Challenge Problem: Sustainable Peace

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ABSTRACT

Our group has been identifying the variables and their interactions needed for sustainable peace in the world. The goals are to provide a basis for further scholarship and a tool for policy makers. We are seeking the help of data scientists in identifying and analyzing the values of these variables and the strengths of their connections from existing public, government, or commercial data sources and through analyzing social media.

1.INTRODUCTION

In a period between 1988 and 2003, more wars ended through negotiations than through military victory than had occurred in the previous two centuries. However, over 25 percent of the wars ending through negotiations relapse into violence within five years, and these failed-peace states can begin an unprecedented phase of downward spiral; states with civil wars in their history are far more likely to experience renewed violence and the longer such conflicts last, the greater the chances of recurrence of war.

The hard truth is that we know very little about sustaining peace. This is because for decades we have studied the pathologies of war, violence, aggression and conflict -- and peace in the context of those processes -- but few have studied peace directly. Geoffrey Blainey, a prominent historian, wrote "for every thousand pages published on the causes of war, there is less than one page directly on the causes of peace".

Today, there are few scholars conducting basic research on the fundamental conditions and processes conducive to sustainable peace. In addition, the complexity, multidimensionality, dynamism, and sustainability of peace are not well understood. However, it is critical that basic, sound, empirically tested models inform policies and practices in order to foster peace most effectively.

2. BACKGROUND

The Advanced Consortium on Cooperation, Conflict, and Complexity at the Earth Institute at Columbia University (http://ac4.ei.columbia.edu), in partnership with the Morton Deutsch International Center for Cooperation and Conflict Resolution at Columbia University (http://icccr.tc.columbia.edu), has conducted and supported research on peace sustainability through the Sustainable Peace Systems Mapping Initiative (http://ac4.ei.columbia.edu/ac4-supported-initiatives/sustainable-human-development/sustainable-peace-systems-mapping-initiative/). This project aims to enhance our shared understanding of the fundamental dynamics of sustainable peace by convening a diverse group of stakeholders (including: academics, peacebuilders, and policymakers) in a multi-phase process and developing a systems map visualization of the complex dynamics of sustainable peace.

The observation is that the "communal system of interlacing forces which affect the relative probabilities of destructive conflict and peace" is complex and conceptually opaque. Elucidating and visualizing this network of interlacing forces requires an emphatically multi-disciplinary perspective. This project is the first of its kind to employ complexity science as an integrative platform to help synthesize our understanding of the most robust empirical findings from distinct areas of science in service of a more comprehensive and fundamental view of sustainable peace.

2.1 Phase 1. A survey was developed to elicit information from subject matter experts from the scientific community on the core components of sustainable peace and the interconnections among those components. This survey consisted of very few open questions, inviting experts to outline their understanding of sustainable peace. We asked respondents to describe metaphors, propose their working definition, discuss factors that influence sustainable peace and that are influenced by it, and finally describe the factors that inhibit or frustrate sustainable peace.

To streamline data collection, processing and coding, subject matter experts were asked to highlight or self-code the section of text that they consider most relevant and salient. This would enable machine-based processing of the data and would minimize the error in semantic processing.

The survey was completed by 70 respondents. The results were assessed and analyzed at a Peace Mapping Workshop of the Core Group (authors cited here) that was held on May 15-16, 2015 at Columbia University. Continuing from those discussions two working groups then individually developed possible Causal Loop Diagrams. The further development of the next generation of Causal Loop Diagrams based on those first two preliminary diagrams is currently in progress. A mathematical model based on ordinary differential equations representing one of those preliminary maps is also being developed.

2.2 Phase 2. A second (building) phase is currently actively being planned. This will focus on building the Causal Loop

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Diagrams and the meta-model out from the core. Based on the results from the preparatory phase it will be possible to identify knowledge areas in need of expert input. Experts can then be invited to write science reviews to address those gaps. Based on these science reviews the models can be further developed. There will be an interactive modeling platform that allows for easy integration of new pieces of evidence. Typically this is an iterative process. At least one workshop will be needed to come to a pre-final version of the deliverables (the Causal Loop Diagrams, the meta-model and any satellite models that we may want to derive from the meta-model).

3. CAUSAL LOOP DIAGRAMS (CLDs)

A Causal Loop Diagram (CLD) is proposed as the preferred vehicle to analytically come to grips with this complexity. This is a qualitative model that relies on a straightforward syntax of variables (boxes) and 'causal' links (arrows) or feedback loops.

3.1 CLD Strengths. It has been shown that these CLDs have a number of characteristics that make them well suited to capturing complexity:

- *Familiarity*: a CLD is a format that has been used in numerous systems mapping and foresight policymaking efforts. Assumedly this engenders a growing literacy that facilitates acceptance and uptake of these kinds of maps.
- *Multi-disciplinarity*: a CLD integrates variables from a wide variety of sources and disciplines. Hence a CLD is very suitable as a canvas for synthesis of a heterogeneous, multi-disciplinary evidence base.
- *Interactivity*: today we have tools to embed CLDs in a truly interactive, web-based environment. This creates opportunities for an unprecedented level of visual refinement and analytic flexibility.
- *Segmentation*: a CLD can be investigated through the lenses of various analytic filters. For instance, a systems map can be considered for specific socio-economic, ethnic or gender groups or geographies. Conceptually this amounts to adding a categorical variable and particularizing the master-CLD for each level of that variable. In other words: the master-CLD is segmented for that given categorical variable. This provides considerable analytic flexibility.
- *Knowledge management*: embedding a CLD in a web-based environment provides opportunities to connect the elements of the system map directly to the underlying evidence base. The CLD becomes a portal to access a very diverse body of literature and research data.

3.2 CLD Limitations. However, we need to be mindful of the fact that a causal loop diagram also has potential drawbacks.

- *Complexity*: CLDs built around complex issues tend to be complex themselves due to the great number of variables and connections. Typically a significant part of the intended audience feels overwhelmed when confronted with such a complex model. This may impede uptake of the model. Visual strategies have to be developed to interactively modulate the level of complexity of a CLD.
- *Dynamics*: while a CLD reflects the dynamic architecture of a system (in terms of its constituent feedback loops) it is not always able to provide a good feeling for the dynamics themselves. A qualitative assessment of the interactions between a set of interlinked feedback loops is very hard. Additionally the weights of the connections come into play. In a comprehensive CLD it requires significant resources to assess these weights. In many cases the data to substantiate these assessments will not be available.
- *Normativity*: inevitably a CLD is based on a particular framing of a complex issue. That framing may or may not have a strong normative bias. It is important to be aware of such a bias as recipients may welcome or resist it.
- *Conditional logic*: the simplicity of the syntax of a CLD is also constraining. It is impossible in our experience to mesh the causal logic of a CLD (A leads to B) with a conditional logic (B happens if A is present). This type of reasoning is, however, very prevalent: "if governance is good, then this variable is not a problem". Analytically the effect of governance can only be integrated in a CLD via a segmentation strategy.
- *Prediction*: a CLD is a qualitative model and as such unsuitable for predictive purposes. Conceptually a CLD can provide a basis for the development of a system dynamics model but in practice the translation from one into the other is hard.

These limitations should not detract from the fact that a CLD remains a quite effective vehicle for getting a handle on messy challenges.

4. WORKING GROUP CLDs

The core team of eight people was divided into two separate working groups, each of which independent proposed a CLD.

4.1 CLD from Working Group A. This CLD, shown in Figure 1, emphasized the content and connections derived from an analysis of the survey data. The categories of the six macro-level principle variables are rooted in the micro-level variables identified in the survey. These variables are not specific to any one scientific field and would be welcoming to the participation in this project of a wide variety of scholars and practitioners, including: political scientists, anthropologists, economists, social psychologists.

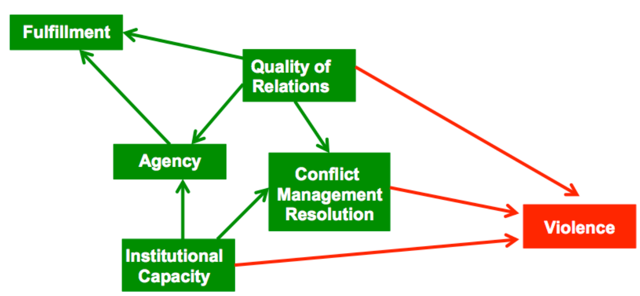

Figure 1. The six variables of the Causal Loop Diagram from Working Group A. Positive factors and connections are indicated in green and negative ones in red.

In constructing this CLD, the survey data was used to identify the frequency with which one important word following another in the definitions of sustainable peace. This is shown in Table 1. The micro-level variables associated with each macro-level variable are shown in Table 2.

	1-Violence	2-Conflict Management and Resolution	3-Quality of Relations	4-Agency	5-Institutional capacity	6-Fulfillment
1 : Violence	66	15	10	6	12	8
2 : Conflict Management and Resolution	15	78	20	12	18	9
3 :Quality of Relations	10	20	159	40	2	15
4 : Agency	6	12	40	195	13	29
5. Institutional capacity	12	18	2	13	34	4
6 : Fulfillment	8	9	15	29	4	69

Table 1. Factor matrix of frequencies of two-variable associations in the survey data.

Factor	Description/notes	Secondary factors (or basic dimensions- that is the case for violence and fulfillment)
1. Violence	"Life without war, aggression, or major conflict" "The absence of violences, long term peace" Goes from violence to nonviolence (gives the negative peace)	Basic dimensions: - Conflicts - Deaths - Relations with neighbouring countries - Criminality in society - Political instability - Terrorist activity - Homicides - Violent crime - Violent demonstrations - Jailed persons p - Military expenditure - Armed-services personnel - Weapons
2. Conflict Management and Resolution	"An established on-going successful process of working out problems" "A state of existence where conflict is handled constructively" "resolve and transform conflict in a non violent way"	- CR Competencies and skills: communication - Access to justice (also under Agency) - CR Institutions: mediation, - Reconciliation mechanisms - Community and Political participation (also under Agency)
3. Institutional Capacity	"Inclusive, effective and accountable political institutions"	- Rule of law - Corruption - Accountability - Government effectiveness
4. Quality of Relations	The principles that guide our lives, which result in good interpersonal and intergroup relationships. "cultural values, psychological constructs, social patterns, and educational approaches that develop and maintain an aversion for settling conflicts violently"	- Shared values of inclusion - Cooperation - Trust - Concern for others - Recognition and respect for diversity - Taboos against violence - Peace education
5. Agency	It refers to the access to the necessary resources that will guarantee a capacity to participate as an agent in social and political processes. It includes the environment, natural dynamics, and the ecosystem more broadly, which directly affect the access to resources and the well-being of those who inhabit it.	- Community and political participation (also under CMR) - Economic opportunity - access to justice (also under CMR) - freedom of speech, - access to information - access to healthcare - law enforcement and crime control - access to education, - Security and defense - Social protection - Access to arts - Leisure time - Freedom of religion - Social and income inequality (includes gender) - Environmental protection - Natural resources and space - Environmental factors and natural disasters - Self-determination
6. Fulfillment	Perceptions of harmony, satisfaction, freedom from fear, harm, and stress.	Basic dimensions - Confidence in government - Life Satisfaction - Psychological Wellbeing - Happiness

Table 2. The macro-level variables (first column) are identified with the micro-level variables (third column) of the Causal Loop Diagram from Working Group A.

4.2 CLD from Working Group B. This CLD, shown in Figure 2, emphasized an interpretation of the survey data informed from the findings of other studies, especially from the anthropological and psychological study of human interactions. It focused on intergroup rather than individual interactions, on the ratios of two properties as the values of the variables, and established the ratio of the positive to negative interactions as a central nodal variable. It also provided more structure in how the variables are connected and an overall organization of the variables stretching from the past on the left to the future on the right.

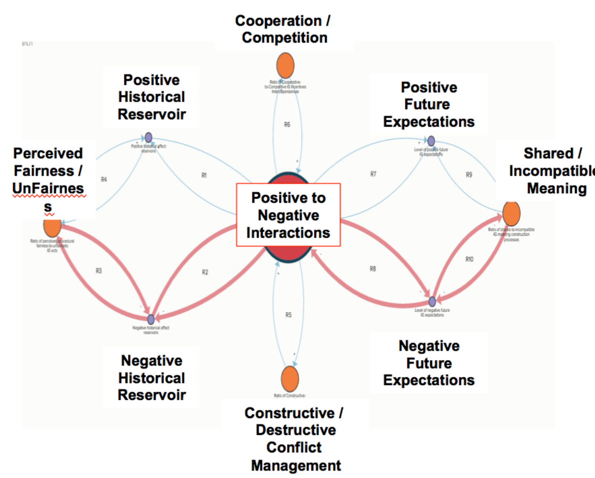

Figure 2. The nine variables of the Causal Loop Diagram from Working Group B. Positive connections are indicated in blue and negative ones in red.

5. MATHEMATICAL MODEL

5.1 Uses of a Mathematical Model.

In order to better understand the influence of the variables on each other we also have been developing rigorous mathematical models of these Causal Loop Diagrams. In order to formulate the mathematical structure and determine the parameters of these mathematical models has also raised questions that are potentially helpful in further developing and using the Causal Loop Diagrams:

- *Variables*: Should the values of the variables be positive numbers, negative or positive numbers, a single measure, the difference between a positive and negative measure, or the ratio of a positive and negative measure?
- *Connections between variables*: What is the quantitative range in the strength of the positive and negative influences between the variables?
- *Network structure:* What is the expected network structure of the Causal Loop Diagrams, random connections, a central core and a periphery, or a community structure of multiple hubs?
- *Operational definitions*: How can the variables be defined so that their values can be estimated from current knowledge, new data, or new methods of measurement?

Moreover, a mathematical model can also prove useful in:

- *Computer simulations*: Determining how the values of the variables depend on the connection strengths and the initial conditions can be useful in better understanding the functioning of the Causal Loop Diagrams and also be of use in training sessions to show the relative importance and consequences of different aspects of the model.
- *Prediction*: If the model is meaningful and its parameters can be sufficiently determined by observational data then it could be used for quantitative predictions.

5.2 Initial Mathematical Model.

As a starting point, we developed a mathematical model of the Causal Loop Diagram from Working Group B. The model uses coupled, non-linear, ordinary differential equations. It is an extension of our previous models of two people interacting [1] and of many people interacting on a small world network [2].

The rate of change of each variable x_i depends on three terms:

- $-|m_i|x_i$: which reduces the value of each variable x_i by a constant proportion so that it cannot increase to infinity and the parameter m_i sets the time scale for the rate of change of x_i.
- b_i: which is the self-excitation increase by each variable, usually referred to as autocatalysis in the modeling of chemical reactions.
- $\Sigma_{(j=1,n)}\, c_{ij} \tanh(x_j)$: which is the influence of the other variables where c_{ij} is the strength of the influence of x_j on x_i and we use the hyperbolic tangent function $tanh(x_j)$ so that the effect of each variable cannot exceed the threshold set by c_{ij}.

The model is then given by

$$\frac{dx_i}{dt} = -|m_i|x_i + b_i + \sum_{j=1}^{n} c_{ij} \tanh(x_j)$$

where we approximate the derivative by its differential and numerically integrate by the Euler method with $\Delta t = 0.001$.

$$x_i(t+\Delta t) = x_i(t) + \Delta t \left\{ -|m_i|x_i(t) + b_i + \sum_{j=1}^{n} c_{ij} \tanh(x_j(t)) \right\}$$

to determine how all the variables evolve in time from a set of initial conditions. These equations were coded in Python 3.4.1.

5.3 Initial Model Parameters.

The adjacency matrix c_{ij} was chosen to represent the connections in Figure 1. Specifically, $c_{ij}=0$ if two variables are not connected, , $c_{ij}=+3$ if the influence of of x_j on x_i is positive, and $c_{ij}=-3$ if the influence of of x_j on x_i is negative. (The value of *3* was chosen because we know from previous models [1] that unless $|c_{ij}|>1$, all the variables will relax toward zero.) We set all the self-excitation $b_i=0$ and all the time scale $m_i=-0.9$. The only exceptions were that since the effects of negative emotions are both stronger and more long lasting, the effect of the negative historical reservoir on the nodal variable of positive to negative interactions and on the perceived fairness/unfairness variable were set to *-6* and the time scale m of the negative historical reservoir was set as $m=-0.2$. We determined the evolution of this system for a range of initial conditions. For this model we also treated the positive and negative future expectations as one, rather than two variables.

5.4 Initial Model Results.

This model, even with its crudely assigned parameters, yielded some surprisingly interesting (and tantalizing) results.

5.4.1 A Good Outcome

As shown in Figure 3, with the initial conditions $x_i=1$, since everything starts positive, the Positive Historical Reservoir (2/greenyellow) builds, the Negative Historical Reservoir (3/hotpink) decays very fast and stays at zero, and the Nodal variable Ratio of Constructive/Destructive Interactions (1/thick navy blue) grows and stays at a positive value.

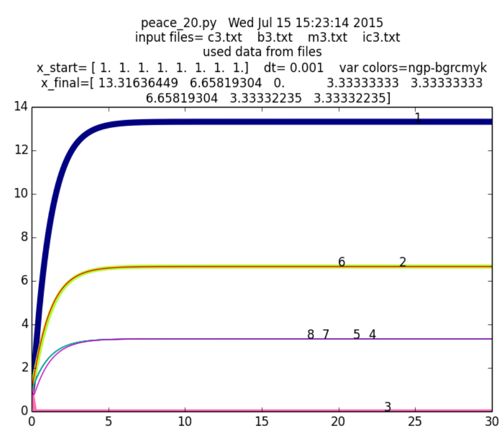

Figure 3. Graph of the variables as a function of time. Initial conditions: all variables = *1*.

5.4.2 A Bad Outcome

As shown in Figure 4, both the Positive and Negative Historical Reservoir start at 1 and all the other variables start at zero. Since the Negative Historical Reservoir (3/hotpink) has a stronger effect and a longer memory than the Positive Historical Reservoir (2/greenyellow), the Negative Historical Reservoir increases in time and drives all the other variables down, including the Nodal variable Ratio of Constructive/Destructive Interactions (1/thick navy blue).

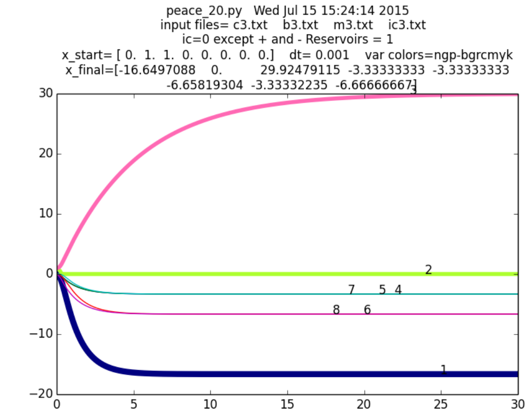

Figure 4. Initial conditions: Negative and Positive Historical Reservoirs = *1*, all other variables = *0*.

5.4.3 Attractors
For many different initial values, the Nodal variable (1/thick navy blue) at long times is either at *+13.316* or *-16.649*. In fact, all the 8 variables reach one of two possible sets of values. These are called "attractors". The long time (steady state) values of the variables do not fall in-between those of the "bad" or "good" attractor, they are either one or the other. If we push the system a little off from the attractor, it falls back into the attractor. That's why it's called an attractor.

5.4.4 Not Escaping the "Bad Attractor"
Now we explore what happens if we try to push the system away from the "bad attractor" in Figure 4 where the Nodal variable (1/ thick navy blue) = *-16.649* to try to get to the latent "good attractor" in Figure 3 where the Nodal variable (1/thick navy blue) = *+13.316*. Since the input into the Negative Historical reservoir comes from the Nodal variable and from the Fairness variable, lets make those very strong, maybe +20 to reduce its negativity. As shown in Figure 5, this does lower the negative reservoir (3/ hotpink) for while, but the system relaxes back to that "bad attractor".

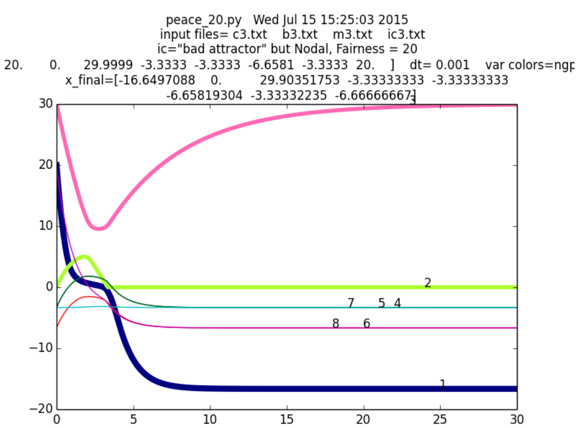

Figure 5. Initial conditions: "bad attractor" but Nodal and Fairness variables = *20*.

5.4.4 Escaping the "Bad" Attractor"
Again, we start the system at the "bad attractor", but now set the Nodal and Fairness variables stronger at +30. As shown in Figure 6, the system now evolves out of the "bad attractor" and into the "good attractor" where the Nodal variable (1/thick navy blue) is +13.316. Note that the Nodal and Fairness variables do not stay at 30, all the variables go to their values of the "good attractor" in Figure 3.

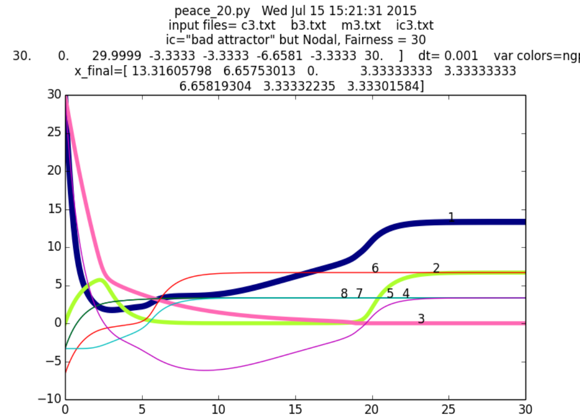

Figure 6. Initial conditions: "bad attractor" but Nodal and Fairness variables = *30*.

6. CHALENGE FOR DATA SCIENCE
We are presenting this paper to seek assistance from the data science community in determining the real-life values of the variables and the strengths of the connections between them in both the Causal Loop Diagrams and mathematical models. The value of these diagrams and models for both scholarly research and assistance to policy planners in making decisions depends on the accuracy of those parameters. Specifically, we want to know how existing public, government, or commercial data sources or analyzing social media content and frequency can be used to determine:

- the micro-level variables of column 3 in Table 2
- the strengths of the connections in Figure 1
- the values of the macro-level variables in Figure 2
- the strengths of the connections in Figure 2

7. ACKNOWLEDGMENTS
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8. REFERENCES
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