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Theory and Feasibility of Implementing Economic Input/Output Analysis of the Department of Defense to Support Acquisition Decision Analysis and Cost Estimation

28 November 2011

by

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Abstract

In this project, Economic Input/Output analysis was used as the inspiration for a new approach to accounting for the supply-chain burden in estimating the fully burdened cost of fuel in the U.S. Department of Defense. A general model for the fully burdened cost of fuel was developed to demonstrate the multiplier effect by which the total amount of fuel required to supply a single gallon to the warfighter is greater than one gallon, due to fuel consumption in the supply chain. Using data on costs for the Defense Logistics Agency–Energy's bulk fuels supply chain, a spreadsheet model was constructed and used to estimate the delivery costs for fuel to all consumption points in that supply chain. They ranged from less than a penny to over 70¢/gal. Using information provided on the U.S. Marine Corps' supply chain in Afghanistan, a model for fuel consumption at each location and in both transportation and force protection was constructed to estimate the fuel multipliers for each location. Several excursions from the baseline scenario illustrated the effect of potential changes in the supply chain. This work demonstrated the applicability of an Input/Output-based approach to estimating the supply-chain burden of fuel and other supplies in the Department of Defense, and highlighted data challenges in populating such a model.

Keywords: Economic Input/Output analysis, supply chain burden, cost of fuel

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I.   Introduction

The Defense Logistics Agency Energy (DLAE) provided 132,000 barrels of petroleum products to the Services in 2010, for a total cost of about $13 billion (DLAE, 2010). Reducing this fuel demand would save the cost of fuel, reduce the size and cost of the logistics tail, including force protection, and increase the capability of the fighting force.

The Army Environmental Policy Institute (AEPI) estimates that there were over 3,000 resupply convoy casualties, mostly attributable to fuel and water supply, during the five-year period from 2003–2007 in Iraq and Afghanistan (AEPI, 2009). Every gallon of fuel consumed not only incurs dollar costs but also puts convoy personnel at risk.

To more accurately incorporate the system-wide effects of fuel consumption, both federal statue (Duncan Hunter National Defense Authorization Act of Fiscal Year 2009, 2008) and Department of Defense (DoD) policy (Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics [OUSD(AT&L)], 2007) now call for the use of fully burdened cost of fuel (FBCF) in acquisition decisions. The FBCF may be defined as "the cost of the fuel itself (typically the [DLAE] standard price) plus the apportioned cost of all of the fuel delivery logistics and related force protection required beyond the [DLAE] point of sale to ensure refueling of this system" (Defense Acquisition University, 2009).

One of the challenges in estimating the FBCF as applicable to acquisition decisions is capturing the multiplier effect. A reduction (increase) in the fuel requirement in one part of the organization has a cascading effect as it reduces (increases) demands on supporting organizations, multiplying the effect of a change in usage along the supply chain. In a multistage supply chain, a naïve approach to attributing logistics costs will neglect the multiplier effect and therefore underestimate the FBCF.

The burden of delivering fuel is different for different end-using locations and the appropriate allocation of costs for different transportation modes and different paths through the supply chain to a given end-using location is not obvious. These issues pose further challenges in estimating the FBCF.

Economic Input/Output (IO) analysis uses a set of coefficients that represent the amount of output of a given component required per unit of output of another component. These coefficients, together with the output quantities of each component, and the assumption of a mass balance (the outputs of each component must satisfy the input requirements of all others) are a fully determined system of equations. These may be used to explore the effect of changes in any single part of the system, for example, a reduction in the fuel requirement in one component.

First conceived, and most often applied, as a method to analyze national economies (Leontief, 1986; Dietzenbacher & Lahr, 2004) using industries and sub-industries as the units of analysis (components), IO is simple but powerful tool. The research literature is rich with applications to Life Cycle Assessment (LCA), which is the estimation of the environmental impacts of consumption of products and services, traced back through a complex supply chain (Hendrickson, Lave, & Matthews, 2006), and is the closest analog to this work.

In the present work, the boundary of the system is drawn more narrowly than in typical LCA analyses. We have considered only costs to the DoD and/or fuel consumed within the DoD. The consumption of fuel within the DoD does imply impacts, including fuel consumption, elsewhere (most immediately by contractors that provide either fuel or transportation services), which are not captured in the two DoD models developed in this research.

We formulated a simple supply chain model using an IO approach and address its potential applications in the DoD as well as the challenges and limitations of DoD applications. We supervised two thesis projects that used the

IO approach to model portions of the DoD fuel supply chain. Dubbs (2011) modeled a portion of the U.S. Marine Corps (USMC) supply chain in Afghanistan, estimating the total amount of fuel required at Camp Leatherneck per gallon consumed in warfighting at each component (location) in the chain. Dubbs also explored excursions from the baseline scenario, demonstrating the value of his model in estimating the effect of changes in the supply chain. Hills (2011) used data provided by the DLAE to build a model of the DLAE bulk fuels supply chain and estimate the 2011 delivery costs for each delivery point in the chain, which ranged from less than 1¢/gal to more than 70¢/gal.

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II.   Results

This report documents the work performed under this award, in particular the formulation of a general IO model for DoD fuel supply chains and the notional demonstration of its application, followed by a summary of the DLAE bulk fuels supply chain model and the USMC Afghanistan supply chain model.

During the course of this project, Eva Regnier visited DLAE on May 31, 2011, to meet with Linda Barnett, Chief, Inventory & Distribution Management at DLAE. On June 3, 2011, Eva Regnier visited Col Bob (Brutus) Charette, Director of the USMC Expeditionary Energy Office and his deputy, Gayle von Eckartsberg.

A.   Modeling a Supply Chain with Input/Output Analysis

An IO model consists of defined components (in national accounts, the components are industries) that represent the unit of analysis, plus a matrix of coefficients (sometimes called technical coefficients). For each pair of components (i, j), the coefficient a_{ij} is the amount of output of component i required as an input to component j, per unit of output from component j. These coefficients, together with an output quantity x_j from each component j, satisfy a set of linear equations that enforce mass balance for each component—its output must be exactly enough to satisfy the input requirements of the other components. Figure 1 shows a notional example of the coefficient matrix and output quantities, developed by LT John Hills and LCDR Sean Dubbs.

An IO model can be used to account for the multiplier effect, as illustrated in Figure 2. A naïve analysis would estimate the total fuel required in this system at 1,560 gal (the 1,000 required by the warfighting component, plus 15% for Stage 1, 30% for Stage 2, and 20% for Stage 3), which would

understate the total requirement by 234 gallons. This is described in more detail and related to cost in Regnier and Nussbaum (2011).

Regnier and Nussbaum (2011) also modeled a linear supply chain and a more complex supply chain using an IO approach and demonstrated the calculation of the multiplier—that is, the total requirement of fuel entering the supply chain from outside required per unit consumed by a consuming (warfighting) component. This portion of Regnier and Nussbaum (2011) is reproduced in Section B.
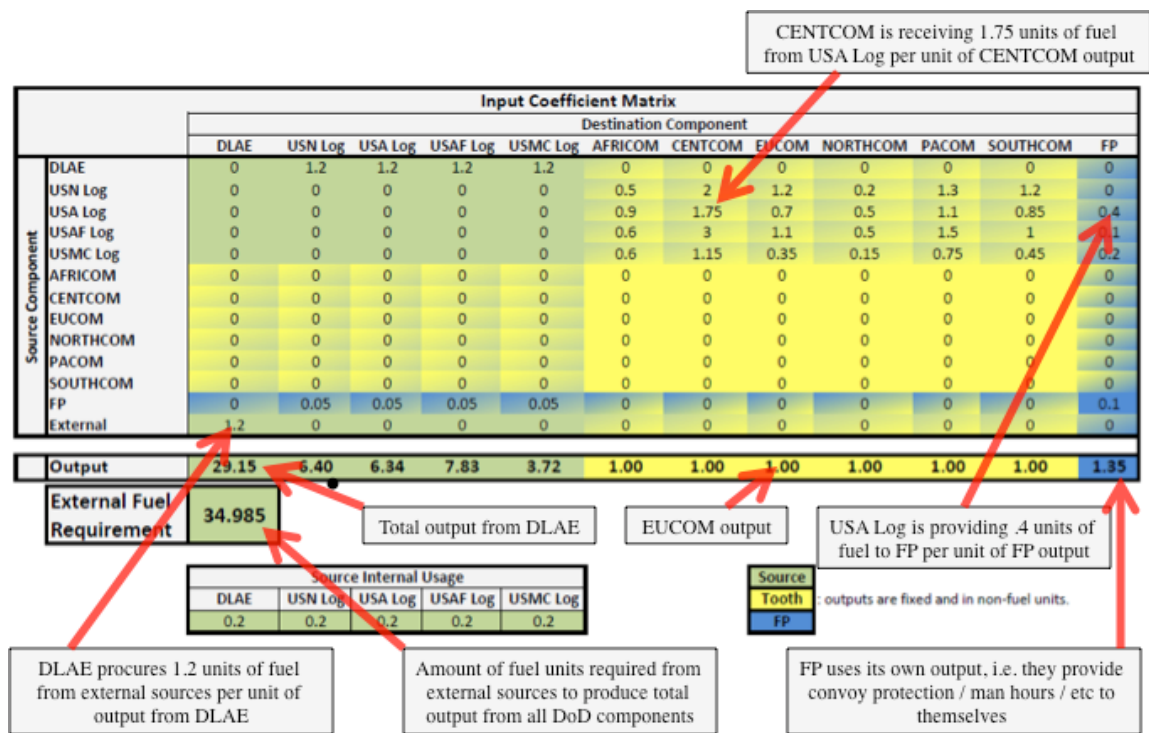

Figure 1.   Notional Input/Output Coefficient Table for the DoD

Note. This figure shows supply components (in green), consuming components (in yellow), and force protection (in blue). Output for each component, required to satisfy mass balance, is shown in the row below the coefficient matrix.
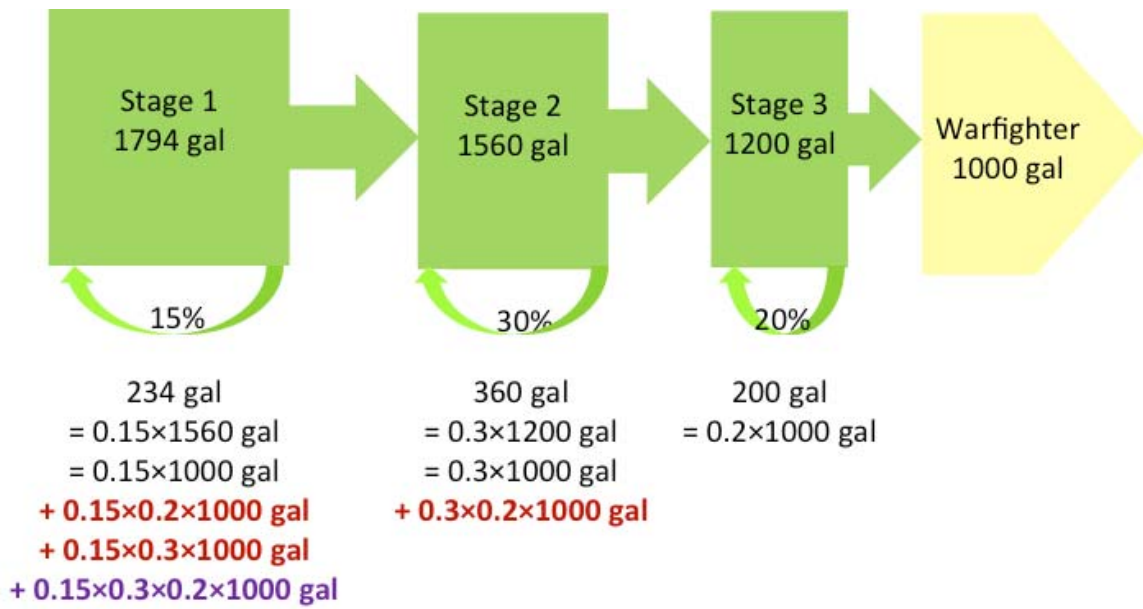
Figure 2. Illustration of the Multiplier Effect in a Linear Supply Chain
(Regnier & Nussbaum, 2011, p. 56)

B. Excerpt from Regnier & Nussbaum (2011)

Modeling a system using EIO requires first, defining the components, or unit of analysis, which determines the level of data that will be required to populate the model. Second, the model requires a populated matrix of the type shown in Table 1. An EIO model is a static snapshot, representing the flows of resources among components of the modeled system. For national accounts, the snapshot is usually an annual total. For the DoD, an annual average or total representation of the supply chain would likely be used, and results would reflect averages over the period. This section formalizes the model.

Linear Supply Chain

Components are indexed $i = 1,\ldots,n$, where n is the warfighter component, and $1,\ldots, n-1$ are links in the supply chain transporting fuel to component n. Think of component $i = 1$ as DESC (DLAE), and each component $i < n$ directly supplies only component $i+1$. Each supply

component has precisely one output: delivered fuel. The amount of fuel delivered by each component is denoted x_i.

Using the convention of EIO analysis, let a_{ij} = the number of units of output from component i required to produce each unit of output from component j. Often, both a_{ij} and x_i are normalized in terms of dollars. We will instead assume a_{ij} and x_i are in units of fuel, with all fuel treated identically. The exception is x_n, the output of the warfighter component, which might be steaming hours, patrols performed, or other output measure.

We will also introduce an external component, indexed X, which represents any supplier outside the organization. In our example, this captures purchases of fuel from the private sector. In classical EIO, the entire economy is modeled. In some cases, such as national accounting, imports are purchases external to the organization.

The total fuel requirement for the organization is $\sum_{j=1}^{n} x_j a_{Xj}$. The input-coefficient matrix is shown in Table 1.

Table 1.   General Input-Coefficient Matrix

			destination			
			component			
			1	2	3	n
source	component	1	a_{11}	a_{11}	…	a_{1n}
		2	a_{21}	a_{22}	…	a_{2n}
		…	…	…	…	…
		n	a_{n1}	a_{n2}	…	a_{nn}
		external	a_{X1}	a_{X2}	…	a_{Xn}

The values of a_{ij} and x_i satisfy the n equalities:

$$x_i = \sum_{j=1}^{n} a_{ij} x_j, \forall i = 1,...,n,$$

which means that each component i produces exactly enough of its output, x_i, to satisfy the input demands of all components for its output. The above can be rearranged as follows:

$$x_i = \frac{\sum_{\substack{j=1 \\ j \neq i}}^{n} a_{ij} x_j}{1 - a_{ii}} . \tag{1}$$

Since we are assuming a very simple supply chain in which component 1 supplies component 2 (and no one else), and so on, and the model accounts for exactly one input type (fuel), the input coefficient matrix has a special structure:

$$\forall i = 2,...,n-1 \; a_{i-1,i} = 1 + \alpha_i , \text{ and } a_{ij} = 0 , \; \forall j \neq i+1 ,^1$$

where the value α_i is the amount of fuel consumed by component i in delivering one unit of fuel. It is assumed that the fuel any component consumes is not its own delivered (output) fuel, but rather the fuel delivered by the component that supplies it.[2] The input-coefficient matrix is given in Table 2.

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[1] We will further assume that the units of output from component n are defined in such a way that $a_{n-1,n} = 1$, although this is for simplicity and is not otherwise required, since the output from component n is of a different type than components $i < n$.

[2] A fuel-supplying component's efficiency is therefore $\frac{1}{1+\alpha_i}$.

Table 2.   Coefficient Matrix for Linear Supply Chain.

			Destination				
			Component				
			1	2	…	$n-1$	n
Source	component	1	0	$1+\alpha_2$	…	0	0
		2	0	0	…	0	0
		…	…	…	…	…	…
		$n-2$	0	0	…	$1+\alpha_{n-1}$	0
		$n-1$	0	0	…	0	$a_{n-1,n}$
		n	0	0	…	0	0
		External	$a_{X1}=1+\alpha_1$	0	…	0	0

For components $i < n$, each component's output (gallons of fuel) is $x_i = a_{i,i+1}x_{i+1} = \left(1+\alpha_{i+1}\right)x_{i+1}$, and the total organizational fuel requirement is

$$x_X = \prod_{i=1}^{n-1}\left(1+\alpha_i\right)a_{n-1,n}x_n \, . \tag{2}$$

$x_X = x_1 a_{X1} = \prod_{i=1}^{n-1}\left(1+\alpha_i\right)a_{n-1,n}x_n$, as shown in the example below, with three

supply chain links (components 1–3) and one warfighter component (4). The warfighter component's output is exogenous, and arbitrarily it is set to 100. The total fuel required by the organization is 1.15 × 1.3 × 1.2 × 1000 = 1794.

Table 3.   Input Coefficient Matrix for Simple Supply Chain Example

input coefficient matrix				
destination		component		
source	1	2	3	4
1	0	1.3	0	0
2	0	0	1.2	0
3	0	0	0	1
4	0	0	0	0
external	1.15	0	0	0
output by component	1560	1200	1000	1000
total external requirement	**1794**			

For a given component, we will define its **fuel multiplier** (denoted β_i) as the factor by which the organization's total fuel requirement from the external source would increase (decrease) with a change in the component's fuel output (either as a result of decreased demand from the next stage in the supply chain, or as a result of an increased efficiency) or decrease in demand for its product. The EIO approach assumes that changes in input requirements are proportional to changes in output (constant returns to scale). Hence, $\beta_i = {x_X}/{x_i}$. We can rewrite Equation 2

as $x_X = \prod_{j=1}^{i}(1-\alpha_j)x_i$, for any $i = 1,...,n-1$ implying that $\beta_i = {x_X}/{x_i} = \prod_{j=1}^{i}(1-\alpha_j)$.

More Complex Supply Chain

Within the DoD it is more realistic for a supply chain to include complexities such as the following:

- Multiple warfighter components

- Force protection components, distinct from warfighting components, and produce an output (protection) that warfighting and logistics components may use

- Each component may receive fuel directly from more than one fuel-supply component

- Nonlinearities, e.g. one component may both supply and be supplied by another component

In this case, the general matrix in Table 1 is applicable, together with a vector of outputs, x_i for all i. The consistency constraints in Equation 1 still apply. An example is shown in Figure 1.

As before a_{ij} = the number of units of output from component i required to produce each unit of output from component j, and the units are the units of i's output over then units of j's output. This means that $a_{ij}x_j$ is the amount of output of component i consumed by component j, in the same units that component i's output is measured. The output of force-protection components is also not in units of fuel but rather in units of force protection.

Additional constraints are required to ensure that each component receives the required amount of input of a given type. In particular, if component j supplies fuel, then the total input it receives from all fuel-supplying components must equal $1 + \alpha_j$.

C. Bulk Fuels Distribution Model

In his thesis research, LT John Hills built a spreadsheet-based model of the DLAE bulk fuels supply chain, and used it to calculate the 2011 delivery cost for each of 473 DoD components within the DLAE bulk fuels supply chain that consume bulk fuels (i.e., JP-5, JP-8, and F-76; Hills, 2011). Many components, including the locations in the Dubbs USMC Afghanistan model (Dubbs, 2011), receive bulk fuels after further delivery by the Service, beyond the end of the DLAE supply chain, or by direct purchase. These components are therefore excluded from Hills' analysis.

The data provided by Linda Barnett (personal communication, April and May, 2011) and the DLAE bulk fuels division included the 2011 bulk distribution plan and the bids for acquisition and transportation of bulk fuels. Hills, together with research assistants Paul Roeder and Lee Whitaker, extracted from these data the prices for the awarded contracts and created a model that captures the cost of all stages required to get fuel from an external supplier to a DoD component that consumes fuel (Hills, 2011).

We do not have data about costs to contractors for providing transportation services, only about the prices they bid. The prices may differ from their true costs for many reasons. Their bids may exceed their true costs because they require a profit, and they may, in some cases, be lower than their true costs for a given origin and destination because there is synergy with another route they bid on. Given the data available regarding the contracts awarded, we estimate that delivery costs to DLAE range from less than 1¢/gal to over 70 ¢/gal, as shown in Figure 3.
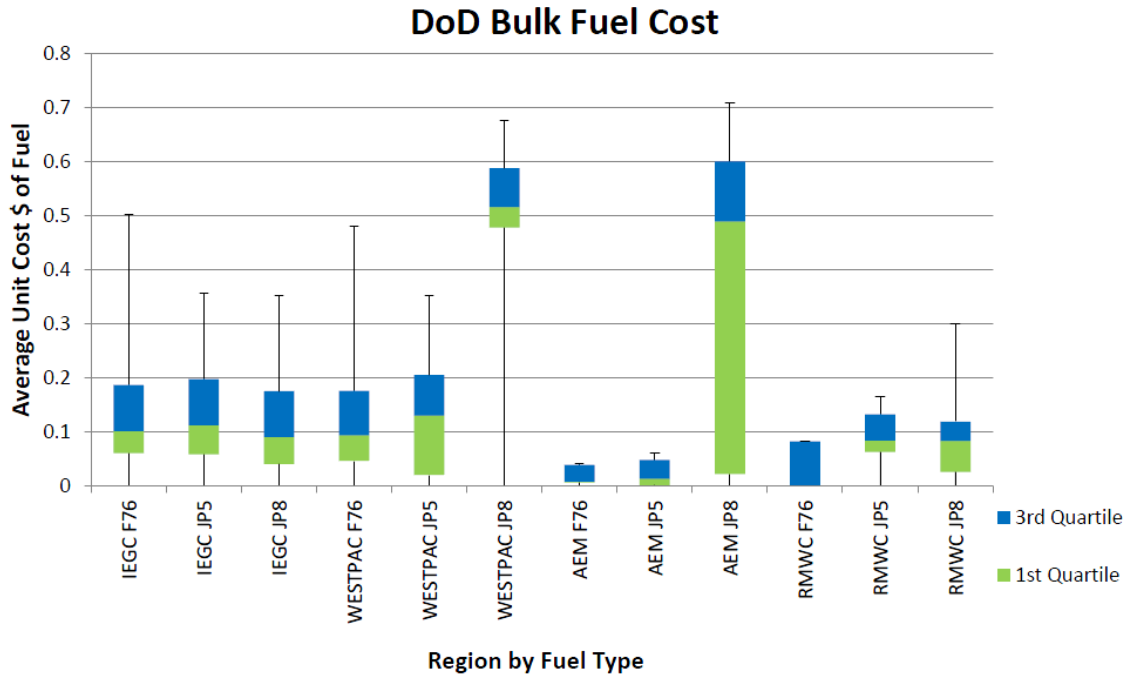
DoD Bulk Fuel Cost

Figure 3. Delivery Cost per Gallon by Region and Fuel Type

Note. Figure is from Hills (2011), p. 25. Regions are Inland East and Gulf Coast of the U.S. (IEGC), West Pacific (WESTPAC), Atlantic Coast of the U.S., Europe and Mediterranean (AEM), and Rocky Mountain and West Coast of the U.S. (RMWC).

The DLAE charges the Services a single standard price, regardless of where in the world the fuel is delivered. The Office of the Secretary of Defense's seven-step FBCF method calls for using the DLAE (formerly, the DESC) standard price as one of the inputs to the FBCF estimate. However, as Hills (2011) showed, the DLAE's costs differ substantially as a function of delivery point. This indicates that the standard price is sending distorted price signals to the Services. An inaccuracy of similar magnitude is created by DLAE's practice of setting their fixed price based on an 18-month average of fuel purchase prices. However, the effect of time smoothing gives an instantaneously incorrect signal to all components about the cost of fuel; the error will sometimes be positive and sometimes negative and will average approximately zero. The inaccuracy created by averaging geographical differences will systematically understate the cost for operations in Korea, for example, possibly distorting incentives for fuel consumption throughout the DoD.

Hills (2011) concluded that, if Service-specific data analogous to the data provided by the DLAE were available, an IO-type model could be used to consolidate the seven-step FBCF process to a single step.

D. Marines' Afghanistan Supply Chain Model

In his thesis research, LCDR Sean Dubbs built a model of a portion of the USMC supply chain, which includes Camp Leatherneck and all main operating bases (MOBs), forward operating bases (FOBs), and combat outposts (COPs) supplied through Camp Leatherneck, as shown in Figure 4.
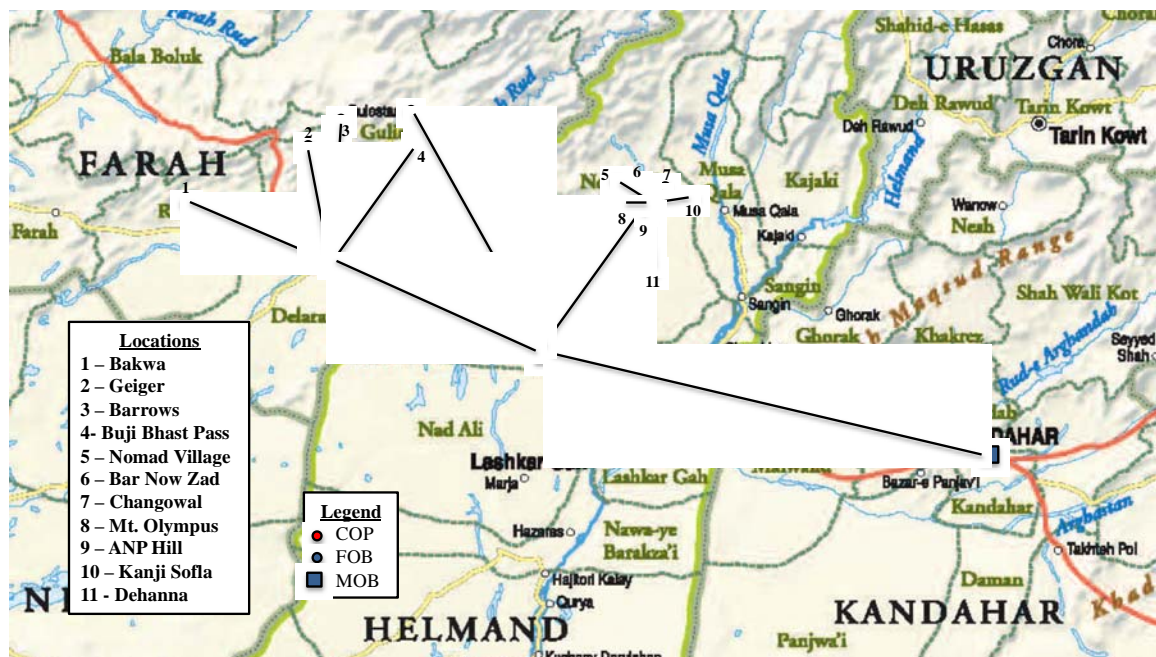

Figure 4.   Map of the USMC Supply Chain From Camp Leatherneck
(Dubbs, 2011, p. 20).

Perhaps the biggest challenge in this thesis work was finding data appropriate to estimating the IO coefficient matrix. Dubbs built his model based on interviews with a USMC logistics officer recently returned from the theater. He modeled the convoys used to transport fuel within the modeled region and estimated the fuel requirements for operating each delivery and force protection asset as a step to estimating the coefficients and weekly fuel demand from each component. The

coefficients and fuel demand became the IO model. This model produced estimates of the fuel multiplier for each component, as shown in Figure 5 for the baseline scenario (representing historical operations).
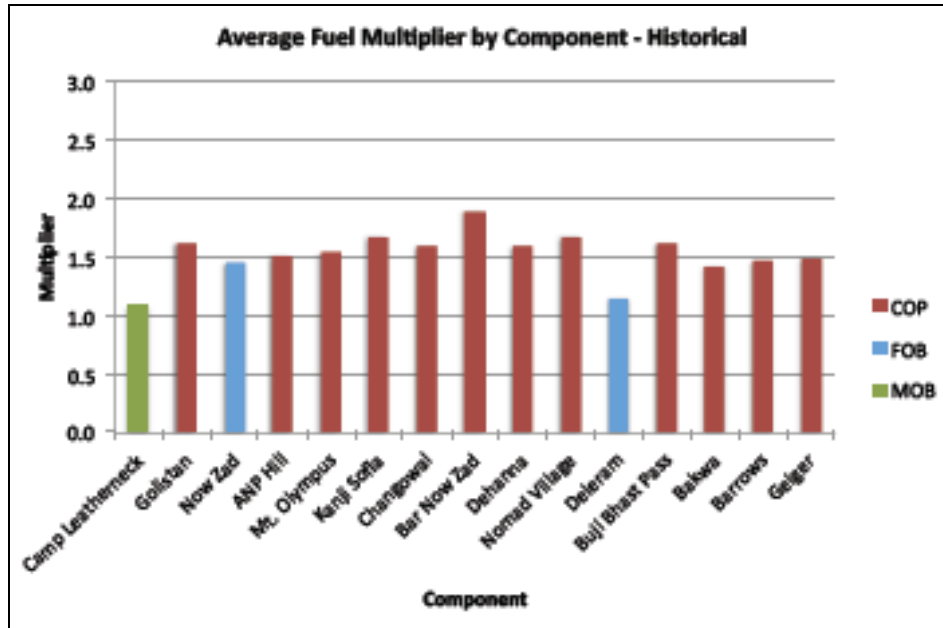

Figure 5.   Results from Dubbs's Model

Note. This figure from Dubbs (2011, p. 34) shows the fuel multiplier for each component in the supply chain, which is the amount of fuel that must be delivered to Camp Leatherneck per gallon consumed at the component.

Dubbs (2011) also demonstrated how an IO model can be used to explore the impact of changes in the supply chain and the sensitivity of its results to the assumptions underlying the transportation model used to calculate the coefficients. Dubbs explored six excursions from the baseline scenario, as detailed in Table 4.

Table 4.   Impact of Excursions From Baseline Scenario
(Dubbs, 2011, p. 46)

Change in Fuel Requirements from Historical Scenario			
Scenario	Overall	Transport	Force Protection
(1) Payload Increase	–4.74%	–27.03%	–6.98%
(2) Efficiency Increase	–5.99%	–36.78%	0.00%
(3) Transit Limit	6.84%	64.41%	–75.06%
(4) Reduced Consumption	–46.32%	–37.53%	–16.21%
(5) Reduced FP	–2.16%	–0.97%	–41.15%
(6) MATV Only	–0.82%	–0.97%	–13.72%

Dubbs (2011) demonstrated the applicability of the IO approach to modeling an in-theater organic supply chain and exploring realistic changes in the supply chain. In addition, he found that, within his model, the fuel demand incurred for convoy force protection was less than 5% of the total supply chain requirement. The common belief is that force protection requirements dominate other costs (Rosenthal, 2010).

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III. Conclusions

This work has demonstrated the applicability of the IO approach to estimating the FBCF in the DoD.

At the outset of this research, we anticipated that finding appropriate data to populate an IO model would be very difficult. With the invaluable cooperation of Linda Barnett and the DLAE bulk fuels division, we were able to build a functional model of the DLAE supply chain and populate the model for 2011 using DLAE data to estimate the delivery costs for bulk fuels.

We were able to build a realistic model of the in-theater USMC fuel supply chain in Afghanistan. Although force protection is believed to be a very important contributor to the FBCF, the results of Dubbs' model indicate that it is less important than expected and that reducing the force protection requirements would have a relatively minor effect on the total fuel required for the supply chain (Dubbs, 2011).

Dubbs (2011) identified an important potential role for an IO model in supply planning. He noted that supply officers may not be able to anticipate the system-wide effect of a change in demand at a warfighting component. Therefore, they may underestimate the fuel required to meet a surge in warfighter demand, potentially leading to short-term shortages in theater. An operational IO model could help.

The two models each capture a piece of the DoD supply chain. In particular, Hills has created and populated a complete model of the DLAE bulk fuels supply chain, but it captures only the dollar costs and does not capture the multiplier effect associated with the fact that fuel is consumed in transporting and handling fuel within the supply chain (Hills, 2011). Because the DLAE contracts out most of the transportation functions within the bulk fuels supply chain, fuel consumption is built into contractors' prices, but is not visible to them, nor available to our model.

On the other hand, Dubbs' model captures only fuel requirements, and does not capture other costs; for example, those costs associated with personnel for transportation and force protection, and non-fuel support of transport and force protection vehicles and aircraft.

Both the Dubbs and Hills models describe acyclic networks, so that for each consuming organization, the path traveled by its fuel is linear (with the exception that there are two same-directional arcs of different costs in at least one case in the Dubbs model, representing both ground and air transportation connecting two nodes). However, as described previously, the IO approach can be used to capture more complex supply chains.

Based on the success of this initial effort, we have identified several avenues for follow-on research. One is seeking appropriate Service-level databases that could be used to build Service-specific models that could be linked together and linked with the DLAE model to capture the delivery costs (in fuel and dollars) associated with the entire DoD supply chain. A more complete model would break out the major cost categories and could incorporate the multiplier effects associated with other types of supplies, such as drinking water (required by personnel involved in the supply chain) and batteries.

Our models are based on data, and, in that sense, are based on the past. It is possible to estimate the impact of changes by using predictions of the parameters of the model, as in Dubbs' excursions from the baseline scenario. It would be similarly possible to construct new networks to evaluate the multipliers and FBCF associated with them. Therefore, another promising avenue for future research is to model supply chains more generally, and estimate coefficients associated with different transportation and force protection options to allow for more general conclusions about the FBCF or fully burdened cost of other supplied items, as a function of the network. Scenarios could be developed to estimate the future FBCF in future supply chain configurations.

List of References

Army Environmental Policy Institute. (2009). Sustain the mission project: Casualty factors for fuel and water supply convoys. Retrieved from http://www.aepi.army.mil

Defense Acquisition University. (2009). Fully burdened cost of delivered fuel: Methodological guidance for analyses of alternatives and acquisition tradespace analysis. Retrieved from https://acc.dau.mil/fbcfmethod

Defense Logistics Agency Energy. (2010). *The Defense Logistics Agency energy fact book fiscal year 2010* [ebrary version]. Retrieved from http://www.desc.dla.mil/dcm/files/Fact%20Book%20FY10%20Final%20Web.pdf

Dietzenbacher, E., & Lahr, M. L. (Eds.). (2004). *Wassilly Leontief and input–output economics.* Cambridge, UK: Cambridge University Press.

Dubbs, S. R. (2011, September). *Estimating the fully burdened cost of fuel using an input–output model—A micro-level analysis* (Master's thesis, Naval Postgraduate School). Retrieved from http://edocs.nps.edu/npspubs/scholarly/theses/2011/September/11Sep_Dubbs.pdf

Duncan Hunter National Defense Authorization Act for Fiscal Year 2009, Pub. L. No. 110-417, 122 Stat. 4356 (2008).

Hendrickson, C. T., Lave, L. B., Matthews, H. S. (2006). *Environmental life cycle assessment of goods and services: An input–output approach.* Washington, DC: Resources for the Future Press.

Hills, J. (2011, December). *Modeling the DoD bulk fuels supply chain using input output analysis* (Unpublished master's thesis). Naval Postgraduate School, Monterey, CA.

Leontief, W. (1986). *Input–output economics* (2nd ed.). New York, NY: Oxford University Press.

Leontief, W. (1970). Environmental repercussions and economic structure—Input–output approach. *Review of Economics and Statistics, 52*(3), 262–271.

Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (OUSD[AT&L]). (2007). *Memorandum for the Deputy Under Secretary of Defense, Acquisition & Technology, 10 April, 2007.* Washington, DC: U.S. Government Printing Office.

Regnier, E. D., & Nussbaum, D. A. (2011). Theory and feasibility of implementing economic input/output analysis of Department of Defense to support acquisition decision analysis and cost estimation. In *Proceedings of the Eighth Annual Acquisition Research Symposium* (Vol. II). Retrieved from http://www.acquisitionresearch.net/_beta/files/FY2011/NPS-AM-11-C8P15R03-057.pdf

Rosenthal, E. (2010, October 4). U.S. military orders less dependence on fossil fuels. *The New York Times.* Retrieved from http://www.nytimes.com/2010/10/05/science/earth/05fossil.html

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- Contractors in 21st-century Combat Zone
- Joint Contingency Contracting
- Model for Optimizing Contingency Contracting, Planning and Execution
- Navy Contract Writing Guide
- Past Performance in Source Selection
- Strategic Contingency Contracting
- Transforming DoD Contract Closeout
- USAF Energy Savings Performance Contracts
- USAF IT Commodity Council
- USMC Contingency Contracting

Financial Management

- Acquisitions via Leasing: MPS case
- Budget Scoring
- Budgeting for Capabilities-based Planning
- Capital Budgeting for the DoD
- Energy Saving Contracts/DoD Mobile Assets
- Financing DoD Budget via PPPs
- Lessons from Private Sector Capital Budgeting for DoD Acquisition Budgeting Reform
- PPPs and Government Financing
- ROI of Information Warfare Systems
- Special Termination Liability in MDAPs
- Strategic Sourcing
- Transaction Cost Economics (TCE) to Improve Cost Estimates

Human Resources

- Indefinite Reenlistment
- Individual Augmentation
- Learning Management Systems
- Moral Conduct Waivers and First-term Attrition
- Retention
- The Navy's Selective Reenlistment Bonus (SRB) Management System
- Tuition Assistance

Logistics Management

- Analysis of LAV Depot Maintenance
- Army LOG MOD
- ASDS Product Support Analysis
- Cold-chain Logistics
- Contractors Supporting Military Operations
- Diffusion/Variability on Vendor Performance Evaluation
- Evolutionary Acquisition
- Lean Six Sigma to Reduce Costs and Improve Readiness

- Naval Aviation Maintenance and Process Improvement (2)
- Optimizing CIWS Lifecycle Support (LCS)
- Outsourcing the Pearl Harbor MK-48 Intermediate Maintenance Activity
- Pallet Management System
- PBL (4)
- Privatization-NOSL/NAWCI
- RFID (6)
- Risk Analysis for Performance-based Logistics
- R-TOC AEGIS Microwave Power Tubes
- Sense-and-Respond Logistics Network
- Strategic Sourcing

Program Management

- Building Collaborative Capacity
- Business Process Reengineering (BPR) for LCS Mission Module Acquisition
- Collaborative IT Tools Leveraging Competence
- Contractor vs. Organic Support
- Knowledge, Responsibilities and Decision Rights in MDAPs
- KVA Applied to AEGIS and SSDS
- Managing the Service Supply Chain
- Measuring Uncertainty in Earned Value
- Organizational Modeling and Simulation
- Public-Private Partnership
- Terminating Your Own Program
- Utilizing Collaborative and Three-dimensional Imaging Technology

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