Re-Configuring RECONS Regional IO Models as Multi-Regional IO Models

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ABSTRACT

The US Army Corps of Engineers (USACE) is one of the world's largest public engineering, design, construction and management agencies, and its civil works mission areas include navigation, flood risk management, hydropower, water supply, recreation, and environment with an annual budget of $5 billion (US). To estimate total regional economic impacts of USACE's programs, a Regional Economic System (RECONS) was developed for both direct federal spending and related economic activities associated with USACE's infrastructure and programs. The RECONS database currently contains more than fifteen hundred single-regional input-output (S-RIO) models of individual counties, multi-county areas, states, multi-state regions and the US. This collection of S-RIO models includes geographic redundancies, as a state-wide model may implicitly include a county contained in another local area model. As a result, estimated impacts cannot be reliably aggregated over the geographic hierarchy of models: county-level impacts may not sum to state impacts and state-level impacts may not sum to nation-wide impacts. To overcome these shortcomings, RECONS S-RIO models are being re-formulated as multi-regional (MRIO) models. Three alternative formulations of MRIO models are being considered. *Alternative A* formulates a suite of 3-region MRIO models each with 3 endogenous regions (Local, Rest-of-State, and Rest-of-US). *Alternative B1* formulates a single MRIO with 50 State-level endogenous regions but includes no "local" regions. *Alternative B2* formulates a single MRIO with 3,142 County-level endogenous regions. These alternative formulations are evaluated considering how well they support aggregating results both vertically and laterally. Impacts on users due to increased complexity of using MRIO models was also examined. Finally, computer storage and the practicality of computational requirements of the alternative MRIO models for implementation as an online model for use across the nation were also evaluated.

RECONS and Single-Region I-O Models (S-RIO)

The US Army Corps of Engineers (USACE) is one of the world's largest public engineering, design, construction and management agencies, and its civil works mission areas include navigation, flood risk management, hydropower, water supply, recreation, and environment with an annual budget of $5 billion (US). To estimate total regional economic impacts of USACE's programs, a Regional Economic System (RECONS) was developed to examine the economic impacts of both direct federal spending and related economic activities associated with USACE's infrastructure and programs (Chang, et. al., 2019).

The RECONS database currently contains more than fifteen hundred single-region input-output (S-RIO) models of three types: *Local* S-RIOs of individual counties or multi-county areas, *State* S-SRIOs for individual States or multi-State regions, and a *US* S-RIO of the entire US national economy. The characteristics of S-RIO models are also shown in Table 1. All RECONS S-RIO models were built by extracting economic multipliers and ratios from IMPLAN economic modeling system (IMPLAN, 2018). Technically, the endogenous region of *Local* and *State* S-RIO models consists of a single region (county, multi-county, or State), with two exogenous trade regions: domestic (Rest-of-US) and foreign (Rest-of-World). The *US* S-RIO model consists of one endogenous domestic region and exogenous foreign (Rest-of-World) trade regon.

Table 1. RECONS S-RIO Model Types

Types of RECONS Single-Region IO Models (S-RIO)	Geographic Extent of the S-RIO Models
Local S-RIO Models	County/Multi-County
State S-RIO Models	State
US IO Model	US

USACE program impacts are typically described for three geographic contexts: *Local* impacts (using a *Local* S-RIO model), impacts on the *State* economy (using a *State* S-RIO), and nation-wide impacts (using a *US* S-RIO). Attempting to aggregate impacts across the geographic hierarchy from the results of three separate S-RIO models can produce inconsistencies. For example, as a *State* model may implicitly include a county contained in *Local* area model. As a result, impacts cannot be reliably aggregated "vertically" in the geographic hierarchy of *Local-State-US* S-RIO models. That is, *Local* impacts may not sum to *State* impacts and *State* impacts may not sum to *US*-wide impacts. Similarly, impacts cannot be reliably aggregated "laterally" across the same geographic strata, such as summing all *Local* or all *State* impacts. These characteristics are shown in Tables 2 and 3.

Table 2. Analysis Scope of S-RIO Models

Type of S-RIO	Local Scope	State Scope	US Scope
Local S-RIO Models	County/Multi-County ONLY	NONE	NONE
State S-RIO Models	NONE	State Only	NONE
US IO Model	NONE	NONE	US Only

Table 3. Aggregation of S-RIO Impacts

Type of S-RIO	Vertical Aggregation of Model Results	Lateral Aggregation of Results Between Models
Local S-RIO Models	UNRELIABLE	UNRELIABLE
State S-RIO Models	UNRELIABLE	UNRELIABLE
US IO Model	UNRELIABLE	UNRELIABLE

Alternative MRIO Model Formulations

To resolve the inconsistencies that can arise when aggregating impact results from separate S-RIO models both vertically and laterally across geographic hierarchies, two alternative formulations of multi-regional input-output models (MRIO) are being considered. The first type of MRIO, referred to as "*Alternative A*" has 3 endogenous regions, *Local and Rest-of-State* (*RoS*), *Rest-of-US* (*RoUS*), and 1 exogenous *Rest-of-World* (*RoW*) region. The second type of MRIO, "*Alternative B*", has two variants. *Alternative B1* has 50 endogenous regions, one for each *State*, and one exogenous *RoW* region. *Alternative B2* has 3,142 endogenous regions, one for each *County*, and one exogenous *RoW* region. Re-populating the RECONS database with *Alternative A*-type MRIO models would require one MRIO for each *Local* reporting area. While there are currently about 1,200 Local S-RIO, the collection of Alternative A type MRIO-type models could potentially have as many as one for each county and each multi-county area. In the cases of *Alternative B1* and *Alternative B2*, the RECONS database would contain a single MRIO model respectively, as shown in Table 4.

Table 4. Number and Geographic Scope of MRIO Models

	# of Models in RECONS Collection	Geographic Extent of the MRIO Models
Alt A 3-Region MRIO Models	As many as 3,142 or more	Local > RoS > RoUS
Alt B1 States-Only MRIO Model	1	State > US
Alt B2 All-Counties MRIO Model	1	Local > State > US

RECONS with a Collection of *Alternative A*-type MRIO Models

Each RECONS MRIO model following the Alternative A formulation has 3 endogenous regions in a geographical hierarchy of *Local > RoS > RoUS*. This means that each *Alternative A* MRIO models covers the entire geographic hierarchy, as shown in Table 4. For each *Alternative A* MRIO, vertical aggregations would be consistent. This is a huge benefit compared to the current RECONS collection of S-RIO models. However, lateral aggregations between *Alternative A* MRIO models are not possible since each MRIO model defines *Local* or *RoS* differently. Table 5 summarizes *Alternative A* MRIO models with respect to vertical and lateral aggregation.

Table 5. Vertical and Horizontal Aggregation of MRIO Models

	Vertical Aggregation	Lateral Aggregation
Alt A 3-Region MRIO Models	YES	UNRELIABLE
Alt B1 States-Only MRIO Model	YES (No Local)	YES (No Local)
Alt B2 All-Counties MRIO Model	YES	YES

RECONS with a Single *Alternative B1*-type MRIO Model

A single RECONS MRIO model following the *Alternative B1* formulation has 50 endogenous regions representing a geographic hierarchy of *State* > *US*. That is, the economic impacts on each State or group of States could be identified and all 50 represent the *US* economy in sum. Of course, limiting the spatial granularity to 50 States means that the *Alternative B1* MRIO model do not have a *Local* component in the geographic hierarchy, as shown in Table 4. Both vertical aggregations from *State* to *US* and lateral aggregations among States can reliably be made using the Alternative B1 MRIO (see Table 5). This is a significant improvement over both the current S-RIO and *Alternative A* MRIO, albeit without a *Local* component.

RECONS with a Single *Alternative B2*-type MRIO Model

A single RECONS MRIO model following the *Alternative B2* MRIO configuration has 3,142 endogenous regions encompassing a geographic hierarchy of *Local* > *State* > *US*. *Local* economic impacts can be readily aggregated into any multi-County, *State* or multi-State groupings including the entire *US* economy in sum. In other words, the Alternative B2 MRIO spans the entire *Local* > *State* > *US* geographic hierarchy and can reliably be aggregated in both the vertical and lateral dimensions as shown in Table 5.

Computation and Storage Considerations

MRIO models with high geographic granularity with respect to endogenous regions have a clear advantage for supporting the reporting requirements of USACE program analysis. However, the computational and computer media storage costs increase exponentially with respect to the number of endogenous regions. Tables 6 describes the computer storage requirements of individual S-RIO and MRIO models. Table 7 shows the computer storage requirements of each collection of models. Of course, for Alternatives B1 and B2 there are only one MRIO model in the collection.

To estimate the computer storage requirements, it was assumed that there are 536 industries in each region. The number of bytes of computer storage is estimated as the number of matrix cell values a model has multiplied by 4 since each cell value requires 4 bytes of computer storage. The number of multiplier matrix cells a model has is the square of the number of industries multiplied by the number of endogenous regions.

Apart from the *Alternative B2* MRIO, storage requirements are modest ranging from 3 to 30 Gigabytes (GB). However, Alternative B2 consumes nearly 11,000 GB or about 11 Terabytes (TB). A model this size is not a deterrent, but rather is an indicator of substantial time and costs. And it is likely that applying sparse-matrix methods could reduce the storage requirements substantially.

Table 6. Computer Storage Requirements of Individual Models

Type of Model	Individual Model # of Industries	Individual Model # of IxI Matrix Cells	GB per Model
S-RIO	536	287,296	.001
Alt A 3-Region MRIO Models	1,608	2,585,664	0.010
Alt B1 States-Only MRIO Model	26,800	718,240,000	2.675
Alt B2 All-Counties MRIO Model	1,684,112	2,836,233,228,544	10,565.792

Table 7. Computer Storage Requirements of Alternative Model Collections

Type of Collection	# of Models in Collection	GB per Collection
S-RIO	3,193	3.4
Alt A 3-Region MRIO Models	3,142	30.2
Alt B1 States-Only MRIO Model	1	2.7
Alt B2 All-Counties MRIO Model	1	10,565.8

Analyst Usage Considerations

While not especially onerous, MRIO models increase the amount of information that must be provided by the user/analyst when assessing policy scenarios. Current established procedures using RECONS S-RIO models require that the user/analyst essentially make a binary choice regarding each of a scenario's direct effects. The choice is whether the procurement is made from a supplier located within the single endogenous S-RIO region or not. For example, if a project requires wood pilings, the choice must be made of whether the pilings are purchased from a supplier located in the *Local* endogenous region or not. If the supplier is *Local*, then the direct effect is applied to the *Local* S-RIO model; if the supplier is in the exogenous region, none of the direct effect is applied to the *Local* S-RIO model. As shown in Table 8, the choices for locating direct effects get more complex with MRIO models. With an *Alternative A* MRIO model, the analyst must explicitly allocate the direct effect among the 3 endogenous regions (*Local*, *RoS*, and *RoUS*) and 1 exogenous *RoW* region. With an *Alternative B1* MRIO model, the analyst must explicitly allocate scenario direct effects among 50 endogenous *State* regions and 1 exogenous *RoW* region. With an *Alternative B2* MRIO model, the analyst must explicitly allocate scenario direct effects among 3,142 *Local* endogenous regions and 1 exogenous *RoW* region.

Table 8. Burden on Analysts

Type of Model	Number of Choices for Locating Direct Effects
Single-Region	1
3-Region MRIO	3
All-States MRIO	50
All-Counties MRIO	3,142

Building RECONS MRIO Models

All S-RIO models currently in the RECONS database were constructed using off-the-shelf IMPLAN's data (both control total data and trade flow data) along with IMPLAN's Pro desktop software (IMPLAN, 2017). *Alternative A, B1 and B2* MRIO models also use off-the-shelf IMPLAN control total data, however revised trade flow data are derived using a USACE custom trade model developed specifically for RECONS MRIO models. Further, the MRIO models are assembled using custom software procedures developed for RECONS. The USACE in-house custom MRIO model-building and trade model were developed because IMPLAN's Pro desktop software does not support building these types MRIO models or modifying the IMPLAN trade flow estimates. Using IMPLAN's data to build RECONS MRIO models is permitted under a license agreement granted by IMPLAN Group LLC to USACE.

Conclusions and Recommendations

As one of the major engineering and construction agencies in the US, RECONS provides provide consistent and defensible estimates of jobs, incomes and other economic impacts associated with USACE infrastructure and programs. Since RECONS incorporates impact area data, as well as multipliers, direct ratios (jobs to sales, income to sales, etc), and geographic capture rates that were extracted from the IMPLAN models, it's essential to develop enhanced procedures to build economic impact models for the purpose of updating and enhancing the RECONS economic impact analysis system.

The paper provides a foundation for a managerial evaluation and alternatives for improving RECONS by moving from S-RIO to MRIO modeling. The evaluation criteria, including computer storage requirements, and the efficacy of vertical and lateral aggregation of impact results, are all practical challenges and are important to how USACE move RECONS forward in anticipating of the high computing power and larger capacity in both storage and bandwidth.

For future recommendations and implementations, this administrative review could be part of consideration for future development of the methods to extract IMPLAN data set and build "physical" models in RECONS. Instead of a pre-determined set of "regions" with multipliers and economic ratios, MRIO, regardless which alternative discussed in this paper, will allow a finite number of models in RECONS with virtually infinite combinations of regions to be analyzed in RECONS. As Corps analysts not only have used the tool to track progress and justify the continued operation, maintenance and construction work, they also constantly in need of evaluating new projects or infrastructures in various proposed locations. These MRIO alternatives will provide not only a reliable aggregation/disaggregation with spatial granularity, but will also serve as a powerful tool for the Corps' planning process.

References

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