Modeling Complex Social Behavior: A System Dynamics Approach

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Abstract: *System Dynamics (SD) will be used to facilitate a holistic representation of the British counter-insurgency (COIN) in Ireland with a view to events and relationships from a macro to micro perspective. SD modeling facilitates assessment of cause and effect factors, direct and indirect variables, and corresponding and correlative relationships of insurgency as a complex system. The model characterizes the relationships between and among inorganic and organic factors, i.e., events and human behavior / response. The purpose of the study is to better understand what served to unite the Irish insurgency, self rule, and what would have moderated the British COIN. Resultant model iterations allow for in depth analysis of case studies to explore hypothetical scenarios and what if questions.*

1. Introduction

The Systems Dynamics (SD) modeling paradigm is used for analyzing complex systems in many different areas. This modeling technique characterizes causal and correlative relationships between and among inorganic and organic factors, *i.e.*, events and human behavior / response. Specifically, SD facilitates a holistic representation of those events, and it can progress from the macro to micro perspective. SD also allows for sensitivity and statistical output analysis. Resultant model iterations allow for in depth analysis of case studies to explore hypothetical scenarios and *what if* questions.

The paper uses an SD to model complex social systems. First, is a discussion of SD as a modeling paradigm and the development of causal loops and stock and flows. SD will be used to explore the evolution and escalation of civil uprising (1916) and war (1919-1921) in Ireland specific to the relationship between and among the protagonists during this period. The significance of the research comes in the form of an analysis of the models and their outputs with comments on the model's function in explaining and understanding the case study.

2. System Dynamics

SD is a methodology for modeling and subsequently studying complex systems such as those found in political or other social systems as entities that maintains their existence through the mutual interaction of their parts (Forrester, 1991). The methodology consists of:

- Identifying a problem or system to be modeled
- Developing a hypothesis to explain the cause of the problem or the behavior of the system
- Developing a model to capture causes/ behaviors
- Validating the model to show that it reproduces the real-world behavior
- Devising possible solutions to the problem or modification of the behavior
- Testing these solutions in the model to show the possible outcome or impact of the proposed solution

SD models are defined and represented by causal loop diagrams (that serve to identify factors and their relationships to explain how the system behaves) and stock and flow diagrams. Both are a critical in the modeling process as they serve as the foundation for capturing / explaining how the system behaves. Figure 2.1 is a causal loop diagram of factors that influence highway road construction.

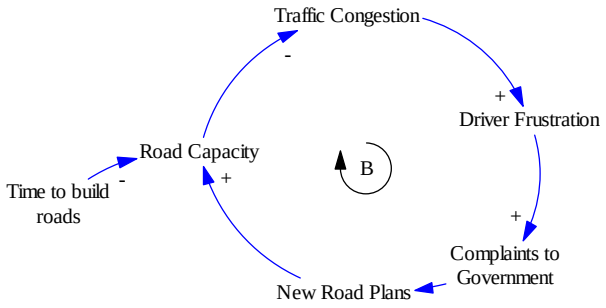

Figure 2.1 Causal loop diagram for road construction

Each arrow in the diagram represents a causal link between two variables (e.g., as traffic congestion increases driver frustration increases; in turn causing more complaints to government; which leads to new road plans and more road capacity; with more road capacity traffic congestion decreases). The plus signs indicate the *effect variable* changes in the same direction as the *cause variable*. A negative sign (-) indicates an opposite change. The minus sign in the center of the loop shows this as a balancing relationship (the loop continues to feed on itself in a negative manner causing an exponential decrease in traffic congestion). Opposite this is a reinforcing loop indicated by a central plus sign. These behaviors describe an important concept in SD: *feedback loops*, which refer to situations where variable X affects variable Y and Y in turn affects X possibly through a chain of causes and effects. Studying these links independently to predict how the system will behave is not possible as only the study of the system with its multiple feedback loops connected to one another will lead to proper results.

Causal loop diagrams provide a conceptual model of how the system behaves. To turn the model into a functional simulation of the system requires translating the causal loop diagram into a stock and flow representation. *Stocks* are system variables whose values can be accumulated over time. *Flows* are the rate variables that govern the changes to the stock levels. Figure 2.2 is a stock and flow diagram for the traffic congestion example.

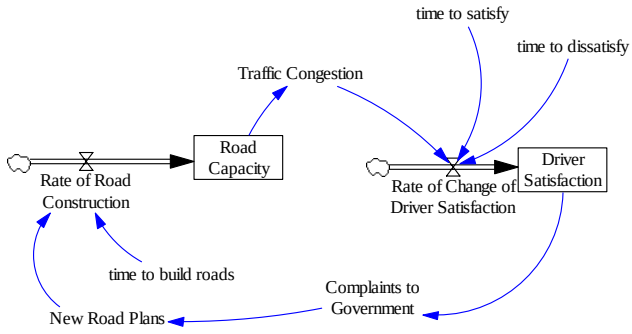

Figure 2.2 Stock and flow diagram for traffic congestion

In Figure 2 the rectangular boxes represent the stocks; here interest is placed on how road capacity and driver satisfaction change over time. The large arrows represent the flows with a valve symbol characterizing an adjustable rate of road construction and driver satisfaction. The other variables control these rates and thus the levels of each stock variable.

3. British Counter-Insurgency and the Easter Rising 1916

Civil uprising and insurgency are appropriate case studies to model as they are complex social systems that can be represented using SD. This study on Ireland looks at violence at the turn of the 20th century: the Easter Rising of 1916 and the Anglo-Irish War of 1919-1921. The following is a succinct discussion of these events.

In 1912 the British House of Commons passed the *Home Rule in Ireland Act*. If approved Home Rule could serve to split northern and southern Irish. The Protestant-Unionist-Loyalist-Irish of the northeast resisted this measure believing they would become a minority population among the Catholic-Nationalist-Gaelic-Irish of the south. To combat this measure of devolution **Unionists** organized as a group of militant rebels, the **Ulster Volunteers**, men who had no qualms about taking-up arms against the southern Irish or the King.

The Ulster Volunteers were countered in the south by **Nationalist** supporters of the Act who in 1913 organized, took arms, and called themselves the **Irish Volunteers**. The Act was never implemented due to the outbreak of World War I in 1914. Britain's commitments in this war gave way to the call for Allied support among citizens of the empire to include all Ireland; and many Irish enlisted.

Members of the predominant **Irish Parliamentary Party** (IPP) hoped to use this gesture of war support as a bargaining chip in that when the war was over arguing the institution of Home Rule based on the show of Irish goodwill and support for the allies. Not all Irish agreed with this political tactic; in fact, many in the south opposed fighting the war in general, and more specifically fighting the war for Britain. Concurrently, another organization, more radical in its ideals and approach to Irish self-rule, began to prepare for a domestic revolt against British governance in Ireland. The **Irish Republican Brotherhood** (IRB), a secret society that came to be the most radical expression of nationalism, along with other Irish Volunteers planned an insurrection to establish an Irish Republic (Kostick, 1996).

In 1915 the Nationalists under the direction of charismatic leader Michael Collins p, with the help of Irish-American ties in New York, arranged for a shipment of arms from

Germany for the following spring. Both the Germans and the Volunteers knew that an Irish uprising aimed at the British could benefit both the German offensive in Europe and the uprising to lay claim to a Republic of Ireland.

An arms exchange was foiled as the German ship bringing arms was intercepted off the Kerry coast. The arms seizure signaled two things: the British were now aware of the covert activity taking place between the Irish and enemies of the realm and the Volunteers knew that without arms their planned Uprising was futile. Still, it was decided to go ahead with the Uprising as the Nationals sought to strike with what they had before the British had an opportunity to regroup and respond. Thus, a handful of Volunteers, reconciled to failure and willing to lose their lives, proceeded with the uprising. Some even believed a *blood sacrifice* was needed regardless of the odds against a victory (Walsh, 2009).

On 24 April 1916 approximately 150 Volunteers marched into the Dublin's General Post Office and ordered the staff to leave. The Volunteers took advantage of three things: Britain's overseas commitments, Ireland's tie to the Catholic Church and its condemnation of the war, and the threat of conscription.

The Easter Rising resulted in 1,351 wounded, 318 killed, 179 buildings destroyed, 3,430 men interned, and 92 death sentences (Kostick, 1996). The Rising lasted 6 days because it took that much time for British authorities to flood the city with troops. In Britain, the Rising was viewed as a stab in the back and it was believed that the Irish Volunteers were assisting the Germans. As such, British military policy and reprisals created many martyrs.

British reprisals in the form of execution and severe treatment of any associated with the Rising effectively changed the mood of Irish Nationalists, civilians and Volunteers, as they became more amenable to a radical means to an end (Auguseijn, 1996). In fact, the failed rebellion resulted in an emotional response by the Nationalist population and it accomplished precisely what the Volunteers sought, a revived civilian support for an Irish Republic (Hart, 2003).

3.1 Modeling the Easter Rising

The above narrative highlights the cause, ideologies, events, protagonists, and results of the incident. These can be dissected to construct the causal loops and stocks and flows.

The modeling effort begins with an analysis of the above narrative following the SD methodology outlined earlier in the paper. The task is to develop a model of the Anglo-Irish insurgency. In analyzing the above events one can see that the majority of the Irish citizens preferred self-rule because of their dissatisfaction with British dominance. This dissatisfaction was caused by the imposition of British rule and British culture, which was different than the Gaelic-Catholic heritage that had been suppressed. This socio-cultural factor was a catalyst for ripening longstanding conditions causing a call to insurgency and the 1916 Rising. These are variables that can be used to begin the causal loop diagram. This segment of the loop is shown in Figure 3.1.

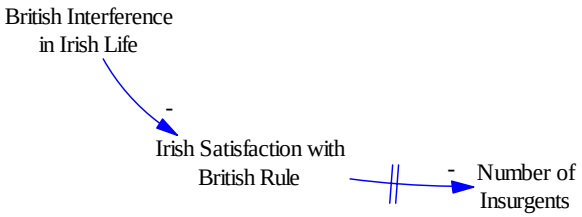

Figure 3.1 Initial causal loop diagram segment

Here, British interference in Irish life caused dissatisfaction with British rule leading to a growing number of insurgents.

As the number of insurgents grew so did the threat of violent incidents. This culminated with the takeover of the Post Office on Easter Monday 1916. The British were now under pressure to respond. British soldiers retaliated with many acts of killing and brutality, which only caused the perception of more interference by the British on Irish civilian life. This chain of events will allow additions to the causal loop diagram of Figure 3.1 and it completes a reinforcing loop that continues to feed the rise of the insurgency in Figure 3.2.

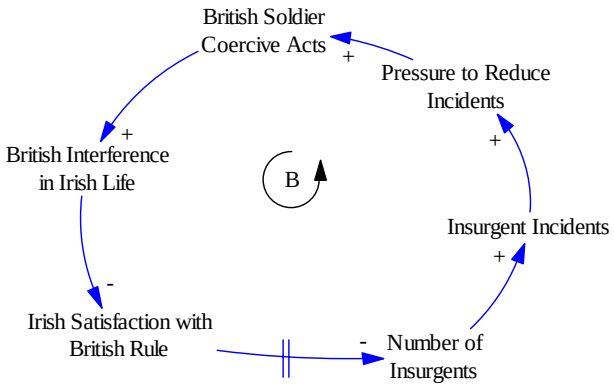

Figure 3.2 Insurgency creation loop

Because dissatisfaction with British rule does not instantaneously create new insurgents, a delay symbol (two parallel lines) was added to the segment connecting

Irish Satisfaction with British Rule with *Number of Insurgents* to indicate this delay. This model now sets the stage for the Anglo-Irish War.

4. British Counter-Insurgency and the Anglo-Irish War 1919-1921

Modeling the next phase of the case study calls for a revised explanation of the ideology and intent of insurgency, the shifting populations among the protagonists, the structured tactics of the insurgents, and the formal counter-insurgency policy implemented. Importantly, since these are continuous events, the model must note the tipping points that result in desired or proscribed outcomes of the protagonists.

For purposes of modeling the Anglo-Irish War the designations will follow as such: the **post-1916 Nationalists** are outraged by British reprisals after the Easter Rising and are much more amenable to using nefarious acts in a tit-for-tat environment; some Volunteers changed their ideology and consider themselves **Republicans** seeking a free Ireland with no political stipulations. By 1920 these Irish Volunteers reorganize and become the **Irish Republican Army** (IRA) under Michael Collins (Fitzpatrick, 1998). Coupled with a Republican posture, the IRA sought autonomy over the entire state and escalated the rebellion via guerrilla tactics throughout the pre-war, from post-Rising 1916 through 1919, and then during the heated battle which began in 1920 until the truce of June 1921.

The executions that immediately followed the Easter Rising served to shift the support of many civilians to the Republican cause. All but one of the leaders of the Rising lost their lives. Irish politics now shifted: Parliamentary elections held in 1918 placed the IPP in low esteem and gave way to overwhelming wins for Sinn Fein (Augusteijn, 1996). This public support was the impetus for a provisional government, an Irish Parliament (Dail) which convened on 21 January 1919. It is with this self-proclaimed government that Collins reorganized the Volunteers into the IRA who swore allegiance to both the Republic and the Dáil.

The IRA was perceived by some members of the Dail to possess a mandate for war against the British. As such, the IRA began a methodical campaign of guerrilla warfare by first targeting British soldiers. It benefited from public support in waging this campaign for the years between 1916 and 1918 were bloody; many Irish families suffered from British brutality. The most significant event during this period was the *anti-conscription campaign*.

By April 1918 conscription of Irishmen was enacted and it yielded much ill-will on the part of all Irish. As such, *conscription was the catalyst to a united cause*. Many strikes and an anti-conscription rebellion resulted in the designation of 13 counties as Special Military Areas with large numbers of British troops deployed to keep the peace. At the close of 1918 this number exceeded 100,000 (Walsh, 2009). Sinn Fein membership increased from 66,000 in December 1917 to over 100,000 members in April 1918 (Hopkinson, 2002). Two things are significant regarding this crisis: 1) conscription was the catalyst to a united cause among civilians and Volunteers, and the Church contended that the Irish people had a right to resist; 2) the British were hard pressed by the various tactics (labor strikes and guerrilla operations) used in the resistance.

In March 1920 support was brought in to buffer RIC losses and the escalation of violence in the form of the **Black and Tans**. The British government placed 7,000 Tans under the administration of the Royal Irish Constabulary (RIC). The Tans conducted their affairs like a para-military force. A second quasi-military force was introduced that same summer, the **Police Auxiliary Cadets**. They, too, were to bolster the RIC, control the Tans, and avoid military conflict. They numbered 2,215 and were all too often just as bad as the Tans in their mistreatment of civilians; however, they focused on the IRA. By end of 1921 there were 17,000 RIC officers and 80,000 British troops in Ireland (Kostick, 1996). Collins estimated IRA membership during the war was 100,000 nominally, with 15,000 actively serving, and 3,000 who can be trusted to be drawn up at any time. The IRA benefited by the widespread civilian support throughout the counties primarily in civilian refusal to provide any information to the British.

As the war escalated two incidents took place that brought the conflict to levels beyond which the protagonists could tolerate: the 21 November 1920 killings that became infamously known as *Bloody Sunday* (the simultaneous assassination of fourteen officers, in eight Dublin locations). Bloody Sunday represented the microcosm of the whole conflict in respect to the role of intelligence, appalling violence, revenge, and propaganda. No set of incidents was so decisive in changing British attitudes of the Anglo-Irish War as corpses of assassinated British officers taken in succession through the streets of London to a massive funeral in Westminster Abbey (Hopkinson, 2002).

In the aftermath of Bloody Sunday, attacks on property of Sinn Fein sympathizers became a regular occurrence with thirty-three documented cases and the destruction of 191 houses (Hopkinson, 2002). IRA arrests abounded: 1,478 in January increased to 2,569 in March a final total of 4,454 in July. On 25 May 1921 the *Burning of the Custom House* in Dublin resulted in additional political

damage for the Parliament and continued guerilla attacks against British forces. The British military saw the worst casualties during the summer of 1921 with forty-eight killed (Hopkinson, 2002). Internally, confusion existed in the form of military authority over police authority and the relationship of Martial Law to Civil Law. By July 1921 Parliament called for an end to the Anglo-Irish stalemate via a truce.

4.1 Modeling the Anglo-Irish War

The synopsis of the Anglo-Irish War depicts the continued effort by the Irish insurgents to affect their will on the British government and the various actions taken by the British to counter that effort. The British employed military responses to get control of the insurgency and to destroy it continuing their interference with Irish life n an effort to end insurgency. This portion can now be added to the causal loop diagram of Figure 3.2 to represent the insurgent suppression loop. This update is shown in Figure 4.1.

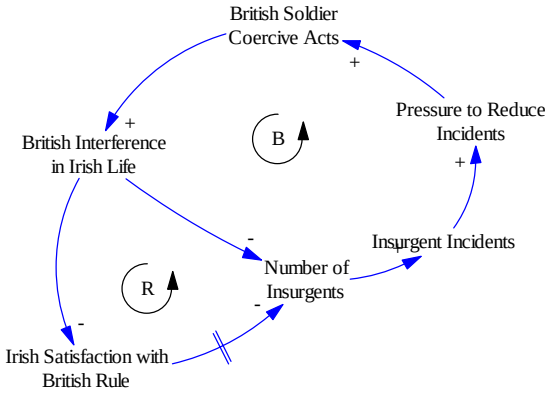

Figure 4.1 Addition of insurgent suppression loop

As a response to the continued pressure by the Irish insurgents to affect their will on Ireland, the British government felt pressure to regain control of the situation. This pressure came both from the *internal* violent acts that insurgents perpetuated and from *external* world opinion of the situation. As a result, Britain committed an increasing number of soldiers and other law enforcement personnel in an attempt to quell the violence and regain control of the situation. Figure 4.2 shows the addition of a British perception loop and its affect on British troop levels in Ireland.

Thus far the model has accounted for the major cause and effect relationships influencing the Irish insurgency for the period 1916 through 1921. With these relationships in place a stock and flow diagram can be constructed and a simulation developed to replicate this situation. With this an investigation of *what-if* scenarios can be conducted to see what may have produced more favorable results.

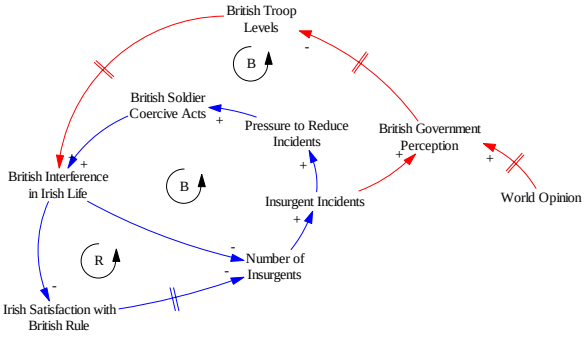

Figure 4.2 Addition of British perception loop

To begin the stock and flow diagram one must decide what variables to track from a quantitative standpoint. For the purpose of this example the *Number of Insurgents* and *Irish Satisfaction with British Rule* will be principal variables of interest. The *Number of Insurgents* is affected by an insurgent creation rate, an insurgent loss rate, and an insurgent retirement rate. *Irish Satisfaction with British Rule* is governed by the change in their satisfaction level. This initial stock and flow diagram is shown in Figure 4.3.

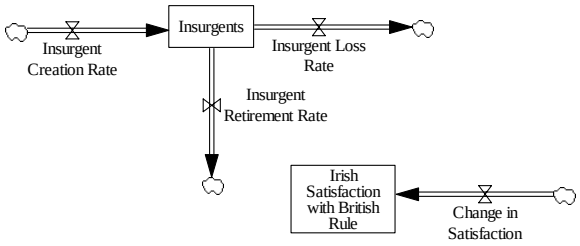

Figure 4.3 Initial stock and flow diagram

From the causal loop diagram of Figure 4.3 one can see that the rate at which insurgents are created is dependent upon Irish satisfaction level. However, it is also dependent upon the tendency of a small portion of the general Irish population to be drawn to an insurgency because of its inherent disposition. This would account for a core group of people who would be part of an insurgency no matter what the circumstances. The number in this group is dependent on the size of the population and the fraction of that population that would be predisposed to insurgency. This number would then be added to that portion of the population affected by British

rule thus providing the overall contribution to the insurgent creation rate. Figure 4.4 shows the addition of these factors to the initial stock and flow diagram.

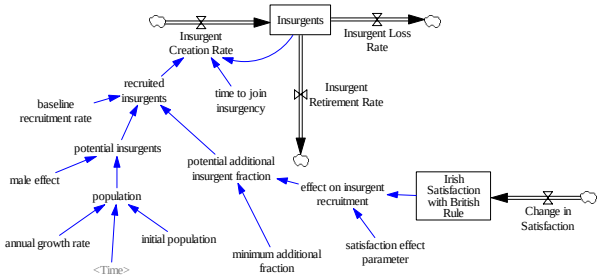

Figure 4.4 Stock and flow diagram showing affect on insurgent creation rate

The population is dynamic, that is it grows over time at some annual growth rate from an initial base population. Thus, the growth must be accounted for in a dynamic model of this type. In the Irish insurgency case, the active insurgents were mostly male, so the population figure must be adjusted to account for this demographic.

Figure 4.4 provides a graphical representation of the variables controlling the insurgent creation rate. Underlying each of these variables is a numeric value or equation that implements the computation necessary to simulate the insurgency. For example the equation to compute *population* would be:

$$population = initial\ population * (1 + annual\ growth\ rate)^{time}$$

The other variables are computed in a similar manner.

One can continue to build the entire stock and flow diagram in a manner as outlined above using the final causal loop diagram of Figure 4.2. The complete model is shown in Figure A.1 at the end of this article. A similar approach was taken by Anderson in his approach to capturing the dynamics of this insurgency (Anderson, 2006).

With a completed model, step 4 of the System Dynamics process requires validation so that its output is a proper reflection of the real-world system. (Several formal methods exist for validation, see Petty, 2009.) For this model, variables such as Irish population, insurgent levels, and British troop levels were compared to historical values. Model parameters where adjusted to achieve calibration against historical results. At this point the model is an accurate reflection of the Irish insurgency during the period of time under study. One can then run the simulation to obtain model output reflective of the insurgency behavior. Figures 4.5 and 4.6 provide graphs of simulation results of insurgent level and British troop level**.**

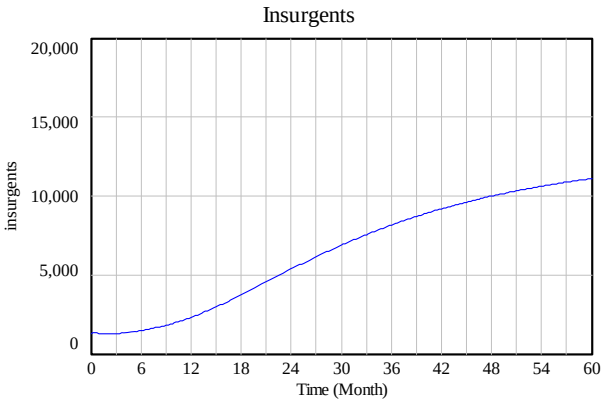

Figure 4.5 Irish insurgent level 1916 – 1921

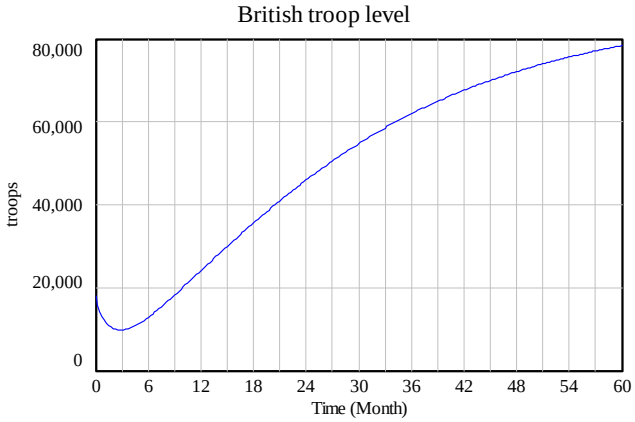

Figure 4.6 British Forces in Ireland 1916 – 1921

As noted above some model parameters were adjusted to calibrate performance. It is important to know how sensitive the model output is to make changes in these parameters. Model results may be relatively insensitive to some parameter changes indicating that precise values for them may not be significantly important. Small changes in other parameters may cause a dramatic change in output, thus having more exact values for them becomes significant to model accuracy.

One model parameter that was manipulated to match British troop levels with historic values was *troop factor*. For the results in Figures 4.5 and 4.6 this value was set at 0.15. If this value was allowed to uniformly vary between 0.10 and 0.20 what impact would that have on troop level? Figure 4.7 shows the output of this sensitivity analysis based on 200 runs of the model.

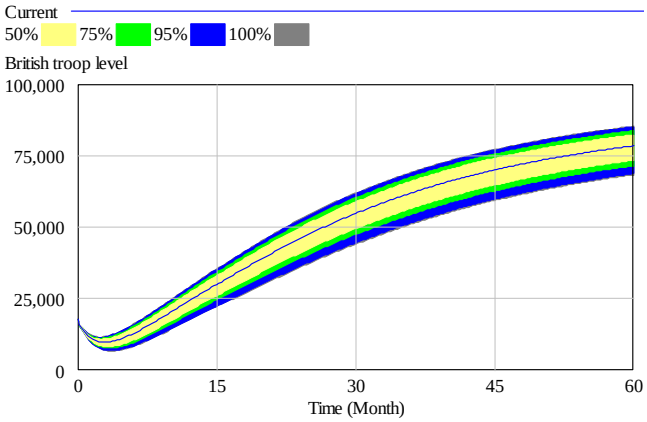

Figure 4.7 Sensitivity analysis for troop factor

The shaded areas of the graph represent confidence intervals for *British troop level* given the assumed random variation. This indicates that *British troop* level is relatively insensitive to small changes in this parameter.

4.2 What-if Analysis

Per steps 5 and 6 of the System Dynamics modeling process, simulation facilitates exploring different outcomes of a situation by changing particular model parameters. This capability is significant for social systems such as this one since these types of systems often times cannot be experimented on or readily manipulated as they can be in a simulation. Starting with a calibrated model that closely replicates historical results one can see how changes in policy would have possibly affected the outcome of the historical event.

The case study reflects brutal treatment by the British on Irish insurgents; this spilled over to the general Irish population. If the British would have adopted a less brutal approach what impact might that approach have had on the outcome? To investigate this scenario one can reduce the *max coercive acts* parameter, which governs the number of coercive acts committed by each British soldier on a monthly basis. The historical result was based on a value of 0.2 for this parameter. Suppose the British government implemented a policy that better controlled how the soldiers behaved and the number of acts was reduced to 0.1 acts per soldier. Figure 4.8 shows the affects of this policy. Figure 4.9 shows effects on Irish satisfaction with British rule.

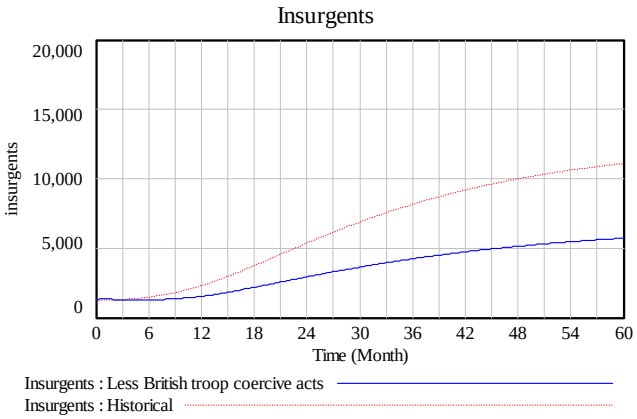

Figure 4.8 Effect of less coercive acts by British troops on insurgent level

Figure 4.9 Effect of less coercive acts by British troops on Irish satisfaction

From a cause and effect analysis, fewer coercive acts resulted in less dissatisfaction with British rule, which resulted in a lower insurgent creation rate. It is also helpful to look at the ratio of British troops to insurgents for both the historical case and the hypothesized fewer coercive acts case. Figure 4.10 shows the British troop levels for both cases.

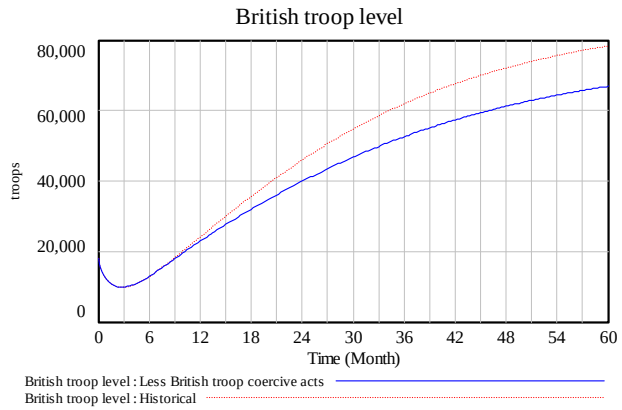

Figure 4.10 British troop levels for historical and what-if cases

At the end of the conflict this ratio was 7.05 troops to insurgents. With fewer coercive acts on the part of the British troops this ratio was computed to be 11.7. This change is due to the fact that fewer acts of troop harassment or brutality reduces distress in the Irish community, thus lowering support or need for the IRA. Therefore, there are fewer men who desire join the insurgency. With this higher troop to insurgent ratio one could postulate that a safer environment existed in Ireland thus making the Irish population more at ease and more benevolent towards the occupying British forces. As a benefit to Britain, fewer troops would be required to suppress insurgent activity lowering the cost of the counter-insurgency. This draws attention to the importance of troop behavior in these types of operations.

5. Conclusions

SD was used to explore the evolution and escalation of the insurgency events in Ireland via observing causal loop relationships to determine more precisely how the behavior / relationship of the British to the Irish incited discontent. The initial stock and flow data from the Easter Rising was included as part of a larger SD model of the Anglo-Irish War. The output of that model provided a computational explanation of insurgent activity incited by tit-for-tat nefarious acts on the part of all protagonists.

The analysis and *what if* discussion yielded commonsense conclusions; however, it also had the added benefit of being able to determine exactly how much of a draw down or decrease in British troops and/or modification in troop behavior is needed to change social behavior among Irish civilians as well as affect insurgency recruitment / sustainability. This is a very useful tool in social science research relative to human behavior modeling for it allows social science modelers to work toward *estimating the odds of being correct* rather than *getting predictions right*. It also addresses the difficulty of representing social science knowledge analytically and the challenge of expressing approximate knowledge in understandable terms independent of any computer programming language, mathematical formalism, or disciplinary background (Davis, 2009).

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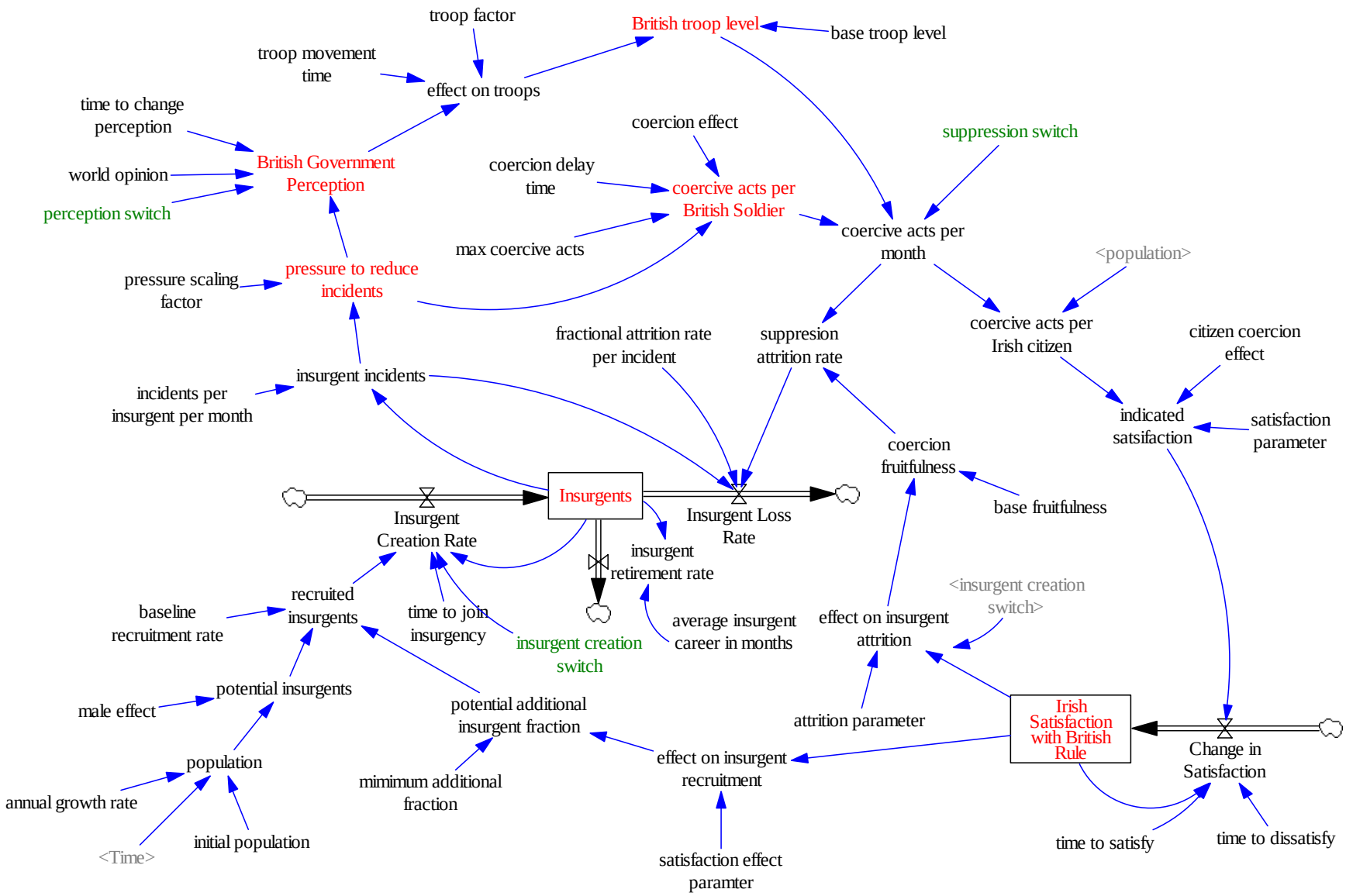

Figure A.1 Complete Irish insurgency stock and flow diagram