model to several countries, the team selects Bhutan as their target nation. They clearly state their rationale for this selection, including a complete set of data allowing a thorough initial analysis and a citation for a national document from Bhutan that expresses the nation's own desire to become more sustainable. The paper follows the selection section with a comprehensive look at how Bhutan performs in each of the six sustainability domains. This analysis addresses quantitative results with qualitative reflections, putting the mathematical results back into the context of Bhutan's situation.

In an effort to increase the likelihood of adoption, the proposed 20-year plan balances the results of the model with the priorities given by the Bhutanese themselves in a cited document. The plan provides clear and actionable steps towards increased sustainability. To assess the sustainability of Bhutan following the execution of the sustainability plan, future input parameters are presented and justified based on contextual reasoning, as opposed to a sophisticated mathematical prediction approach.

The main reason why this paper rose to the top was that, despite a rather unsophisticated mathematical approach, the team demonstrates strong modeling skills both in translating from the real world to a meaningful model, and from mathematical results back to meaningful conclusions about the real world. The level of depth and insight in each of the six domains is unparalleled by any other paper; and the references, including the data sources, are strong, lending credibility to the results presented.

NC School of Science and Mathematics, Durham, North Carolina, USA: "A Particle Swarm Optimization of an Iterative Function Map for Sustainable Development in Zambia"

The title of this paper reflects the criticality of the second and third tasks, the application of the sustainability model and development of possible 20-year plans for Zambia. The team's dedication to detailed analysis of the problems in Zambia and their mathematical approach for optimization of the allocation of investment dollars in that nation set their paper apart from the others. Additionally, the team's continuous assessment of strengths and weaknesses throughout their process communicated to the judges a deep understanding of the chosen mathematical constructs within the context of sustainability.

The development of a model to assess a nation's sustainability is succinct, with the inclusion of simple factors in two different indices measuring an environmental and socioeconomic component. The team initially keeps their two metrics separate and analyzes trade-offs between the two components before analyzing every nation with their model and providing great insight into where the least-developed nations tend to fall. Their next step is to compare their indices to known recognized measures of sustainability in order to validate their measures; this is a feature that the judges saw in many of the best papers.

The team clearly provides insight into the current state of Zambia, which allows them to develop a function map for key factors associated with both of their developed indices, ecological and socioeconomic. This function map, as shown in **Figure 2**, developed specifically for Zambia, is based on Zambia's current state, needs, and desires for the future, and allows the team to quantify each of their indices as a function of an individual cost of a particular program.

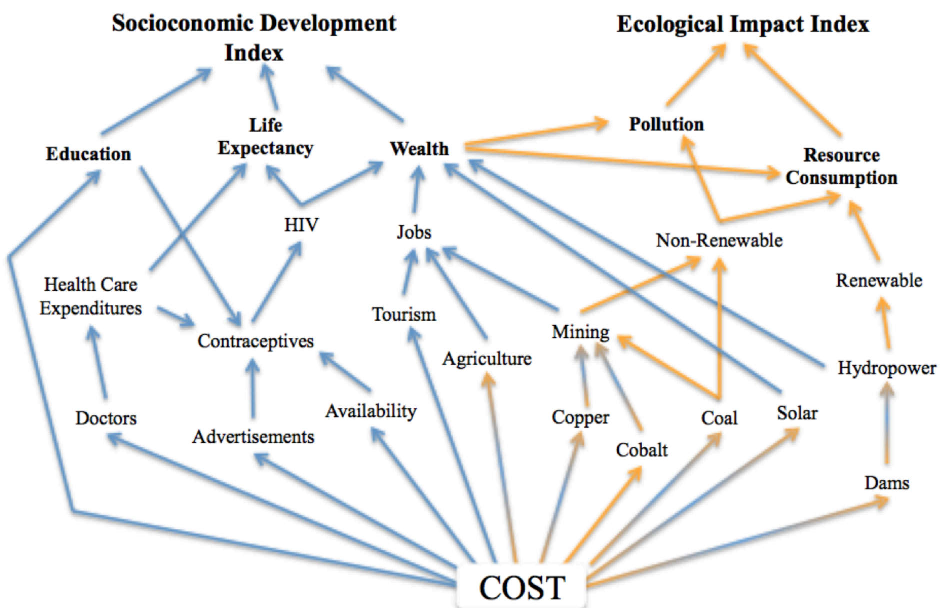

Figure 2. The winning paper from North Carolina School of Science and Mathematics included a function map of key factors.

The team's goal, using particle swarm optimization, is to find the optimal distribution of invested funds to the appropriate factors included on the function map. The team actually investigated four different techniques, summarizing the three that did not provide the best results before presenting their preferred method, particle swarm optimization. The judges appreciated the discussion of different techniques that could be applied in order to achieve their goal and their decisiveness of the chosen solution.

The team combines their two indices based on an investor's or the nation's desire for environmental stewardship. This allows the appropriate weighting of their two indices based specifically on a desire for future good, whereas the indices themselves are based on levels and factors currently seen in a society. The result is a nicely demonstrated model for a 20-year plan.

Lastly, the team does not simply leave it up to the ICM to decide the appropriate amount to allocate or the level of environmental responsibility to apply. Instead, the team evaluates their model and recommends a 20-year plan that changes funding to programs over time and specifies which programs should receive how much funding. Throughout their well-written report, the team includes appropriate visuals and graphics to clearly present the models and display the results in a meaningful way, while citing the expert literature used to support their approaches.

Zhejiang University, Hangzhou, Zhejiang, China: "Is It Sustainable?"

The team from Zhejiang University develops an initial model with two indices to measure both the social-economic and environmental contributions to sustainability. They utilize some of the same approaches that the judges saw in many of the other well-written papers, but then they distinguish themselves by going one step further, to provide not only metrics for the current level of sustainability of a nation but also a visual depiction of the ideal development direction.

Their sustainability measure includes two indices and a direction for the future that would bring the country in line with a balanced state of development. The inclusion of such a model is possible only through a deep understanding of the problem, which the team expertly indicate in their introduction and initial formulation section.

The first two components to the model, social-economic and environmental contributions, are based on a refinement of the ecological footprint ideas from the 1990s. The team discusses the initial model, finds weaknesses, and then devises a method to correct the drawbacks of the initial ecological footprint model, by including principal component analysis, entropy evaluation, and a weighting method based on CRITIC. The team then focuses in on the key of balance between the two indices, which is indicated by the standard development line on their sustainability measure and indicates a balance between socioeconomic development and environmental conservation.

The team develops their "harmonious development measure" as the magnitude of the intersection angle between the ideal development direction and the actual development direction of a nation through regression analysis, as shown in **Figure 3**.

The final result of the model is an output metric that the team calls "hyperbolic sustainable distance," which represents the hyperbolic distance between the current development and goal development for a nation. The team formulates a benchmark based on this metric in order to evaluate a nation's sustainability, which now includes the incorporation of the two initial indices as well as the development balance factor. Their formulation of such a metric, inclusion and description of their **Figure 4** for five sample nations is outstanding. To evaluate the model, the team chooses varying nations over a 10-year period. The judges appreciated the detailed analysis for the diverse nations as a way to understand the implications of the model.

A particularly impressive feature of this paper is the incorporation of both the forecast with intervention, and the forecast without intervention,

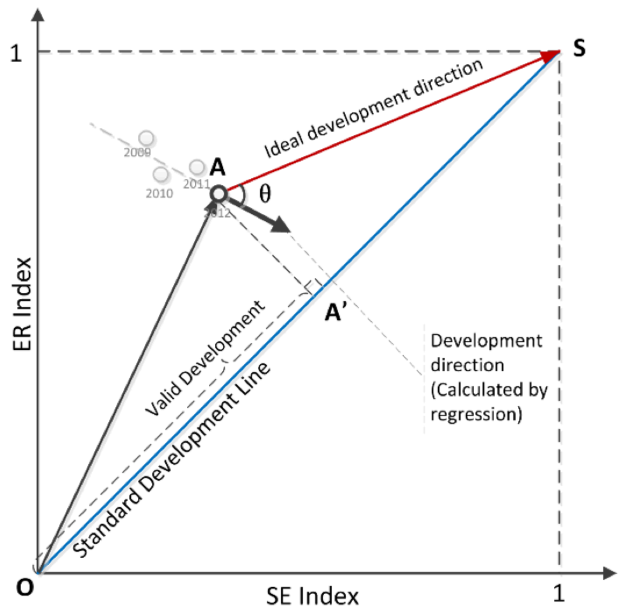

Figure 3. The winning team from Zhejiang University introduces its angle-based metric.

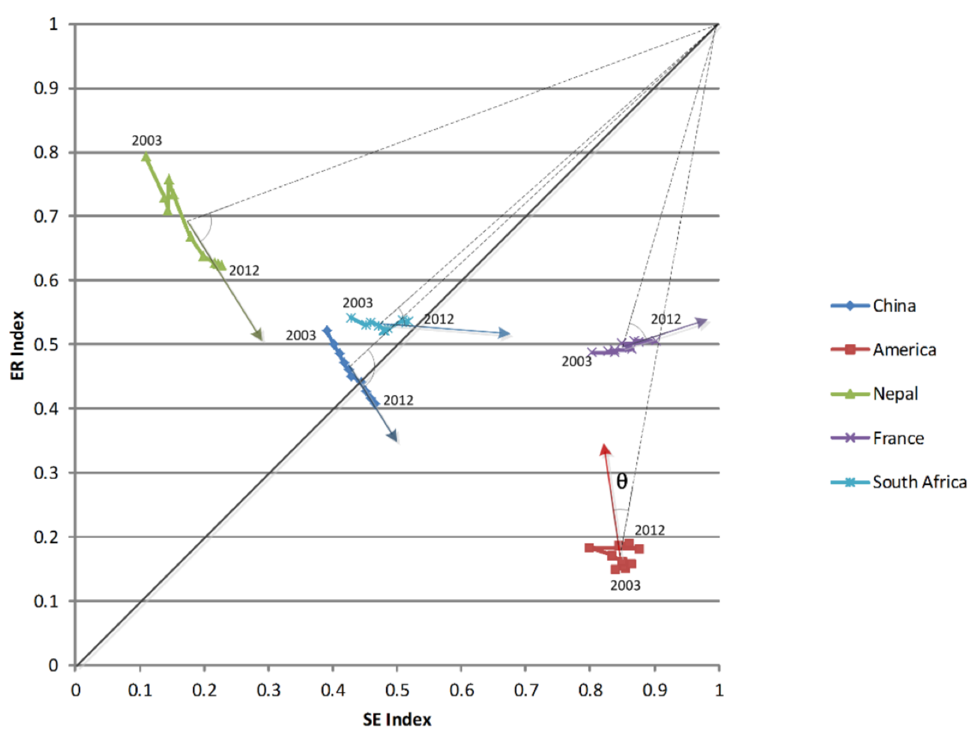

Figure 4. The angle-based metric in action for five nations.

for the chosen nation of Nepal. This was not seen in many papers but critical in order to understand the contribution of the 20-year plan to making a nation more sustainable through the intervention and use of additional funding vs. the already-established trajectory of a nation's path towards sustainable growth. The team's policy descriptions are very solid as they make a distinction between reasonable and effective policies.

The team sought to improve upon their model to predict sustainability with intervention by including a dynamic approach to modeling the interactions between subcomponents of their development metrics. The judges appreciated the model updates and insight into this complicated problem with interdependency of involved factors. The team's analysis concludes with a well-done simulation of four possible courses of action, which include no intervention and three different focuses for the aid intervention. At the end, the team recommends a course of action for the ICM to adopt, supported by strong analysis and discussion.

Xi'an Jiaotong University, Xi'an, Shaanxi, China: "Sustainability? Responsibility!"

This submission opens with powerful statements about the definition of sustainability, all backed by a wide variety of references. What immediately impressed the judges was the thorough literature search on the topic, as well as the way the team explains how they leveraged this existing work to develop their own model. For example, all of their sustainability development indicators, which serve as model inputs, are selected based on prevalence in the literature.

After scaling and normalizing all of their inputs, the team then uses an entropy method to assess three aspects of a nation's development: environmental, social, and economic. Based on the results of the entropy analysis, two indices are calculated:

- The Development Index (DI) offers a linear combination of each of the three aspects.
- The Coordination Index (CI), which also leverages existing research, addresses the interplay of the three aspects.

These two indices are presented as the coordinates of a point, and the sustainability score is then calculated as the distance between the point $(\mathrm{DI}, \mathrm{CI})$ and optimal sustainability, defined as $(1, 1)$.

The team then proposes the use of Lanchester's equation to propagate the state of sustainable development forward in time. National sustainability trajectories are presented as a means of visualizing the expected improvement, as shown in **Figure 5**.

The team selects the Congo as the target nation for its sustainability plan. One of the more impressive features of this paper is the extensive

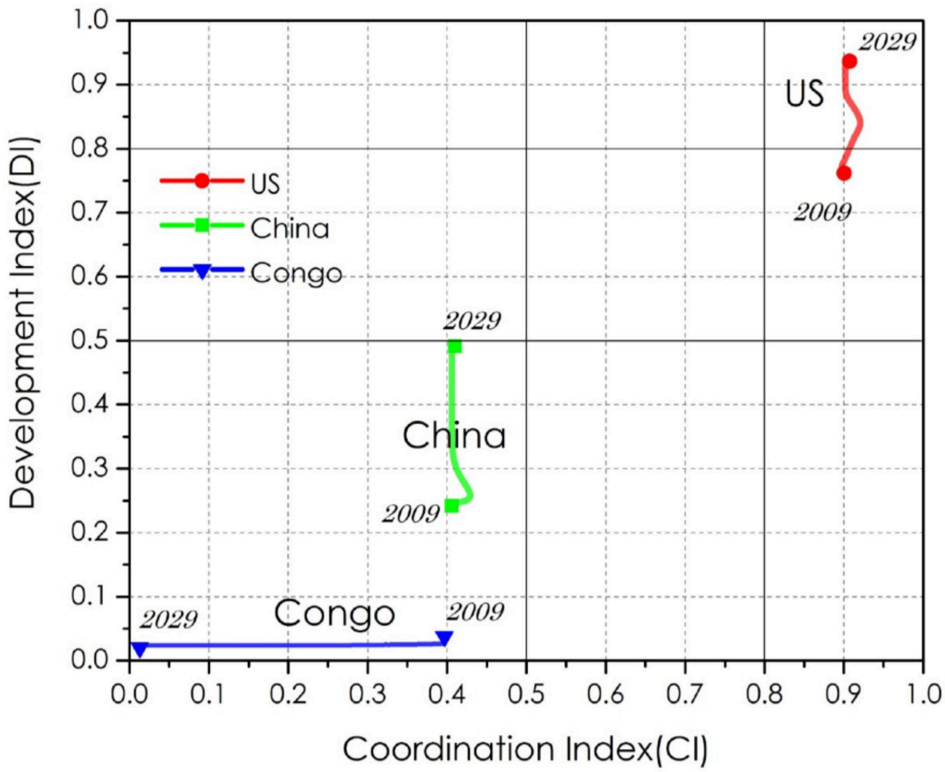

Figure 6. The Xi'an Jaotong paper used trajectory plots to illustrate improvement over time.

study presented as the team explores the effects of differing levels of support, different aspects of support, and the introduction of a perturbation, including both positive (e.g., foreign investment) and negative (e.g., natural disasters). The team also presents two final 20-year trajectories for the Congo, one without intervention and another with intervention, making a strong case for the adoption of their intervention program by the ICM.

Conclusion

The judges were impressed by the ability of so many student teams to combine modeling, science, and effective communication skills in order to tackle this intensive concept of sustainability. Among all the papers, there were so many strong and innovative submissions the judging was both challenging and exciting.

Recommendations for Future Participants

- **Manage your time.** Every year, there are submissions that do a tremendous job on one aspect of the problem but then are unable to complete their solution due to a lack of time. We encourage teams to have a plan for the 96 hours and then adjust as needed r to ensure a completed solution and submission.

- **Coordinate your plan,** by leveraging the strengths of individual team members. The more your team can coordinate the efforts of its members and integrate the writing into a seamless paper, the stronger your final submission will be. Leave time for your best writer to edit and ensure smooth transitions between pieces of the report. It is obvious in weaker papers that the work and writing was split up among the group members and then hastily assembled. Time needs to be allocated in your plan and execution for the editing of the paper into a streamlined submission.
- **Answer the problem.** Since time is limited, all initial efforts must be dedicated to answering the questions asked. Outstanding teams always address all aspects of the problem as addressed and then often go beyond for a particular aspect.
- **Do more than just model.** *The model itself is not the solution.* Outstanding teams always use their models to produce interpretable results and a recommendation for a solution.
- **A simple model can be just as effective as a complex one!** As noted in the Outstanding paper summaries, a simple model that is nicely researched, explained, and implemented can impress the judges when coupled with excellent interpretation within the context of the real-world problem that we are trying to solve.
- **Explain what you are doing and why.** Judges desire explanations of what a team is going and descriptions of why they are doing it, instead of lists of equations and numbers without words.
- **Do your research.** It is important to do research and understand the context of the problem—this is interdisciplinary! The judges do not expect the teams to be experts in all the aspects of a particular problem, but we do expect you to read about the situation and make sure you know what you are modeling!
- **Use strong references and cite them!** This last aspect is so critical. Please give appropriate credit to sources used in your research.

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About the Authors

Kristin Arney is an active-duty U.S. Army officer currently pursuing her Ph.D. in Industrial Engineering at the University of Washington. Kristin began her military career as a Military Intelligence officer after graduating with a B.S. in Mathematics from Lafayette College. During her career, she has served in assignments all over the globe (including two deployments), received her M.S. in Operations Research from North Carolina State University, and taught as an Assistant Professor at the U.S. Military Academy at West Point, where she will return and rejoin the faculty in January 2017.

Jessica Libertini started her career as an engineer, earning a B.S. and an M.S. in mechanical engineering from Johns Hopkins University and Rensselaer Polytechnic Institute. She spent nine years at General Dynamics working on projects ranging from the design of submarines to the development of a multinational layered missile defense system. After earning her Ph.D. in applied mathematics from Brown University in 2008, Jessica left industry and began her academic career at the U.S. Military Academy at West Point, where she held the positions of Assistant Professor and National Research Council Fellow. While at West Point, Jessica used her engineering background to motivate students to address large open-ended and meaningful questions both in the classroom and as the coach of the competitive mathematics team. She has since served on the faculty at the University of Rhode Island and is currently an Assistant Professor of Applied Mathematics at Virginia Military Institute. Given her background in engineering, her research spans a wide variety of mathematical approaches to modeling, analyzing, and simulating medical, military, and physical applications; she also participates in the scholarship of teaching and learning, focusing on undergraduate pedagogy and the elements of a successful transition from high school to college.