Input-Output Modeling for Effects Based Operations

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ABSTRACT

Technological advances in munitions, weapons delivery systems, and command and control operations have advanced a new methodology in military strategy called effects based operations (EBO). This methodology brings about new opportunities for the analytical community. In the past, analysts relied on large attrition models based on a static enemy with studies that took months to complete. The new reality emphasizes the ability to strike critical targets in a matter of days from initial notification, to measure the effects of target destruction, adapt and re-plan in a matter of hours. For target selection to move beyond the subjective skills of those in charge of the air tasking order (ATO), the analyst must be prepared with a model that represents the enemy as a system, solves quickly, has continuously updated data, and is adaptable to test many strategies quickly. When targets are determined, the effects of hitting these targets need to be anticipated so intelligence collecting platforms can be properly positioned. Finally, based on the intelligence collected, the model must be quickly adapted, solved, and run again to provide guidance for the next ATO. The Leontief Input-Output model holds the potential to perform this task.

The Input-Output model is designed to measure the interactions between the major industrial sectors of an economy. Data on a large number of countries is updated on a regular basis—countries belonging to the Organization for Economic Cooperation and Development (OECD) update their national accounts quarterly. Since the input-output model is a system of linear equations, the system is tractable. This paper provides a case study of the input-output model and examines applications used to explain systems beyond economics that are applicable to EBO. The results demonstrate how the analyst can be relevant using the EBO methodology and may be used as a blueprint for future research in this area.

INTRODUCTION

A recent buzz humming along the halls of the Pentagon refer to the Revolution in Military Affairs (RMA). As part of this “Revolution” other terms are being added to the defense lexicon such as rapid decisive operations (RDO), parallel warfare, and EBO.

In his paper *Effects Based Operations: Change in the Nature of Warfare*, BGen David A. Deptula establishes a scorecard of how the new terms fit together. In essence, parallel warfare is the application of force across multiple enemy systems simultaneously. If parallel force is applied to obtain desired effects in an overall strategy at all levels of war, then you are engaged in EBO. If the strategy guiding EBO was correct and the execution of parallel warfare was adequate to bring about a prompt and decisive conclusion to the conflict, RDO was achieved. In short, we should have a good strategy and execute it from the outset of the war. Haven't we always done that?

The answer is—No! BGen Deptula points to the limits of the Tactical Air Control System used by the Air Force entering the Gulf War to generate the ATO. The system was designed to service targets selected for and prioritized by multiple ground commanders each concerned with his own strategy instead of being based on a overarching strategy. Much of the success in the Gulf is attributed to working around this system using effects based targeting (Clancy, 1999). In response, BGen Deptula calls for organizational change from a ground-centric view of military operations to one of strategy-centric operations constrained by the following observations:

> The evolving security environment requires: greater responsiveness—the ability to act in hours rather than weeks or months; long range—the ability to span the globe without forward basing; effective punch—the ability to deliver weapons with precision to achieve desired effects; and high leverage—the ability to reduce personnel, support, and overall dollar costs (pg 19).

and

> Focusing on effects—the end of strategy, rather than the traditional military means to achieve them through force-on-force—enables us to consider different and perhaps more effective ways to accomplish the same goal with fewer resources (pg 26)

Whether or not these ideas are revolutionary or just the fulfillment of the strategies suggested by early airpower theorists will not be debated here. Instead, the focus of this paper is the opportunity for Operations Analyst to again be relevant in developing the straties and application of military force in the near future. In order to excel in this arena, the analyst must be equipped with tools that are simple, fast, and powerful in their explanatory value. The Input-Output model is the tool recommended here.

The following paragraphs introduce the Input-Output model in its original form and provide examples of how the economic model may be used by the military. A non-economic application demonstrates the dependent nature of targets. This overview and the examples are meant to be an introduction to the salient points of the Input-Output model to highlight where further research is needed for military applications.

THE INPUT-OUTPUT MODEL

Wassily Leontief earned the 1973 Nobel Prize in Economics for the development and applications associated with the input-output model. Based on his work, a System of National Accounts (SNA) was developed and updated in 1993 by the United Nations Intersecretariat Working Group on National Accounts. The group consisted of officials from the OECD, the International Monetary Fund, the United Nations Statistical Division, the World Bank and the Commission of the European Communities (Technical

Note on OECD, 2001). All OECD countries release their accounts according to SNA93 standards. Such effort for standardizing the accounting practices of so many countries attests to the analytical value of the input-output model.

In order to introduce the input-output model in a meaningful way, Table 1 contains the data of the interindustry transactions in the California Delta for 1994 (Goldman, 11).

Producing Industry	Local Industry Purchases										Row Total	Total Exports*	Final Demand*	Industry Output
	Agric	Mining	Construc	Manufac	TCPU*	Trade*	FIRE*	Services	Govern't	Other				
Agriculture	77	0	4	80	1	4	5	1	0	0	172	686	54	911
Mining	0	2	3	26	21	1	0	1	2	0	55	128	6	189
Construction	4	18	1	37	131	41	82	41	74	0	430	0	1,528	1,958
Manufacturing	21	3	130	442	52	64	13	78	9	0	812	2,957	758	4,527
TCPU*	11	6	30	155	371	95	38	65	38	0	808	929	729	2,466
Trade*	17	3	130	213	88	90	15	60	8	0	613	218	2,211	3,043
FIRE*	19	11	20	44	84	133	340	117	7	0	775	385	1,513	2,673
Services	7	3	72	127	121	246	125	259	14	0	974	9	1,888	2,871
Government	2	1	4	22	38	18	24	20	5	0	133	301	2,187	2,621
Other	0	0	0	0	0	0	0	0	0	0	1	4	0	5
Column Total	158	46	394	1,147	908	692	643	632	156	0	4,773	5,616	10,875	21,264
Total Imports*	161	26	382	1,462	426	315	243	327	63	0	3,386			
Value Added*	584	117	1,166	1,884	1,099	1,989	1,763	1,865	2,409	5	12,880			
Misc.	8	1	16	45	33	47	24	47	3	0	225			
Total Industry Outlay	911	189	1,958	4,527	2,466	3,043	2,673	2,871	2,621	5	21,264			

*TCPU = Transport, communications, and public utilities
Trade = Retail and wholesale trade
FIRE = Financial, insurance, and real estate
Exports = Sales outside of the Delta region
Final Demand = Household consumption, federal, state and local government purchases, inventory purchases, and capital formation
Imports = Purchases outside of the Delta region
Value Added = Employment compensation (wages and salaries), proprietors' and other property-type income (dividends and interest), and indirect business taxes.

Table 1: Interindustry Transactions (millions of dollars)

The core of the input-output transactions table is that each industrial sector produces output used either as input to other industrial sectors or to support final demand (in this case Exports and Final Demand). The distribution of these outputs can be read across the rows of the table. In the example, the Manufacturing sector (4th row) sells $21M its of output to the Agricultural sector, $3M to Mining, $130M to Construction, $442M within it's own sector… The columns of the table show the inputs required. Again, the example shows the Manufacturing sector (4th column) purchases $80M from the Agricultural sector, $26M from Mining, $37M from Construction, $442M from it's own sector… When a table is complete and all transactions within the economy are accounted for, the inputs (column totals) are equal to the outputs (row totals). In addition, the exogenous variable of final demand (Exports and Final Demand) is equal to inputs (Imports, Value Added and Misc.). These totals suggest all income from a sector is spent in materials, manpower, profits and taxes.

Assumptions That Power the Model

There are three assumptions that give the input-output model analytical power: fixed coefficients of production, constant returns to scale, and homogeneity of input resources. The following paragraphs develop each assumption individually and are used to develop a working model of the California Delta.

Fixed coefficients of production assumes there is some minimum level of input required (which could be zero) in order to get one unit of output. In our example, $80M of Agriculture was used to produce $4527M of Manufacturing or 0.018 units of agriculture are required in each unit of Manufacturing. Imbedded in this assumption are assumptions of an efficient market and the concept of no free goods in the system that generated the data. The same manufacturing output could have been produced using $200M of agriculture. But because agricultural products have value and the manufacturing sector wishes to make a profit, excess money will not be wasted and the manufacturing sector will use agricultural materials as efficiently as possible to produce it's output. The input or technical coefficients are obtained by dividing each entry in a sector's column by the total output associated with that sector (See Table 2 below).

Constant returns to scale implies that if you double the amount of input resources required, the output will double as a result. While some may view this as a severely limiting factor, Robert Dorfman defends the practice:

> …the production-possibility frontier for society is still the broken-line convex polygon we have come across before. It is only when we insist on infinitesimal substitution, on continuously varying marginal rates of transformation, on sensitivity of factor proportions to all price variations no matter how slight, that we have to give up the polygonal frontier for the neoclassical smooth curve. (pg 349)

For the constant returns to scale assumption to be valid, capital expenditures must be included in the transaction table and recognition that large increases in output for capital intensive industries may take a great deal of time to occur.

The third assumption is one of homogeneous inputs. In our example, the inputs from the manufacturing sector used in agricultural output are the same as used in construction. The level of aggregation of the table affects the level of homogeneity of inputs. If you are truly interested in farm equipment manufacturing and data is sufficient to separate farm manufacturers from all others, the table may be de-aggregated by adding another row and column with farm manufacturing as the sector title.

Making the Model

The model developed here is the open static model. Leontief (1986) describes the closed and dynamic models in a comprehensive review of his work. The following table is called the input or technical coefficient table from our example in Table 1. These coefficients are endogenous variables since the structure of an economy is rigid in the short term. The contents of this table is the **a** matrix in input-output notation and is an *m* *x m* square matrix consisting of the number of sectors in the model and each element is constructed by

$$a_{ij} = \frac{x_{ij}}{X_j},$$

where x_{ij} is the value from the transaction table and X_j is the total output for a row in the transaction table.

	Agric	Mine	Const	Manuf	TCPU	Trade	FIRE	Serv	Govt
Agric	0.084	0.000	0.002	0.018	0.000	0.001	0.002	0.000	0.000
Mine	0.000	0.011	0.002	0.006	0.009	0.000	0.000	0.000	0.001
Const	0.004	0.095	0.001	0.008	0.053	0.013	0.031	0.014	0.028
Manuf	0.023	0.016	0.066	0.098	0.021	0.021	0.005	0.027	0.003
TCPU	0.012	0.032	0.015	0.034	0.150	0.031	0.014	0.023	0.014
Trade	0.019	0.016	0.066	0.047	0.036	0.030	0.006	0.017	0.003
FIRE	0.021	0.058	0.010	0.010	0.034	0.044	0.127	0.041	0.003
Serv	0.008	0.016	0.037	0.028	0.049	0.081	0.047	0.090	0.005
Govt	0.002	0.005	0.002	0.005	0.015	0.006	0.009	0.007	0.002

Table 2. Input or Technical Coefficient Table

The following formula describes the input-output table of our example in matrix notation:

$$\mathbf{X = aX+C}$$

Equation 1

$$\mathbf{P=rX}$$

Equation 2

where **X** is a column vector of length *m* representing total output for each sector, **C** is a column vector of length *m* representing final demand, **r** is an *n x m* matrix of input or technical coefficients, and **P** is a column vector of length *n* representing total resource inputs required for the economy.

Equation 1can be solved for **X** as follows,

$$\mathbf{(I-a)X = C}$$

$$\mathbf{X = AC}$$

Equation 3

where $\mathbf{A} = (\mathbf{I-a})^{-1}$ (this is also be called the B matrix in some texts) and **I** is an *m*x*m* identity matrix**.** The results from **Equation 3** can then be substituted into **Equation 2** resulting in a system where total outputs (**X**) are the dependent variable that can be estimated from changes in final demand (**C**) as the independent variable**.**

Before beginning some examples of input-output applications, a brief summary of the necessary conditions for the inverse of (**I**-**a**) to exist is helpful. The conditions are called the Hawkins-Simon criteria; which state that the determinant of **a** along with all of its principle submatrices must be greater than zero and ($1\text{-}a_{ii}$) must be greater than zero for all *i*. In economic terms these criteria mean that each sector must make a positive delivery (both direct and indirect) to the overall output of the economy. If the amount of manufacturing output used as input to agricultural output used as input to manufacturing plus the manufacturing output used as input to construction output used as input to manufacturing plus the manufacturing output purchased directly…exceed the overall production of manufacturing units, the Hawkins-Simon criteria will be violated and an inverse for (**I**-**a**) will not exist. This accounting process of direct and indirect inputs into the system is what gives the input-output model its analytical power.

EXAMPLE 1: MILITARY OPERATIONS OTHER THAN WAR (MOOTW)

This first example works from final demands to discover what overall output from each sector must be in order meet a new demand schedule. This scenario may influence planning the overall strategy in a MOOTW. The scenario assumes the United Nations has decided that peacekeeping operations will begin in the Delta and that member countries are being encouraged to buy exportable products to support the economy. During the operations, members of the peacekeeping force will spend $20M in the open economy primarily in the Trade sector with $5M of that total going toward the Services sector. In addition, member nations have increased demand for manufacturing exports by $500M. What is the impact on the economy?

The answer can be found using Equation 2 (with suggested substitution) and Equation 3 with the following changes to the final demand vector:

$$\mathbf{A} := \begin{pmatrix} 1.093 & 0.001 & 0.004 & 0.022 & 0.002 & 0.002 & 0.003 & 0.001 & 0.0 \\ 0.0 & 1.011 & 0.002 & 0.007 & 0.011 & 0.001 & 0.0 & 0.001 & 0.001 \\ 0.008 & 0.102 & 1.005 & 0.015 & 0.068 & 0.02 & 0.038 & 0.02 & 0.03 \\ 0.03 & 0.028 & 0.078 & 1.114 & 0.037 & 0.03 & 0.012 & 0.037 & 0.007 \\ 0.019 & 0.044 & 0.026 & 0.05 & 1.185 & 0.044 & 0.023 & 0.033 & 0.019 \\ 0.024 & 0.027 & 0.075 & 0.058 & 0.052 & 1.037 & 0.012 & 0.025 & 0.006 \\ 0.029 & 0.073 & 0.02 & 0.02 & 0.054 & 0.059 & 1.151 & 0.055 & 0.005 \\ 0.015 & 0.031 & 0.052 & 0.044 & 0.076 & 0.099 & 0.063 & 1.108 & 0.009 \\ 0.003 & 0.007 & 0.004 & 0.007 & 0.02 & 0.008 & 0.011 & 0.009 & 1.002 \end{pmatrix} \qquad \mathbf{C} := \begin{pmatrix} 740 \\ 134 \\ 1528 \\ 4215 \\ 1658 \\ 2544 \\ 1898 \\ 2012 \\ 2487 \end{pmatrix}$$

Multiplying these together results in:

	Original X Value	New Output	Increase
Agric	912	924	12
Mine	190	193	3
Cont	1957	1965	8
Manuf	4527	5086	599
TCPU	2467	2496	32
Trade	3043	3086	43
FIRE	2673	2681	8
Serv	2871	2898	27
Govt	2622	2622	0
Total	21262	21951	732

How this affects the imports and value added in the economy can be calculated with the formula **rAC** where the **r** matrix is:

$$r := \begin{bmatrix} 0.64 & 0.616 & 0.596 & 0.416 & 0.445 & 0.654 & 0.66 & 0.65 & 0.919 \\ 0.009 & 0.005 & 0.008 & 0.01 & 0.013 & 0.015 & 0.009 & 0.016 & 0.001 \\ 0.177 & 0.137 & 0.195 & 0.321 & 0.173 & 0.104 & 0.091 & 0.114 & 0.02 \end{bmatrix}$$

The results are:

	Original Total	New Output	Increase
Value	12876	13189	313
Misc	224	228	4
Imports	3387	3585	198
Total	16487	17002	515

That can’t be right—how do you increase the overall economy by $732M with a stimulus package of only $520M? The answer is that the stimulus was in final demand products. Each additional unit of final demand output from one sector requires additional inputs from all other sectors in its column. Since each column sector is increasing output, they also need additional inputs according to their column inputs. In the process of all of these rounds of requests, the value added (or salaries) has increased. This will represent new demand on the economy. Economists have formalized these rounds of request in terms of multipliers. Before defining multipliers for this example, it is important remember that this input-output table models the highly integrated economy of parts of California and the stimulus package was significant (2.45% of gross output). Also, the timeline of when this equilibrium would be reached is uncertain and results this dramatic cannot be expected from fragmented third world economies.

To get an idea of multipliers and what they mean, we will develop the Type 1 multipliers for our model. We start with just summing the columns of the **A** matrix. This is called the column multiplier and gives an idea of how integrated that sector is in the total economy. Then, the Value Added coefficient for each sector is pulled directly from the **r** matrix. This represents the direct income as a result of an increase in output. Finally, the indirect income change is computed by multiplying each column element in the **A** matrix by it's associated value added row element in the **r** matrix and summing the products. The Type I multiplier for each sector is the sum of the three multipliers just discussed and is provided below.

	Agric	Mine	Cont	Manuf	TCPU	Trade	FIRE	Serv	Govt
Col Mult	1.221	1.325	1.267	1.337	1.504	1.301	1.313	1.289	1.080
Direct VA	0.640	0.616	0.596	0.416	0.445	0.654	0.660	0.650	0.919
Indirect VA	0.773	0.808	0.747	0.599	0.729	0.835	0.858	0.824	0.964
Type 1 Mult	2.635	2.749	2.609	2.353	2.679	2.789	2.831	2.763	2.962

The Type I multiplier provides a lower bound estimate of direct and indirect income change as a result of unit increases in demand for any one sector. To complete the example, the increase in total output would be

$$\$500M * 2.353 + \$15M*2.789 + \$5M*2.763 = \$1.232B.$$

A Type II multiplier is also used in many areas and involves closing the model to capture additional rounds of consumer spending to provide an upper bound on economic impact. Richardson (1972) explains these and other multipliers used in economic analysis and Binger (1995) contains a lengthy discussion of input-output multipliers along with data from the San Francisco Bay area.

The main point the reader should take away from the discussion thus far is that by increasing demand for one sector, we increase the demand for all related sectors. If the infrastructure of any of these sectors is not sufficient to meet the new demand, the overall outcome will be disappointing. Commanders of MOOTW operations should be aware of the economic impact of their mission to employ the EBO methodology. If, as part of peacekeeping operations, the objectives are to stand-up and stabilize a new or existing government, the military must be prepared to deploy the equipment and expertise necessary to correct infrastructure and administrative bottlenecks in the economic system. Failure to recognize, measure, and adapt to this larger strategy will result in armed troops with military force as the only option in containing a poor, unemployed, and hopeless citizenry.

EXAMPLE 2: STRATEGIES

This example uses the input-output model in developing an overall strategy to defeat an enemy. The model is the same one used in the previous example but now the total output of a sector becomes a military target. In this case we only have economic data and will simply show the functionality of the model to anticipate the effects of targeting certain sectors. In an ideal world, the relationship of the enemy military with its economy would also be part of the model used to develop a truly military strategy. It is important to note that once a sector is picked as part of the overall strategy, normal targeting procedures that exist today would be employed to specify the tactical targets and associated munitions delivery system. The model simply provides a means to estimate the effects of striking such targets, avoid unintended consequences, schedule intelligence assets to assess the degree intended effects have been achieved, and perform the analysis for the next round of tactical sorties. The solution to successive static tables is the basis of the dynamic input-output system. Snodgrass (2000) explains the dynamic system and its possible uses from a military standpoint. The remainder of this example uses only the static model.

The set of linear equations being solved for this example is

$$\text{Max } \mathbf{X}$$
$$\text{Subject To}$$
$$\mathbf{X} = \mathbf{aX} + \mathbf{C}'$$
$$\sum_{i=1}^{m} a_{ij} = \sum_{j=1}^{m} a_{ij} \text{ for all } i, j \text{ (all row totals equal column totals),}$$

where **C**′ is the minimum deviation from the original vector of demand. In other words the strategy of the attacked is to maintain the current standard of living to the largest degree possible.

The total output of each sector was "attacked" one at a time in ten percent increments. Total output was then measured to produce the graph in Figure 1. The figure represents nine different strategies of attacking only one sector at a time with the desired effect being to reduce total output and paralyze the economy.

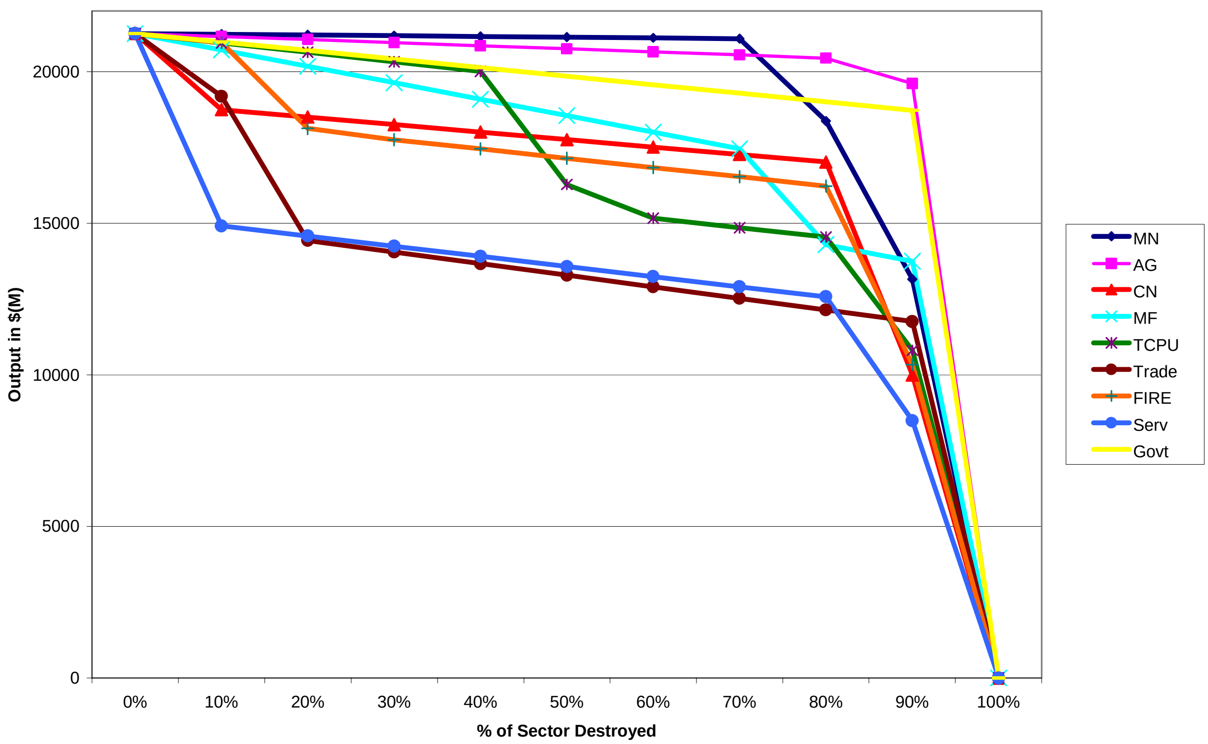

Figure 1. Sector by Sector Attack and Total Output

This example demonstrates that the services sector has the most dramatic initial effect on the total output of the economy. Although the services sector was the one attacked, the most dramatic effect took place in the Manufacturing sector whose total output fell from $4.52B to $1.18B with the first ten percent of services removed. If diminishing the Manufacturing sector was the intent of the attack, then intelligence resources would be directed at evaluating manufacturing output not an evaluation of the amount of destruction of the tactical targets themselves.

An important point referenced earlier is that these results are the equilibrium solution. This equilibrium may never be achieved especially in the case of intensive operations that continue to change the structure of the system on a daily basis. In this case, intelligence estimates must be incorporated into the model on a continuous basis in order to maintain a current picture of the system being attacked. Also, the military values commodities differently than an open economy. Gasoline may only cost $1.50 in the open economy, but fuel for tanks during combat is invaluable. Special attention needs to be paid to quantities of commodities required for military operations rather than costs for the model to be reliable. These areas require further research.

A NON-ECONOMIC APPROACH

In many cases military strategy must be designed to defeat non-economic structures. These structures are usually physically dependent on one another. An example may be the electric grid and telecommunications system. If the effect we wish to generate is to deny telecommunications without destroying it, the solution may be to take down a portion of the electrical grid. Yacov Y. Haimes (2001) uses the input-output model to evaluate such systems. In his approach, the transaction table consists of units of risk of inoperability rather than dollars as was illustrated above. In the guidelines to developing the **a** matrix, he suggests that if there are no physical connections between two infrastructures *i* and *j* then a_{ij} and a_{ji} is 0. If the failure of infrastructure *i* will definitely lead to the failure of infrastructure *j*, then a_{ji} is set equal to 1. Finally, stochastic relationships can be represented by the expected value.

All variables in the system contain values between 0 and 1, inclusive. A value of 0 represents normal performance while a value of 1 represents complete inoperability and the values between represent a linear degree of inoperability. An example that parallels one given by Dr Haimes follows (Haimes, 5-6).

EXAMPLE 3 Physical Systems
Consider a system consisting of four subsystems: a power grid, transportation system, hospital, and telecommunications system. Let the **a** matrix for this system be

	Power Grid	Trans	Hospital	Telecom
Power Grid	0	0.2	0	0
Trans	0.4	0	0	0.1
Hospital	0.6	0.8	0	0.2
Telecom	1	0.2	0	0

Interpretation of the first column is if the power grid fails, the transportation sector is 60% operable, the hospital is 40% operable and telecommunications are completely inoperable. Column two suggests that if the transportation system fails completely then the power grid and telecommunications system will be 80% operable and the hospital will be 20% operable (presumably because personnel and patients can't get to their desired locations). And so on with the rest of the columns.

Now we return to Equation 1 to implement the system where the column vector **C** is perturbations to the system. In this case we wish to employ weapons that can take down 80% of the power grid. The equation takes the form of

$$\mathbf{X} = \begin{bmatrix} 0 & .2 & 0 & 0 \\ .4 & 0 & 0 & .1 \\ .6 & .8 & 0 & .2 \\ 1 & .2 & 0 & 0 \end{bmatrix} \cdot \mathbf{X} + \begin{bmatrix} .8 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

Solving for all of the variables reveals the inoperability of the power grid is 0.89, the transportation system 0.46, the hospital is 1.0, and the telecommunications system is 0.98. In this case, attacking the power grid resulted in a higher level of damage than the initial attack, did not totally dismantle the telecommunications system, but did render the hospital inoperable—an unintended consequence that could be very damaging in the area of public opinion.

In the case above, the system cannot be solved if all of the variables are required to be less than or equal to one. The third constraint (hospital) actually totals 1.09 when the values for the other variables are inserted. In order to account for this, Dr. Haimes solves the equation

$$X_i = \min\{f(x_1, x_2, x_3, \ldots, x_n) + c_i, 1\},$$

called the *extended Leontief* equations. Essentially, this extension eliminates the third constraint once the hospital becomes totally inoperable and a value of one is placed in the third row of **C** matrix if any of the other variables are dependent on the hospital. In this example none of the other constraints were dependent on the hospital and changes in the system of equations were not necessary at the time the hospital becomes totally inoperable.

While this overviews only a small portion the work accomplished by Dr. Haimes in this area, it does provide a valuable tool to planners—the ability to anticipate unintended consequences of striking certain targets. Approval of critical "dual use" targets in a timely manner during Operation Allied Force (Kosovo) was an area of contention and will continue to be an area of concern in future conflicts (Hosmer, xxiv and Clark, 2001). Because the Air Force had little doctrine describing how to tie targets to intended effects and only subjective assessments of unintended consequences, the target approval list became the domain of lawyers from multiple countries (GAO, 3). A model such as this provides objective criteria for defending a target list and speeding the approval process from civilian authorities.

The value of such a model notwithstanding, there is a question of where the data would come from to populate the model. The theme of this article is that data must be readily available to construct the model and draw conclusions in a short amount of time to be useful in EBO. If the data to populate such a model exists or can be obtained quickly by intelligence assessments, further research is required to determine the validity of the results.

CONCLUSION

During this overview of the Input-Output model the concept of the multiplier was developed and explained. The Type 1 multiplier provides a lower bound estimation of the effects due to unit changes in demand. Correctly implementing MOOTW operations with these multipliers in mind will extend the EBO methodology to all areas of military employment. The static model was then used to demonstrate the effects of attacking a specific sector and the power of the model to account for both direct and indirect effects. The dramatic changes in a sector that was not directly attacked may provide opportunities for scheduling intelligence collection to ensure effects based strategies are working. Finally, a non-economic application was demonstrated. While the data for this type of model may not be easily accessible, the model is valuable for determining unintended consequences.

The input-output model is a proven analytical tool for economists but areas of research for military applications are needed. Current data exists in terms of costs to the economy while physical quantities are more important in military operations especially at the tactical level. The conversion from costs to quantities must be explored to increase its military usefulness. The model is solved from one equilibrium point to the next although it is unclear if time will allow any equilibrium to be achieved. Studies in how to collect data and adapt the model in dynamic circumstances such as combat need to be examined. Some theorists have proposed dynamic models that have potential military applications with minor modifications (Haimes, 2001 and Grubbstrom, 1998). It is imperative that the analytical community demonstrates practical applications to gain the confidence of decision-makers.

Our leadership is engaged in a new methodology of employing military power. It involves developing a master strategy and then deploying only the forces necessary to execute that strategy. In the process they are asking questions that the Operations Analyst—prepared with appropriate models supplied with current and reliable data—can help answer under the short time constraints of current warfare. The Input-Output model is such a tool. Data to supply the economic model is collected by nearly every nation and updated regularly. The model itself is relatively simple to explain to decision-makers. It provides confidence the analysis is not coming out of an unintelligible “black box”. Even with a very large model of several hundred sectors, analysis can be performed rapidly with commercially available software—in terms of hours where many of our current models produce useful results in months.

In short, to participate in the "Revolution" Operations Analysts must adopt and perfect tools that provide solutions in time for decision-makers to use the information.

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