Economic Consequences Assessment Model (ECAM): A Tool & Methodology for Measuring Indirect Economic Effects
Disclaimer:
This is not an officially edited publication of the United Nations. The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country or territory or of its authorities or concerning the delimitations of its frontiers or boundaries. The designations of country groups in the text and the tables are intended solely for statistical or analytical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of the names of firms and commercial products does not imply the endorsement of the United Nations.

Note: The designations employed and the presentation of maps in this report do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities or concerning the delimitation of its frontiers or boundaries. Some rights reserved. This work is made available under the Creative Commons Attribution-NonCommercial 3.0 IGO licence (CC BY-NC IGO); https://creativecommons.org/licenses/by-nc/3.0/igo/legalcode

Under the terms of this licence, this work may be copied, redistributed and adapted for non-commercial purposes, provided that the work is appropriately cited. In any use of this work, there should be no suggestion that UNDRR endorses any specific organization, products or services.

The use of the UNDRR logo is not permitted. If a translation of this work is created, it must include the following disclaimer along with the required citation below: "This translation was not created by the United Nations Office for Disaster Risk Reduction (UNDRR). UNDRR is not responsible for the content or accuracy of this translation. The original English edition shall be the authoritative edition."

Users wishing to reuse material from this work that is attributed to a third party, such as tables, figures or images, are responsible for determining whether permission is needed for that reuse and for obtaining permission from the copyright holder. The risk of claims resulting from infringement of any third-party-owned component in the work rests solely with the user. Sales, rights and licensing.

UNDRR information products are available for non-commercial use. Requests for commercial use, rights and licensing should be submitted via: https://www.undrr.org/contact-us

This publication may be freely quoted but acknowledgement of the source is requested.

Citation: UNDRR (2022), Economic Consequences Assessment Model (ECAM): A Tool & Methodology for Measuring Indirect Economic Effects, United Nations Office for Disaster Risk Reduction (UNDRR).

© 2022 UNITED NATIONS OFFICE FOR DISASTER RISK REDUCTION
For additional information, please contact:
United Nations Office for Disaster Risk Reduction (UNDRR)
7bis Avenue de la Paix, CH1201 Geneva 2, Switzerland, Tel: +41 22 917 89 08
Economic Consequences Assessment Model (ECAM): A Tool & Methodology for Measuring Indirect Economic Effects

Synopsis

When measuring potential damages associated with a particular threat, there are both direct and indirect effects. Direct effects include physical structure damage and loss or displacement of life. Indirect effects capture changes to economic activity, such as lost business revenues, changes to household incomes, and employment losses. In some cases, the dollar value of indirect effects is larger than the direct effects.

This chapter describes how these indirect economic effects can be computed using the Economic Consequences Assessment Model (ECAM). This approach has been applied to various hazard threats over the past 18 years, primarily in the United States. ECAM has gradually evolved into a mainstay planning tool by different government agencies, including the Department of Homeland Security, the US Army, the Bureau of Reclamation, and FEMA.

The paper explains how indirect economic impacts are computed, the necessary input data, and includes example applications for a hypothetical multi-dam breach, a hypothetical earthquake, and a hypothetical hurricane in the Caribbean (a non-US example).

Authors

William Lehman¹, Miles K. Light², Ph.D., Richard Nugent¹, Jordan Burns³

¹ Water Resources Systems Division, Hydrologic Engineering Center, US Army Corps of Engineers
² Business Research Division, Leeds School of Business, University of Colorado
³ National Renewable Energy Laboratory
## Contents

Introduction ........................................................................................................................................ 3
Background ........................................................................................................................................... 3
   Indirect Economic Impact: Three Approaches .............................................................................. 4
   ECAM Model Structure .................................................................................................................. 5
   Related Literature ........................................................................................................................... 6
   International Application of ECAM ............................................................................................... 7
Economic Methodology ......................................................................................................................... 7
Necessary Data and Model Inputs ......................................................................................................... 9
Platform and User Interfaces ............................................................................................................... 10
   Web Browser User Interface ......................................................................................................... 11
   ECAM using Software Integration and API ...................................................................................... 13
Examples and Use Cases .................................................................................................................... 14
   Scenario #1: Utah Earthquake ....................................................................................................... 15
   Scenario #2: Flood Event in Michigan ........................................................................................... 16
   International (Barbados) ................................................................................................................ 19
Challenges & Future Work .................................................................................................................... 23
   Improving accuracy and tolerance for small hazard events ......................................................... 23
   Effect of Model Area Size .............................................................................................................. 24
   Applying ECAM to Different Hazard Types .................................................................................. 24
   Occasional Counter-Intuitive Results ............................................................................................ 25
References ............................................................................................................................................. 26
Annex A: Terminology and Notes ....................................................................................................... 27
   Acronyms ......................................................................................................................................... 27
Annex B: Data Details and Examples .................................................................................................. 28
   30-Sector Dataset ........................................................................................................................... 28
Annex C: Manual Calculation of Capital and Labor Loss Ratios ....................................................... 29
   Capital Loss Ratio .......................................................................................................................... 29
   Labor Loss Ratio ............................................................................................................................ 30
Introduction

In many regions, the role of economic resiliency has slowly moved up the list of planning importance. Despite this reprioritization, few methods or accessible tools have been developed to consistently estimate the change in local economic output and employment after a hazardous event.

The Economic Consequences Assessment Model (ECAM) was developed to fill this void. ECAM quantifies changes in output and employment – often referred to as indirect economic impacts – resulting from natural hazard events such as flooding, earthquakes, or hurricanes. The indirect economic impacts are quantified as a function of the direct economic impacts of a given hazard event, that is, the physical damage and life loss attributable to said event. ECAM was originally designed for use within the United States, but the model can be adapted for use in any country or region if a well-defined set of economic accounts exists.

In this chapter, we introduce the ECAM methodology and demonstrate how the tool is applied using three different illustrative examples. Brief sections are included to explain how ECAM differs from other approaches, and what type of input data is needed to run it. Interested readers can request more detailed documentation directly from the authors.

Background

ECAM is an economic general equilibrium model that is designed to pre-assess potential indirect economic impacts associated with a particular type of disaster. The model is typically used to prioritize disaster mitigation efforts or for pre-disaster analysis to support risk analysis frameworks. ECAM provides consistent and defensible estimates across a broad range of hazard levels, across unique regions, and across different infrastructure densities.

The ECAM approach was developed by Dr. Miles K. Light at the University of Colorado beginning in 2003. The original work took place in response to requests from the U.S. Department of Defense (DoD). At that time, the DoD requested a "rapid assessment tool" that could quantify the economic impacts from terror-related events. The tool was intended to work in any specific region across the United States. This request came during a time of heightened fear from terrorist events such as chemical attacks and dirty bombs.

Later, in 2004, a full-fledged CGE model was merged with highly detailed datasets through a collaboration between Professor Thomas Rutherford and Dr. Light. This work resulted in the provision of tools that merge sub-regional datasets (called IMPLAN datasets) with CGE models using a popular algebraic program, the Generalized Algebraic Modeling System (GAMS). Rutherford’s data-handling routines have become popular among US-based users because they combine the power and of GAMS modeling with a broad and consistent dataset system developed by the IMPLAN Corporation.

In 2005, the Bureau of Reclamation commissioned economic impact assessments of dam failure across several major dams in the United States. This large study became the benchmark tool for impact assessment methodology. The ECAM methodology was be extended to include all Reclamation dams in the Western U.S. This led to the deployment of a web-based platform

---

4 IMPLAN is a for-profit company that produces highly-detailed economic datasets to government and private customers. (www.implan.com)
5 GAMS Corporation produces and maintains the Generalized Algebraic Modeling System, a platform for mathematical optimization using different computerized program solvers. (www.gams.com)
for ECAM in 2007 so that government officials could access the tool using an easy to use interface.

Since 2010, several variations on the original CGE model have been applied to meet specific needs from various U.S. government agencies including the Department of Homeland Security, the Bureau of Reclamation, and the Federal Emergency Management Agency (FEMA).

Additionally, the U.S. Army Corps of Engineers, also known as USACE, began using ECAM more intensively for water management, dam safety risk management, and flood risk assessment. After 2012, the USACE integrated ECAM into their flood assessment tool, the Hydrologic Engineering Center’s Flood Impact Analysis (HEC-FIA). HEC-FIA was the Army’s main software product for risk management analysis of dams and levees at that time. As USACE’s dam safety program matured, the tool HEC-LifeSim became the primary tool for risk management for dams and levees, ECAM is accessible through HEC-LifeSim for continuity of service.

ECAM is now under consideration by FEMA as a default tool for indirect economic assessment across multiple hazards, such as floods, earthquakes, and hurricanes.

Indirect Economic Impact: Three Approaches

For completeness, several agencies will include estimates of business interruption or employment losses in reports on hazard events. Such estimates are often derived in an ad-hoc manner using the adding-up or input-output approaches (described in the sidebar below). Conversely, the ECAM model uses computable general equilibrium modeling (CGE), which is complex, but consistent and grounded in economic theory.

The input-output approach is no longer commonly used because there is no clear connection in the methodology between the physical assets being impacted (the buildings, machines, and workers) and economic output. Instead, the researcher must develop their own ad-hoc linkage between physical changes and regional spending, and then use the I-O model to estimate the effect of lower expenditures on goods and services. The I-O method assumes constant ratios of inputs for production before and after the event. However, the availability of inputs are expected to change dramatically after a catastrophic event.

Meanwhile, the adding-up approach continues to be popular within government agencies primarily because this approach is straightforward and easy to use. The adding-up approach simply counts the days that a business is closed and multiplies daily revenues by the number of closed days. A similar approach is used for employees: lost days multiplied by daily wage.

The main problem is that many local regions have large factories producing goods and services for consumption outside of such regions. Employment may be captured for those factories, but output is not. As with the input-output approach, the key flaw is that adding up does not connect the physical changes with the production and consumption inputs. This leads to gross under- or over- estimation of economic losses.

Most economists agree that computable general equilibrium is more consistent, more accurate, and is founded in accepted economic theory. General equilibrium theory directly links the factors of production (labor, capital, land/natural resources, and entrepreneurship) to available outputs and incomes. But until recently, the deployment of GGE models has been too slow, too difficult, and too costly to use across multiple regions and hazard types.
ECAM was a viable solution for government agencies because the approach could utilize each of the 3,800 county-level datasets to generate a model and conduct impact analysis instantly.

**ECAM Model Structure**

Unlike Input-Output models or econometric reduced-form equations, CGE models explicitly designate different agents and resources in the mathematical model. Figure 1 shows how ECAM models the relationship between Households, Firms, Goods & Services, and the resources needed to produce them (such as labor, machinery, intermediate inputs, and natural resources).

*Figure 1. Conceptual diagram of the relationship between agents of the market and the resources needed to produce goods and services.*

In the model – basic factors of production (labor, capital, natural resources) are owned by private households, or government agencies. These factors are then sold to companies, who produce outputs – this occurs in the box “Local Production”. Outputs from local production are either sent to local distributors, or they are exported. Locally-sourced products and services are then combined with imported goods and services, creating an “Aggregate Supply” – sometimes called an Armington aggregate good. An example is a typical fast-food hamburger which is partly sourced locally (bread, vegetables, meats, labor) and partly imported (condiments, other chemicals, and specific inputs).

These amalgamated supplies in the local area are then either sold to local companies for production or sold to households as final consumption. Some portion of supplies are purchased by the government, or by investors to construct new buildings and machinery. That is the flow of labor, capital, and resources through the economy, and back to final consumers.

In the case of an external shock to the economy like a flood or an earthquake— the availability

---

of labor and capital inputs is diminished, leading to a constraint on firm production. The severity of the constraint is an input to ECAM – and is usually generated using direct loss estimation in external software tools. This constraint is input into ECAM causing reductions in inputs and demand and the economy is rebalanced through optimization to find the new equilibrium after many iterations of cascading effects of the shock. The resulting change in product and service flows is measured as the change in output which is usually reflected in the local currency based on the format of the input data. The change in demand (and supply) for labor is reported by ECAM as the change in employment.

Related Literature

Leif Johansen developed the first CGE as a means to studying long-term economic growth as a function of changes in policy in Norway (Johansen, 1960). CGE models have since been used to evaluate the effect of wide-ranging policies, including but not limited to policies related to taxation, international trade, and the environment. CGE models also have been widely used to estimate the indirect economic impacts of disasters. To our knowledge, David Brookshire and Michael Mcgee are the first to use a CGE model to assess the indirect economic impacts of a disaster – a catastrophic earthquake (Brookshire & Mckee, 1992). Carol T. West and David G. Lenze soon after developed a computable general equilibrium model in 1994 to assess the regional impact of disasters, including an effort to include the effects of reconstruction, but the authors’ approach requires several more impact estimates than ECAM and does not explicitly include capital stock in the model (West & Lenze, 1994). More recently, Adam Rose and Shu-Yi Lao used a CGE model to assess the effect of a disruption to water service following a major earthquake (Rose & Liao, 2005), and Yoshio Kajitani and Hirokazu Tatano validate the performance of a CGE model in replicating the observed economic losses in Japan following the 2011 Great East Japan Earthquake using the best estimates of the elasticity parameters (Kajitani & Tatano, 2018). The key contribution of ECAM to the literature on the assessment of indirect economic impacts using CGE models is the low cost of use (in terms of access and data requirements, presuming a relevant social accounting matrix is available at the regional level) and wide applicability.

A large body of research is also available for readers who wish to find or generate a Social Accounting Matrix for their target region. SAMs are generally considered to be a natural extension of Input-Output tables, developed almost one century ago by Wassily Leontief. The use and application of Social Accounting Matrices for planning purposes was done primarily by international agencies such as the World Bank. This work was formalized and documented in the 1980’s by two Bank researchers, Pyatt and Round. Further work by Keuning and de Ruiter (1988) describe how to construct a SAM from the country’s national accounts.

These accounts have been used steadily from the 1990’s until now – either as stand-alone tools that show relationships between different economic sectors, or as data inputs for more complex CGE models. There are examples of SAMs being used for disaster analysis back in 1995, most notably by Prof. Sam Cole, where he assessed impacts of a hurricane upon the

---

Integration of SAMs into CGE models was accelerated by the work of Professor Thomas Rutherford, who simultaneously developed specific software for the deployment of CGE models and examples how to easily convert SAM datasets into data arrays for use with CGE models. Rutherford’s approach is documented in the academic literature from 1999. A large number of examples and tutorials are available on his website as well (mpsge.org).

International Application of ECAM

Readers outside of the United States may ask how ECAM can be applied in their situation. If there exists a set of economic accounts for the country or region of interest, then the ECAM model and approach should be possible. ECAM is most useful when there are multiple regions defined within a country. Large countries like Germany or France are likely to have multiple regional accounts that are consistent with the national accounts. These sub-regional datasets can be used in the same way that IMPLAN datasets are used in the United States.

In the next section, we introduce the economic methodology underlying ECAM. In Section 4, we discuss the necessary data and model inputs. In Section 5, we briefly walk through the platform and user interface. Then, in Section 6, we present three examples to demonstrate how the datasets, model, and scenarios are combined to calculate the indirect economic effects of flood, earthquake, and hurricane disasters. Finally, in Section 7, we discuss challenges and suggestions for future work.

Economic Methodology

General equilibrium modeling is a comparative static (before and after) exercise that begins with an initial point before the event called the benchmark. After the event, a new equilibrium point is reached called the counterfactual. The difference in business activity between the benchmark and the counterfactual (usually negative for adverse events) is the net indirect economic impact of the adverse event. Adding this impact to the other direct losses from natural hazards provides a more complete view of the consequences from a particular hazard event.

The timeframe for this model is 1 year. This means that the economic impacts would be most accurate during the 12-month period following the event. The new output level may persist for more than 12-months, or even decline. Over time however, there will be capital investment and immigration, which leads to changing output levels after one year. Thus, the timeframe in the current ECAM implementation is considered relatively short run. Long-run impacts would account for changes to investment and capital formation. A multi-year framework is possible but would require additional assumptions regarding the rate of reconstruction versus the ongoing effects of the lost factors of production.

The ECAM model is a standardized CGE implementation exhibiting the most basic neoclassical assumptions about production and consumption. Producers are assumed to act

---

11 Output declined for more than 12 months after hurricane Katrina, in Louisiana.
12 The typical dynamic model uses a forward-looking household and the traditional trade-off between current consumption versus savings (future consumption). Whether this framework captures the situation described in this paper is less clear.
perfectly competitively. This form of competition implies that no producers earn sustained excess profits. In other words, all production activities return zero economic profit. Consumers spend their labor income (wages) and capital income (investment returns) on goods and services. Even for small counties, consumer labor and capital earnings are assumed to be impacted greatly by local economic conditions so that higher local wage rates will increase household income. Household income derived outside of the impact region is partly accounted for through trade (sales and purchases of goods and services outside of the region), but direct income from outside of the impact county, such as wages earned by long-range commuters or telecommuters, may not be included. The regional aspect of these problems represents an ongoing challenge to economic analysis and modeling.

In the ECAM model, this exercise built on the relationships between supply and demand is simultaneously conducted for all sectors in the model to determine the net demand and supply for each good and each factor of production. To compute the change in business activity and prices, the ECAM model combines regional input-output data, household expenditure data, government expenditure data, and neoclassical economic theory into a system of equations. The model assumes that individuals and companies are optimizing between choices of different prices and products.

CGE analysis differs from traditional input-output (multiplier) techniques, or from a simple adding-up approach. In the CGE approach, each economic agent in the model reallocates time, energy, and resources to maximize their economic welfare, or in some situations, to minimize the losses coming from an adverse event. In such an environment, the agents will reallocate resources to minimize the economic hardship brought about by the disaster. By capturing the optimal reallocation of local production, trade, and investment, the CGE analysis provides a best-practice approach to economic impact analysis for physical and economic events.

The primary drawback to CGE modeling is the difficulty to construct the model. These models require extensive benchmark datasets that correspond to the national or regional accounts of the target area. If a well-defined economic dataset exists for the target area, then the ECAM approach can be easily facilitated.

The ECAM approach requires that the physical impact of an event is translated into economic changes for input into the model. This translation is accomplished by first estimating the loss of physical infrastructure and then using the quantified losses to compute the percentage of productive capital and labor lost due to the natural hazard of interest. Finally, economic impacts are based on the changes to these (and potentially other) production factors. Counties that will experience reductions to irrigation or municipal water need to be identified and the percent reduction in the individual water supplies needs to be estimated. Finally, if the county is a tourist attraction, the percentage of total tourism lost also needs to be computed. The changes to capital, labor, water, and tourism define the scenario for the ECAM model. As ECAM model is designed for adverse economic events, the scenario is typically defined as reductions in the production factors, which represents disruptions to supply channels.

The significance of the natural hazard scenario is defined by the capital, labor, water, and tourism amenity losses. From these inputs, ECAM determines price and quantity changes in each market resulting from the natural hazard, and then estimates the overall change to

---
13 These approaches are described in Section #1 of the report.
annual production and employment for the study area. The primary outputs are dollar reductions to regional production and number of jobs lost in the local area. Other outputs include changes to domestic and international trade, prices, and income.

**Necessary Data and Model Inputs**

As discussed in Section 3, the ECAM system requires inputs related to the economy within the study region, as well as information about the direct damages that have occurred within the target area. Each impact study uses a unique dataset for the location in question. For counties and states in the United States, there is a for-profit business that provides such datasets, albeit at a cost. These U.S. datasets are available at the county (sub-state) regional level, providing a detailed depiction of the economy, with more than 400 activities and product types. In other countries, the requisite economic data is typically available from national statistical offices in the form of a social accounting matrix, as economists often use this data for other types of economic investigations.

The two damage parameters that are required for a compute are the labor loss (reduction in the working population) and capital loss (the damage to the available capital, usually buildings) ratios. The model works best with a detailed geospatially referenced inventory of structures, as well as population for the target region. In the operating manual, capital and labor losses are defined as follows:

- **Capital losses** include damage to non-financial assets used in the production of goods and services, typically consisting of damages to non-residential buildings and their contents. Annex C provides further discussion on methods for computing this input.
- **Labor losses** represent displaced families, lives lost, or temporary relocations that create disruptions in the workforce. Annex C provides further discussion on methods for computing this input.

The required capital and labor loss ratios that are submitted to the tool can be estimated using FEMA’s Hazus software, or any other natural hazard loss estimation tool. Hazus is a nationally standardized collection of data, methods, and tools developed by FEMA for modeling impacts due to hurricanes, earthquakes, tsunamis, and floods. FEMA is currently exploring options for the direct integration of ECAM with the Hazus software interface so that direct and indirect economic impacts can be estimated together by emergency planners. While tools like Hazus will automatically calculate capital and loss estimates, manual calculation is possible and the steps are described in Annex C.

As mentioned in Section 2, the ECAM system may be customized to target a specific type of hazard event. For example, the US Bureau of Reclamation – who oversees the nation’s largest hydroelectric dams – wanted to include costs associated with lost water supply as well as lost recreational tourism from lakes and reservoirs being empty. Those inputs are defined below.

- **Water losses** describe the lost irrigation water that is needed to grow crops or municipal water needed for domestic supplies and to operate certain businesses.
- **Tourism losses** depict a reduction in tourism-related amenities, such as the loss of lake

---

14 Please note that *losses* and *reductions* are used interchangeably in this document for Irrigation Water, Municipal Water, and Tourism.
or canyon access that limits the number of visitors to the area.

The exact number and type of inputs will depend upon the type of natural hazard (e.g. flood, hurricane, or earthquake) and the severity of the hazard. The two primary inputs – labor and capital reductions – are sufficient to accurately compute indirect effects for most hazard events.

Platform and User Interfaces

The model has been deployed using two technologies to increase accessibility and adoption: a stand-alone web interface and an application programming interface (API) that integrates the results from associated software packages. ECAM is a sophisticated software that is deployed using the GAMS Mathematical Programming System for General Equilibrium Analysis. Directly programming or using the model code requires ownership of costly software and presents programming and computer-use barriers.

Figure 2. Data and Requests between ECAM and an External Web Server - using the API

By deploying the software using a cloud-based approach, users can either access the model directly or integrate the model into their own software.

A schematic of the ECAM system is provided in Figure 2. Using the API, scenario requests can be sent directly to the ECAM system; ECAM then returns the quantified indirect economic losses back to the user in a pre-defined format. This allows the model code to be updated and maintained on a remote server with without requiring updates or patches for users to install on a desktop. Similarly, the economic model and options can also be extended through the API without requiring a re-distribution of software. Creating the ECAM engine this way has the benefit of making development of multiple user interfaces simple (from a software development perspective) and easily customizable (from a user perspective).
Web Browser User Interface

The web-based user interface for USBR is shown in Figure 3 alongside an example interactive web-based application in Figure 4. The user interface simplifies the analysis by only asking for a few inputs. The user can simply enter the calculation for *Capital Reduction* and *Labor Reduction* in percentage terms.

Figure 3. Example Web Interface for ECAM - US Bureau of Reclamation
Figure 4. Example ECAM Interface, using the API Facility

Figure 5. Sample Output using the ECAM - API Interface for the US Army Corps of Engineers
This web application shown in Figure 3 was developed for dam owners to compute indirect losses to support risk assessments at USBR. This application contains three additional loss ratios. These are: *Irrigation Water Lost*, *Municipal Water Lost*, and *Tourism Impact* to evaluate impacts unique to the scenario of losing the infrastructure of a dam and the reservoir. For most ECAM deployments, these additional inputs are not part of the model. This shows how user interfaces can be easily adapted to any use case with minimal effort.

**ECAM using Software Integration and API**

The U.S. Army Corps of Engineers HEC-FIA and HEC-LifeSim software packages leverage the ECAM API. HEC-FIA and HEC-LifeSim simplify the computation of loss ratios for the end user by computing them automatically, calling the ECAM API, and presenting the results in standardized reports. The design of ECAM focused on reducing the entry cost of indirect economic analysis so that more information can be easily provided to stakeholders. The tool is designed to support screening level analysis to determine if indirect economic losses are a significant consideration for any project.

When using an API, the user interacts with the larger hazard loss program through interfaces designed and documented by their development team. The calling application submits the region and the respective losses directly to ECAM over the internet. ECAM responds with a machine-readable reply to the API – allowing the host program to re-format ECAM's results before the user sees them. The API approach provides a simplified, seamless way to compute indirect economic impacts – especially for users who lack an economics background. The ECAM API will also allow a broader community of emergency managers to access indirect economic loss modeling capabilities through FEMA's Hazus software. Hazus can be modified to connect with ECAM behind the existing Hazus interface so that risk analysts can leverage authoritative economic data and methods without requiring FEMA to invest in replicating ECAM inside their own tools. This approach is especially effective because it leverages previous federal investment in the proprietary nationwide economic data underlying ECAM.

An example interface is shown in the Figure 4. The region is defined by the user when they click on a specific county in the United States. The user is presented with a simple pop-up form to enter their calculation for the capital and labor loss in percentage change from the benchmark condition.

In this application, labor and capital losses are computed by a separate program, making use of the system easier. Alternatively, he HEC-FIA tool can be used for multiple hazards if the damage ratios are calculated following the basic guidelines.

Reports can be presented to the user in a simple to read table that can be exported by the user as shown in Figure 5.
Examples and Use Cases

This section provides specific examples of the ECAM tool in use. Three examples are provided: a hypothetical earthquake in the state of Utah, a hypothetical flood in the state of Michigan, and a hypothetical hurricane on a Caribbean Island.

Before any economic modeling is done, the user must first determine how the event impacts the target region’s infrastructure and population. This sort of primary research is typically the main part of any disaster analysis, where physical damages and loss of life are determined based on the severity of the event and the local area population.

The outputs from the primary research can be utilized to determine the key inputs needed by the ECAM system. Using the physical damage estimates, the user can calculate the amount of productive capital damaged during the event and the share of the region’s population who are displaced. These steps are detailed in Annex C. Once the physical damage and population displaced estimates are identified, the economic impact analysis can be implemented quickly by the user. The aggregated model takes just a few minutes to find a solution, so that most of the work is spent formatting and interpreting the results. The following examples show how this works.
Scenario #1: Utah Earthquake

Figure 6. Earthquake Impact Region: Wasatch Range in Utah

The Wasatch Front region in north-central Utah contains 80% of the state’s population and is a dominant source of high seismic potential in the inter-mountain West. A magnitude 7.0 earthquake (M7) along the Wasatch Front on the Salt Lake City fault segment would cause massive impacts throughout this urban corridor and has been used by the emergency management community as a scenario for extensive planning efforts (EERI, 2015). As seen in Figure 6, most of Utah’s population centers are clustered along the seismically active Wasatch Fault. (Figure 6 was prepared by the University of Utah.)

Modeling tools like HAZUS\(^\text{15}\) give planners detailed information about community vulnerabilities, to help identify opportunities for risk mitigation and preparedness. In fact, casualty and infrastructure damage estimates for the M7 Wasatch earthquake have been used to drive adoption of “Fix the Bricks” – a successful Salt Lake City mitigation program aimed at reinforcing residential unreinforced masonry structures.

After HAZUS was used to determine the capital and labor losses, the ECAM system was deployed to estimate the economic impacts of an M7 earthquake event in the region. The results show an annual economic loss of $20 Billion USD, and approximately 170,000 jobs lost as a result of the event. Input data to ECAM is shown on the left (in blue) and output results from ECAM are shown on the right (in red).

\(^{15}\)HAZUS is a GIS-based tool maintained by FEMA to conduct impact assessments. Please see: https://www.fema.gov/flood-maps/products-tools/hazus for more information.
Table 1. Direct and Indirect Economic Results for Utah Earthquake

<table>
<thead>
<tr>
<th>Capital Loss (SK)</th>
<th>Capital Value (SK)</th>
<th>Labor Population</th>
<th>Labor Population Reduction</th>
<th>Lost GDP ($M)</th>
<th>Lost Jobs</th>
</tr>
</thead>
<tbody>
<tr>
<td>$74,981,260</td>
<td>$500,896,474</td>
<td>964,619</td>
<td>103,497</td>
<td>$20,035.43</td>
<td>179,777</td>
</tr>
</tbody>
</table>

According to the HAZUS assessment, direct losses to capital were $74.9 billion, compared to a capital stock of approximately $500 billion, and approximately 10% of workers would be displaced in this scenario. ECAM shows that this type of major event leads to an annual economic loss of approximately $20 billion, and 179 thousand job losses. While $20 billion is less than the capital destruction, this loss occurs every year until the infrastructure and population are returned to normal.

Given the importance of the M7 Wasatch earthquake scenario among emergency planners, the availability of indirect economic impact information derived using ECAM adds significant context to future planning efforts. The fact that indirect dollar losses represent 25% of total dollar losses incurred demonstrates the importance of understanding the long-term, significant impacts of major regional events.

Note that in this example, only a summary total was provided. It is also possible to decompose the total effect by economic sector – to see which sectors of the economy are most impacted. The additional context provided by ECAM is helping FEMA planners to better-target individual economic sectors, to increase economic resiliency going forward.

**Scenario #2: Flood Event in Michigan**

The next example is a flood event located in the northern state of Michigan. The Edenville and Sanford Dams are earthen embankment dams located along the Tittabawassee River in central Michigan. They were built in the early 20th century to produce hydroelectric power and also to supply flood risk management services.

During 16-18 May 2020, the surrounding counties of Arenac, Gladwin, Iosco, and Midland experienced a rain event with approximate annual chance of exceedance of .005 (EGLE, 2020). The intense rainfall, estimated between 6 and 8 inches, caused the Tittabawassee River to overflow. At approximately 5:30pm on May 19th, the earthen embankment of the Edenville Dam failed, resulting in a flood wave rushing downstream toward the town of Edenville and into the Sanford Lake, which was created by Sanford Dam. The flood wave continued to cause damage by also bursting the Sanford Dam.

A flood wave approximately over 6 meters tall was unleashed upon downstream residents. The flood wave shrank to approximately 1 meter tall within the next 20 kilometers. Due to a working flood warning system, approximately 11,000 people were successfully evacuated and no major injuries or loss of life were reported. However, approximately 2,500 structures were damaged by the floods resulting in an estimated $250 million in direct damage (EGLE, 2020). In Figure 7 below, an image of the breach of the Edenville dam can be seen on the left\(^\text{16}\), and an image

---

\(^{16}\) Source: https://www.americanrivers.org/2020/05/a-big-dam-problem-the-disaster-in-michigan-and-solutions-for-the-future/
of the resulting flooding in Sanford, Michigan is provided on the right\textsuperscript{17}.

\textit{Figure 7. Photo of Edenville Dam and the flooding in Sanford, Michigan}

\begin{center}
\begin{tabular}{|c|c|}
\hline
Photo: Edenville Dam Breach Event & Photo: Resulting Flood in Sanford, Michigan \\
\hline
\end{tabular}
\end{center}

The direct economic losses were computed at the United States Army Corps of Engineers. The HEC-Lifesim tool in conjunction with the National Structure Inventory (NSI) could be used to determine the capital costs (i.e., direct economic costs) of the dam failure event given hydraulic inputs from HEC-RAS. The direct economic modeling resulted in losses of $219.7 million and 5,600 people displaced across Bay, Gladwin, Midland, and Saginaw counties. A map of the extent of flooding is provided in Figure 8.

\textsuperscript{17} Source: https://www.scientificamerican.com/article/torrent-breaks-michigan-dam-and-reveals-climate-risks/
Next, these direct loss ratios were used to construct capital and labor loss ratios for the ECAM model. In this experiment, the time duration is an important consideration. The flood lasted 3 days, and the reconstruction required 180 days of displacement. Thus, the ratios are adjusted by the time of displacement as well as the size of displaced capital and labor.

The capital loss ratios for Gladwin and Midland Counties are significant enough to have a measurable indirect economic impact. Gladwin County is estimated to have experienced a capital loss ratio of 0.2% (assumed 0%) and a labor loss ratio of 1.5%. The capital and labor loss ratios for Midland County are 1.6% and 2.3%, respectively. These ratios were submitted to ECAM for each county to estimate indirect economic impacts. The ratios and their inputs are displayed in the table below.

**Table 2. Michigan Dam Failure Capital and Labor Loss Ratios**

<table>
<thead>
<tr>
<th>County Name</th>
<th>Non-residential Capital</th>
<th>Non-residential Capital Loss Ratio</th>
<th>2pm Population (Workforce)</th>
<th>Population displaced</th>
<th>Labor Hours Reduced</th>
<th>Labor Loss Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bay</td>
<td>$11,467 M</td>
<td>0.0000</td>
<td>96,399</td>
<td>637</td>
<td>638,289</td>
<td>0.0033</td>
</tr>
<tr>
<td>Gladwin</td>
<td>$1,598 M</td>
<td>0.0020</td>
<td>20,713</td>
<td>610</td>
<td>611,224</td>
<td>0.015</td>
</tr>
<tr>
<td>Midland</td>
<td>$9,134 M</td>
<td>0.0161</td>
<td>80,308</td>
<td>3,752</td>
<td>3,759,217</td>
<td>0.0234</td>
</tr>
<tr>
<td>Saginaw</td>
<td>$26,767 M</td>
<td>0.0002</td>
<td>198,464</td>
<td>1,224</td>
<td>1,226,375</td>
<td>0.0031</td>
</tr>
</tbody>
</table>

The results of the indirect economic analysis are summarized in the table below. Employment is expected to decrease by 1,485 full-time equivalent jobs in Midland County and by 115 in Gladwin County, while output is expected to decrease by $88.29 million in Midland County and $3.87 million in Gladwin County, annually.
Table 3. Indirect Economic Impacts for Michigan Dam Failure

<table>
<thead>
<tr>
<th>County</th>
<th>Pre-Shock Employment</th>
<th>Post-Shock Employment</th>
<th>Change in Employment</th>
<th>Pre-Shock Output (millions)</th>
<th>Post-Shock Output (millions)</th>
<th>Change in Output (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midland</td>
<td>50,091</td>
<td>48,606</td>
<td>-1,485</td>
<td>$4,137.51</td>
<td>$4,049.12</td>
<td>-$88.39</td>
</tr>
<tr>
<td>Gladwin</td>
<td>7,909</td>
<td>7,794</td>
<td>-115</td>
<td>$527.23</td>
<td>$523.36</td>
<td>-$3.87</td>
</tr>
</tbody>
</table>

The breaches of the dams on the Tittabawassee River are thus estimated to have caused a loss of 1,600 full-time equivalent jobs and $92.26 million in annual economic output. This impact added to the direct loss estimate of $219 million brings the total modeled loss to approximately $319 million, roughly 45% greater than the original direct loss estimate alone.

The indirect economic losses estimated for this dam failure event highlight the scope of the impact faced by communities downstream of a dam following the event. That is, in addition to the potential for loss of life and flood damage, downstream communities face reduced economic output and job loss. This intensifies the impact and increases the time necessary to recover. It is also common that these indirect impacts are borne disproportionately across income brackets with greater impact on those with less means to recover. Providing this information to decision makers can improve the efforts and the emphasis of post disaster aid beyond simple measures of direct loss.

Dollar Values and Inflation: Note that the results are based on the year the data were collected. The data year can be seen on the ECAM website, under “Available Regions”. Usually, the economic data will be 2-3 years old – due to lag times for collecting and organizing the final economic data. The user can report the results using the base year, but then must clearly indicate that the dollar impact is different than “current dollars”. For example, the results would indicate that the results are reported using ‘Year 2016 US Dollars’.

International (Barbados)

The final example shows how ECAM can be adapted for international use for scenario analysis for pre-disaster planning. In this case, we estimate the economic losses associated with a Category 5 hurricane moving across the Island State of Barbados. Several FEMA case studies were conducted in the area using the HAZUS system to facilitate transboundary data sharing. While the example here does not correspond exactly to a previous HAZUS study, it provides an example of how physical damage estimates can be used to generate parallel indirect impact estimates for the economy.
It was possible to adapt ECAM to Barbados because we already had a full Social Accounting Matrix (SAM). Typically, the creation or adaptation of the Social Accounting Matrix to international application is the largest cost when performing this sort of analysis. Depending on data availability, these inputs can be difficult to create or sometimes even impossible to realistically generate.

**Scenario Description**

The impact scenario corresponds to a Category 5 hurricane crossing directly over Barbados, with 155 mile-per-hour winds and corresponding storm-surge flooding. According to the direct economic loss analysis, 8.5% of hotels, residences, factories, and distribution centers are flooded and cannot be inhabited before extensive remediation work is done. 11.5% of the population is displaced for at least 6 months, either fleeing internationally, or residing with friends and relatives – for an effective average rate 6.0% reduction in workforce availability after the event.

Several transit corridors are damaged in this event, further limiting the ability for commerce and tourism on the Island for a duration of 6-12 months. For this exercise, the losses associated with transit disruptions are not included in the ECAM system, therefore, the ECAM losses will generally underpredict the significance of the real impact.

As inputs to ECAM, the following units are used:

**Figure 9. Hypothetical Hurricane Scenario for Barbados - Core ECAM Inputs**

<table>
<thead>
<tr>
<th>Ratio</th>
<th>6.0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective Labor Supply Loss</td>
<td>6.0%</td>
</tr>
<tr>
<td>Effective Capital Supply Loss</td>
<td>8.5%</td>
</tr>
</tbody>
</table>
Results

Figure 10. Economic Impact of Cat-V Hurricane in Barbados (Thousand Barbados Dollars $)

<table>
<thead>
<tr>
<th></th>
<th>Baseline (BBS)</th>
<th>Scenario (BBS)</th>
<th>Impact (BBS)</th>
<th>Impact (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-7.4%</td>
</tr>
<tr>
<td>Exports</td>
<td>2,616,819</td>
<td>2,358,455</td>
<td>-258,364</td>
<td>-9.9%</td>
</tr>
<tr>
<td>Imports</td>
<td>3,800,231</td>
<td>3,541,719</td>
<td>-258,512</td>
<td>-6.8%</td>
</tr>
<tr>
<td><strong>Tax Revenues</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Import Duties</td>
<td>207,028</td>
<td>192,907</td>
<td>-14,121</td>
<td>-6.8%</td>
</tr>
<tr>
<td>Hospitality VAT (Hotel Tax)</td>
<td>34,089</td>
<td>29,571</td>
<td>-4,519</td>
<td>-13.3%</td>
</tr>
<tr>
<td>Value Added Tax Revenues</td>
<td>1,106,715</td>
<td>1,031,662</td>
<td>-75,053</td>
<td>-6.8%</td>
</tr>
<tr>
<td>Excise Tax Revenues</td>
<td>144,899</td>
<td>134,212</td>
<td>-10,687</td>
<td>-7.4%</td>
</tr>
</tbody>
</table>

The results have been packaged using the standard ECAM format, together with some additional enhancements that were available for sovereign nations. The results highlight the importance of tourism on the island, with the largest losses coming from the Hotel & Accommodation sector. This sector declines almost twice as much as typical sectors do.

GDP declines by 7.4% in this scenario, with exports declining 9.9% and imports down by 6.8%. The fall in exports is intuitive, because it coincides with a fall in overall output. Imports however, might be expected to increase in order to compensate for shortages caused by domestic limitations. However, there are limits to how much can be imported, based upon the country’s balance of payments for hard currency. If exports decline, then imports must also decline, unless the country can borrow significant amounts of hard currency to fund the account deficit.

In some countries, the current account deficit occurs in conjunction with a rapid decline in the exchange rate. But Barbados maintains a fixed rate with the US Dollar (a 2 to 1 ratio), meaning that this rate would be left to free-fall, in case the pegged rate no longer holds. That is an unlikely outcome, even in the face of a severe hurricane. Instead, we see imports also decline, as required by Balance of Payments (BOP) accounting.

The macro results also show that government tax revenues decline between 6.8% – 13.3%, depending upon the tax stream. Hotel related revenues fall the most, while import duties and VAT revenues (which are often driven by imports) fall the least.
Detailed Results

The ECAM model also produces sector-by-sector activity results. This adds granularity to the event that is often of particular interest to different economic stakeholders. For example, the hotel and hospitality industry may use this information to show that they are more vulnerable to natural disasters compared to other sectors, and therefore they need more resiliency investment when compared to other businesses.

The detailed results show that capital-intensive sectors (especially fixed real-estate) decline in this scenario by more than their labor-intensive counterparts, reflecting the physical destruction wreaking havoc upon economic activity in a tourist region. There is also a reduction in capital availability and therefore a relatively higher price to get work done for those sectors. However, all sectors face a decline in one way or another. Next, detailed employment results are shown in the table below.

<table>
<thead>
<tr>
<th>Barbados Hurricane Impact -- Output / Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>bench</td>
</tr>
<tr>
<td>hotels apartments and guest houses</td>
</tr>
<tr>
<td>distribution</td>
</tr>
<tr>
<td>general administration</td>
</tr>
<tr>
<td>construction</td>
</tr>
<tr>
<td>business and professional services</td>
</tr>
<tr>
<td>communications</td>
</tr>
<tr>
<td>finance</td>
</tr>
<tr>
<td>transportation</td>
</tr>
<tr>
<td>education services</td>
</tr>
<tr>
<td>restaurants</td>
</tr>
<tr>
<td>electricity and gas</td>
</tr>
<tr>
<td>real estate</td>
</tr>
<tr>
<td>insurance</td>
</tr>
<tr>
<td>health services</td>
</tr>
<tr>
<td>personal services</td>
</tr>
<tr>
<td>beverage and tobacco manufacturers</td>
</tr>
<tr>
<td>meat poultry and vegetable processors</td>
</tr>
<tr>
<td>computer services</td>
</tr>
<tr>
<td>grain feed and flour manufacturers</td>
</tr>
<tr>
<td>livestock and dairy producers</td>
</tr>
<tr>
<td>non-metallic mineral products</td>
</tr>
<tr>
<td>bakeries confect. &amp; other food prod. mfgrs.</td>
</tr>
<tr>
<td>collection purification &amp; distribution of water</td>
</tr>
<tr>
<td>dairy product manufacturers</td>
</tr>
<tr>
<td>publishing and printing</td>
</tr>
<tr>
<td>electrical and electronic equipment</td>
</tr>
<tr>
<td>chemicals and chemical products</td>
</tr>
<tr>
<td>textile clothing &amp; accessories</td>
</tr>
<tr>
<td>fishing</td>
</tr>
<tr>
<td>other miscellaneous services</td>
</tr>
<tr>
<td>prefabricated metal prod. &amp; mfg.</td>
</tr>
<tr>
<td>equipment rental</td>
</tr>
<tr>
<td>crude petroleum and natural gas extraction</td>
</tr>
<tr>
<td>sugar refineries</td>
</tr>
<tr>
<td>furniture</td>
</tr>
<tr>
<td>other manufacturing</td>
</tr>
<tr>
<td>vegetable producers</td>
</tr>
<tr>
<td>paper and paper products</td>
</tr>
<tr>
<td>rubber and plastic products</td>
</tr>
<tr>
<td>sugar cane producers</td>
</tr>
<tr>
<td>precision and optical instruments</td>
</tr>
<tr>
<td>quarrying of stone sand and clay</td>
</tr>
<tr>
<td>Total Output Levels:</td>
</tr>
</tbody>
</table>

For Barbados, the results are denominated in thousands of Barbados Dollars. This was used because employment count data was not available at the time of writing. Most labor departments do have a “count” of the number of employees for each sector, so that changes to output and spending can be used to determine the number of employees who would lose work as an effect of the Hurricane.
Hotels and accommodation also experience the largest reduction in employment – as measured by Payroll Spending.

Requirements to use ECAM International

The ECAM model can be adapted for most countries, provided they have a balanced and detailed Social Accounting Matrix (SAM). The level of detail is determined by the dataset.

If a SAM is available, then the dataset must first be re-organized to comply with accounting conditions required by the ECAM model (supply-demand balance, income-constraints, production-consumption conditions). If all of the conditions are met, and the SAM is organized into a format that ECAM can read, then a new model can be generated and used for indirect economic analysis in the target country.

Challenges & Future Work

As with any project, there are strengths and weaknesses arising over time as social priorities change and as technology evolves. Some of the challenges that ECAM has faced are described here.

Improving accuracy and tolerance for small hazard events

A persistent challenge in regional economic analysis is the need to assess very small regional scenarios. Small dams located in remote counties typically have little economic activity. The dataset for these counties can be quite sparse, with only 20-30 of the 440 sectors operating at all. These missing sectors can cause failures within the ECAM computer code, especially when the sector is typically an area of focus for the analysis. For example, irrigation water is a typical input parameter for rural-area scenarios. But for some datasets, the farming sector will show no production, leading to a failure in the model. This, and other small details, can cause errors when trying to calculate the impacts to non-existent or very small sectors.
The ECAM model could benefit from improved handling of these regional areas with small economies. The task may require some reconsideration of the underlying economic principles used in a typical CGE model, compared to the economic realities facing a small, regional economy. Improved tolerance for small economies will also require more robust computer programming. The new programming must be intelligent enough to identify when certain sectors are small or missing, and to seamlessly work around them.

**Effect of Model Area Size**

A natural hazard causes a diverse set of damages across different regions. Often, the modeling team will choose a large region to capture the full extent of the damages. However, such a choice is often a mistake. In a flood event, for example, different regions will face different impact types. Those areas that lie within the direct flood path will be extensively damaged, while other areas may only face a slight rise in water level.

If the region is large, then each effect is amplified onto non-impacted areas, causing large impacts that are not accurate. Instead, teams in the U.S. learned that it's better to keep the regions smaller (e.g., at the county level, rather than state level) and to apply hazard impacts independently to each small region. The overall impact is then computed by combining the separate effects. In general, accuracy is typically higher by separating the regions — especially according to their key attributes and by impact type — rather than aggregating regions according to their geographical proximity. This was an unexpected finding by the study team.

**Applying ECAM to Different Hazard Types**

The ECAM concept was originally developed for a range of potential terrorist threats, during the period just after 9/11 in the United States. The formalized system was then created to model uncontrolled dam-release flood events. Over time, it became clear that the ECAM approach could be applied to several hazard types, so long as the damage parameters were labor and capital. This is the core of the current system.

At different points in time, there were tailored variants of ECAM that captured specific impacts, such as the losses associated with recreation area damage. While the results from these tailored versions were interesting to the specific researchers, the total damages were not significantly different between tailored variants and the non-tailored model (e.g., less than 10%). Instead, simply computing labor and capital reductions generally captured 90% of the overall economic impacts.
Occasional Counter-Intuitive Results

While overall output generally declines for almost all hazard events, it is possible for some or even several sectors to increase output despite the reduction in labor and capital supplies. This type of effect is driven by the relative supply and demand of resources. For example, demand for drinking water typically increases sharply during a hazard event. Output or transport of drinking water can increase sharply due to the spike in demand for this product. Similarly, if certain resources such as manual labor are suddenly freed up, then the price of this resource will decline, leading to an opportunity to use this input more intensively, lower costs, and higher sales. While the overall effect of increasing output seems counter-intuitive at first, it is reasonable after considering how the effect was generated (e.g., increased demand, or decreased input costs).

Of course, if the results appear to be consistently counter-intuitive, this should lead the researcher to investigate whether the model itself has properly solved. At times, the model does not solve due to peculiar data or a uniquely challenging scenario. Even if the model has not properly solved, the computer will still report the results, as they were when the model has stopped – leading to confusing – and incorrect answers.
References


Annex A: Terminology and Notes

This annex provides definitions for some terminology that is used here. A number of words used in this report are either similar, or even identical, to words used elsewhere under different contexts, so the definitions below may be helpful to explain exactly what is being measured – or not measured – using this approach.

### Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOR</td>
<td>Bureau of Reclamation</td>
</tr>
<tr>
<td>CES</td>
<td>Constant Elasticity of Substitution Function</td>
</tr>
<tr>
<td>CGE</td>
<td>Computable General Equilibrium</td>
</tr>
<tr>
<td>CGI</td>
<td>Common Gateway Interface</td>
</tr>
<tr>
<td>DHS</td>
<td>U.S. Department of Homeland Security</td>
</tr>
<tr>
<td>ECAM</td>
<td>Economic Consequences Assessment Model</td>
</tr>
<tr>
<td>GAMS</td>
<td>Generalized Algebraic Modeling System</td>
</tr>
<tr>
<td>IMPLAN</td>
<td>IMPact PLANning Group - Dataset</td>
</tr>
<tr>
<td>M&amp;I</td>
<td>Municipal &amp; Industrial</td>
</tr>
<tr>
<td>MPSGE</td>
<td>Mathematical Programming System for General Equilibrium</td>
</tr>
</tbody>
</table>
Annex B: Data Details and Examples

Although the examples are primarily for the United States, economic datasets exist for nearly all countries worldwide. The datasets used here are roughly equivalent to the NAICS 3-digit economic coding system (similar to ISIC-3 digit). An example mapping between the detailed sector descriptions and the corresponding NAICS codes is listed below as an example. In almost all cases, the full 440 sector database is highly cumbersome, and a 30-sector aggregated dataset is most suitable. This 30-sector dataset is described next.

30-Sector Dataset

In order to provide a faster, and more targeted set of results, we find it best to aggregate the original data into a small, 30-sector dataset. This smaller dataset combines 10 to 15 sectors into a single, larger sector. As a result, most of the sectors are active (non-zero) in almost all counties, and the model solves very quickly, in about 10 seconds. Comparison testing shows that the aggregated 30-sector model results correspond closely with the 440-sector model. Total output changes are typically within 5% of each other when considering standard labor and capital reductions.

The 30-sector aggregation is below it has become the “standard” model size. A brief description of each sector is described in the figure below.

Figure 12. Description of ECAM Model Sectors - The current model distinguishes 30 sectors
Annex C: Manual Calculation of Capital and Labor Loss Ratios

Capital Loss Ratio

Capital losses include damages to non-residential buildings and functional structures such as roads, bridges, and industrial or computerized equipment. Provide this input as a ratio: capital lost to initial available capital. When computing the ratio, ensure that the numerator (modeled lost capital) reflects the same data as the denominator (total initial available capital). For example, if the total available capital does not reflect bridges as an asset, do not to use losses to bridges in the direct economic capital lost.

As described above the capital loss ratio should reflect productive (non-residential) capital. The first step in computing the capital loss ratio is to compute the total capital ($T_{Cc}$) of all non-residential capital in a county ($c$).

$$T_{Cc} = TIC_{c} + TCC_{c} + TPC_{c}$$

Where:

- $TIC_{c}$ is the total non-residential capital for a county ($c$)
- $TCC_{c}$ is the total commercial capital for a county ($c$)
- $TPC_{c}$ is the total public capital for a county ($c$)

The total available capital can be determined using county parcel data or other data sources like FEMA’s Hazus inventory data or the National Structure Inventory. Data for the entire county (not just the impacted area) must be supplied.

Calculate the total lost capital by summing the damage for each structure category. The damage estimates should be based on the same exposed values used in the $T_{Cc}$ expression above. If content values are used, then content damage should be included in the estimate of damages. If content values are not used, then content loss should not be included in the capital loss ratio. The total lost capital ($L_{Cc}$) for a county ($c$) is expressed as follows:

$$L_{Cc} = LIC_{c} + LCC_{c} + LPC_{c}$$

Where:

- $LIC_{c}$ is total lost industrial capital for a county ($c$)
- $LCC_{c}$ is total lost commercial capital for a county ($c$)
- $LPC_{c}$ is total lost public capital for a county ($c$)
Finally, dividing the \((\text{LC}_c)\) and \((\text{TC}_c)\) for a county \((c)\) computes the capital loss ratio \((\text{CLR})\). This ratio, which cannot be greater than one nor less than zero, is calculated as shown below:

\[
\text{CLR}_c = \frac{\text{LC}_c}{\text{TC}_c}
\]

**Labor Loss Ratio**

Labor losses occur due to the displacement of employed individuals or the removal of such individuals from the workforce. Labor loss ratios should reflect the reduction in the workforce as a percentage of the workforce prior to the hazard. Provide this input using an approach similar to the one described with capital loss ratios. The same assumptions used in the generation of the denominator of the labor loss ratio must be carried through in the computation of the numerator of the loss ratio.

One way to compute labor losses would be to assume the labor force is uniformly distributed across the entire population. To carry out this computation, utilize the population for all structures within the structure inventory that are impacted by a hazard. This implies that the population in both residential and non-residential structures will be utilized to calculate labor loss. The assumption of using the entire population for labor loss ratios implies that the distribution of laborers and non-laborers within the study area is homogeneous, both geospatially and temporally. This means that this method assumes that for a given county, the percentage of workers in the population during the day is the same as at night (the workers mostly live in the county they work in) and that the percentage of workers are evenly distributed in structures in and out of the area of impact.

The first step is to determine how long the event impacts the workforce. This impact duration \((\text{ID})\) should reflect the duration of the event \((e)\) itself, the time to clean up post event, and the time required to reconstruct any damaged infrastructure (or housing) limiting workforce participation.

\[
\text{ID}_e = \text{De} + \text{Ce} + \text{Re}
\]

Where:

\(\text{ID}_e\) is the duration of the impact to the workforce for an event \((e)\) in hours

\(\text{De}\) is the duration of the event \((e)\) in hours

\(\text{Ce}\) is the time to cleanup from the event \((e)\) in hours

\(\text{Re}\) is the time required for reconstruction from the event \((e)\) in hours

\(\text{ID}_e\) may not exceed 8,766 hours (equivalent to one year, or 365.25 days).
Compute the workforce \((WF)\) for the county \((c)\) by determining the population \((P)\) in all structures \((N)\).

\[
WF_c = \sum_{n=1}^{N} P_n
\]

Where:

- \(WF_c\) is the workforce in the county \((c)\)
- \(P_n\) is the population in the \(n\)th structure in the county \(N\)
- \(N\) is the total count of structures in the county

Compute the population displaced \((PD)\) for the county \((c)\) by determining the population \((P)\) in all structures \((N)\) impacted by the event \((e)\). If it is possible for the user to compute life loss from the event, the life loss population would need to be removed from the population displaced.

\[
P_D c = \sum_{n=1}^{N} e P_n
\]

Where:

- \(P_D c\) is the population displaced in the county \((c)\)
- \(P_n\) is the population in the \(n\)th structure in the county
- \(N_e\) is the total count of structures impacted by the event \((e)\) in the county

Next compute the number of labor hours reduced \((LHR)\) for the working population across the county \((c)\) by computing the ratio of labor hours in a year, using that ratio to calculate the fraction of the duration of impact \((IDe)\) that affects labor hours, and multiplying through by the displaced population:

\[
LHR_c = IDe \times (2000 \times 365.25 \times 24) \times P_D c
\]

Where:

- \(LHR_c\) is the labor hours reduced in the county due to the event \((e)\) in labor hours
- \(IDe\) is the duration of the impact to the workforce for an event \((e)\) in hours
- 2000 is the number of working hours per laborer per year
- 365.25 is the number of days per year
- 24 is the number of hours per day
- \(P_D c\) is the total population displaced in the county \((c)\)
Finally, compute the labor loss ratio ($LLR_c$) for the county ($c$) by dividing the labor hours reduced ($LHR_c$) by the product of the workforce ($WF_c$) for the county ($c$) and the number of working hours for a year. This ratio, which cannot be greater than one nor less than zero, is shown below:

$$LLR_c = \frac{LHR_c}{WF_c \times 2000}$$

Where:

$LLR_c$ is the Labor Loss Ratio for the county ($c$)
$WF_c$ is the workforce for the county ($c$)
$LHR_c$ is the labor hours reduced for the county ($c$)
2000 is the number of working hours per laborer per year