Simple Models for the Complex Problem of Measuring and Improving Sustainable Development

Jessica M. Libertini of Virginia Military Institute Joint Mathematics Meetings, Denver, CO 16 January 2019



Outline

- The problem
- Rationale for selecting certain solutions for today
- Solution from Humboltd State University
- Solution from Zhejiang University
- Other cool math
- Conclusions and Discussion

The Problem

The Problem (well first...)

The Problem (well first...)

• Sustainable Development

- What is it?
- Why is it hard?
- Who is thinking about this issue?
- Why is it important?

The Problem

- Part 1:
 - Develop a way to compare/rank the sustainable development of a nation
 - Validate the methodology
- Part 2:
 - Select one of nations of the UN's list of 40 least developed nations
 - Develop a specific targeted action plan to advance that nation's level of sustainable development

Commonly used data

• World Bank

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All Countries and Economies

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Country

Most Recent Value

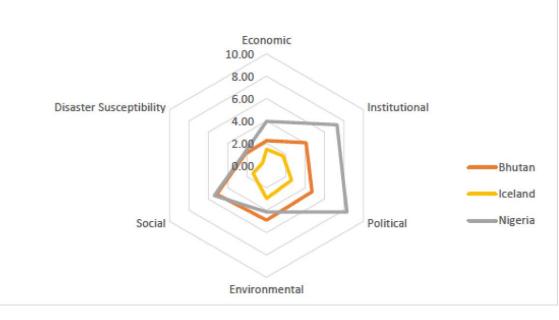
Most Recent Year

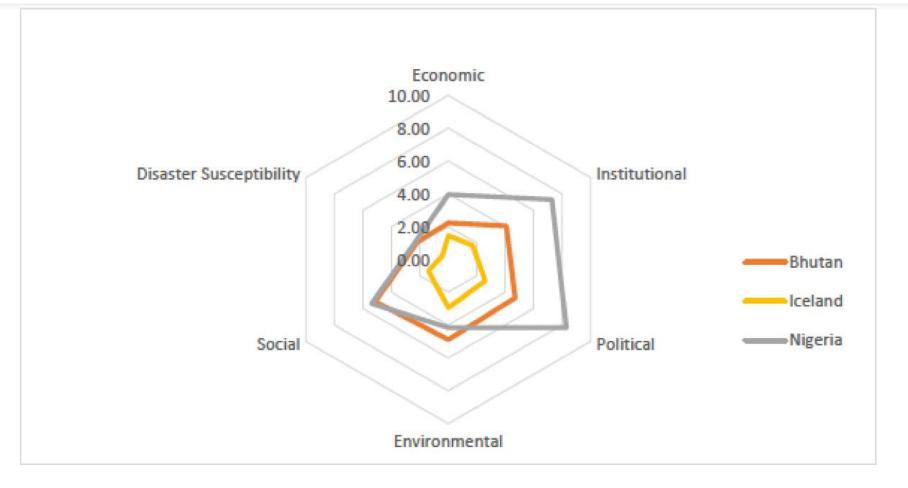
How did I pick the solutions we will discuss?

- Methodology overview:
 - Identified six domains
 - Economics, Risk, Social, Environmental, Political, Institutional
 - Identified country-specific data to create a metric score for each domain
 - So far this was a common approach, so why was this paper outstanding?

- Strengths:
 - Clear rationale for selection of choices
 - Excellent link between mathematical choices and real world clear and convincing discussion!
 - Did *NOT* try to collapse these six domains into a single integrated metric (which was a common approach)
 - So, what did they do instead?

- Radar Plot
 - Used a radar plot visualization
 - Allowed more targeted suggestions for the countryspecific 20-year plan (Bhutan)
 - Allowed a better way to show the outcome of implementing the 20year plan





What level of math was needed?

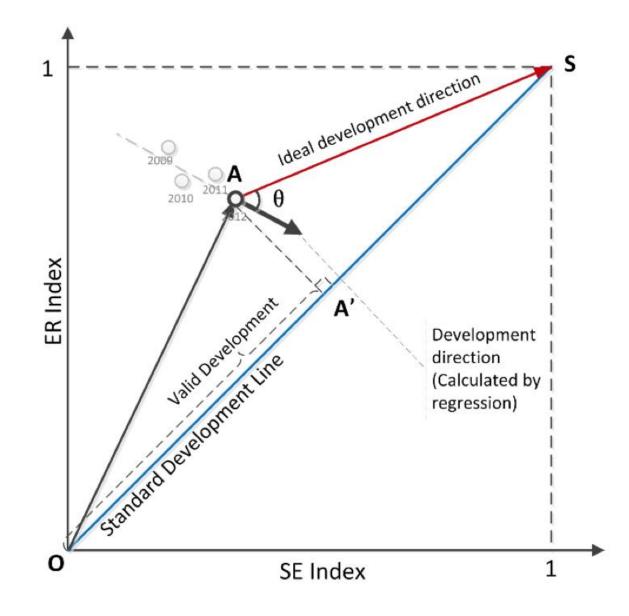
- For each domain, they made and justified a linear weighted metric involving factors that they noted as relevant
- They made a radar plot more about creativity than "math knowledge"
- The beauty of this solution is the simplicity any national leader could understand their logic, their methodology, and their findings.

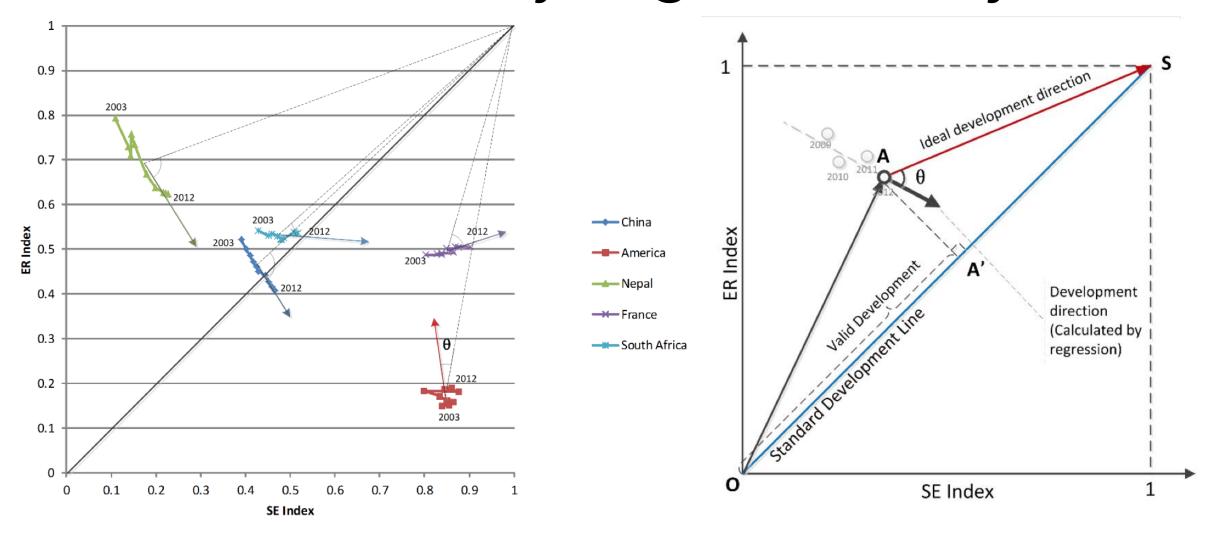
- Methodology Overview
 - As with many teams, this Outstanding paper distilled country data into two indices: socio-economic and environmental
 - They used many of the same approaches as other teams to make their indices (PCA and entropy-based weighting scheme)
 - So, why is this solution special?

- Strength
 - Development of an angle-based measure!
 - Goal was to be balanced between the two indices, so living along a y=x line
 - "Harmonious development measure" defined as the magnitude of the intersection angel between the ideal development direction and the actual development direction of a nation through regression analysis

- Strength
 - Development of an angle-based measure!
 - Goal was to be balanced between the two indices, so living along a y=x line
 - "Harmonious development measure" defined as the magnitude of the intersection angel between the ideal development direction and the actual development direction of a nation through regression analysis
- Wait! This sounds confusing! How is that good...?

- Harmonious Development Measure
 - The magnitude of the intersection angel between the ideal development direction and the actual development direction of a nation through regression analysis
- Single metric as a result which allows easy relative ranking of nations



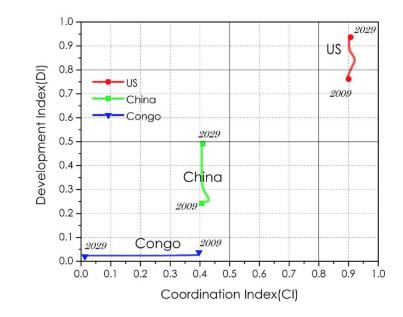


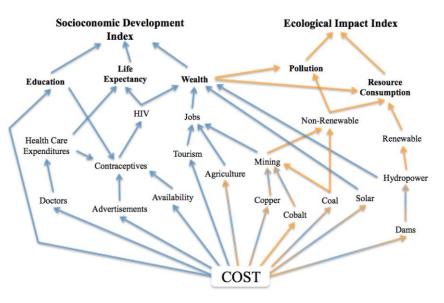
What level of math was needed?

- For each index, they used linear algebra (PCA)
- They used linear trendlines to determine a pattern
- They used trigonometry to define their angle

Some other cool mathematics used!

- Particle Swarm Optimization
- Lanchester Equations
- Trajectory Tracking
- Principle Component Analysis





Conclusions and Discussion

- In these contests, students use a wide range of mathematics
 - Some is advanced and surprising for undergraduates
 - Some is simple and elegant and accessible
 - Good explanations are critical
 - Good visualizations are powerful
- Questions?
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