PRESENTACIÓN ***ÍNDICE***

PRESENTACIÓN

A través de la cooperación técnica del Acuerdo de la Paz firmado por México y los Estados Unidos en el año de 1983, el Instituto Nacional de Ecología de la SEMARNAP, con el apoyo de la Agencia de Protección Ambiental de los Estados Unidos (EPA) y la Asociación de Gobernadores del Oeste (WGA), inició en 1995 el *Proyecto de Inventarios de Emisiones para México*, cuyo objetivo es dotar de herramientas básicas para la planeación, desarrollo y mantenimiento de esta componente estratégica para llevar a cabo programas de mejoramiento y preservación de la calidad del aire en México.

El proyecto comenzó con la elaboración de una Metodología para México y de un Plan de Ejecución e incluye así mismo un curso completo de inventarios de emisiones, manuales para la planeación y estimación de las emisiones de las fuentes contaminantes, estudios de aplicación de la Metodología, entre otros.

Esta versión electrónica del documento tiene como propósito proporcionar el material ya elaborado en idiomas ingles y español, que seguramente tendrá una audiencia nutrida.

A lo largo del proyecto hemos tenido la valiosa supervisión del *Comité Binacional Asesor*, que ha sido integrado por los siguientes expertos:

William B. Kuykendal, U.S. Environmental Protection Agency
Gerardo Rios, U.S. Environmental Protection Agency
William Jones, U.S. Environmental Protection Agency
John R. Holmes, State of California Air Resources Board
Carl Snow, Texas Natural Resources Conservation Commission
Gary Neuroth, Arizona Department of Environmental Quality
George Mike, Arizona Department of Environmental Quality
John T. Leary, Western Governors Association
Richard Halvey, Western Governors Association
Victor Hugo Páramo F., Instituto Nacional de Ecología
Jorge Sarmiento Rentería, Instituto Nacional de Ecología

Las fases iniciales del proyecto fueron contratadas con la compañía consultora Radian Internacional y posteriormente con sus sucesoras que han brindado la expertise de sus ingenieros y científicos a lo largo del proyecto.

Los materiales subsecuentes que se vayan elaborando podrán ser obtenidos directamente de la página Web del INE:

http://www.ine.gob.mx/dggia/cal_aire/

Dr. Adrián Fernández Bremauntz
Director General de Gestión e
Información Ambiental
Instituto Nacional de Ecología

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Methods Evaluation and Proposal for

Mexico Emissions Inventory Program

Prepared for:

Western Governors' Association and
Binational Advisory Committee
Denver, Colorado

August 1995

670-017-05-01
August 24, 1995

John T. Leary
Project Manager
Western Governors' Association
600 17th Street
Suite 1705, South Tower
Denver, CO 80202

Subject: Mexico Inventory Methods Evaluation and Proposal

Dear John:

Please find enclosed the revised Methods Evaluation and Proposal for the Mexico Inventory Program. Previously, we submitted these materials in draft form as two separate documents. For the final submittal, we have combined the draft materials into one consistent document. The enclosed material also reflects the comments we received from INE.

If there are any questions regarding the enclosed material, you may call me at 916-857-7467.

Sincerely,

Ronald J. Dickson
Senior Staff Engineer

c: Binational Advisory Committee
Dr. José Ortega, Corporación Radian

670-017-05-01

METHODS EVALUATION AND PROPOSAL

FOR

MEXICO EMISSIONS INVENTORY PROGRAM

FINAL

Prepared for:

Western Governors' Association
Denver, Colorado

and

Binational Advisory Committee

Prepared by:

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Radian Corporation
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August 23, 1995

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LIST OF ACRONYMS

AIRS	-	Aerometric Information and Retrevial System
AMS	-	Area and Mobile Sources
BAC	-	Binational Advisory Committee
CAINTRA	-	Cámara de la Industria de la Transformación
CEC	-	Commission of the European Communities
CEM	-	Continuous Emissions Monitor
CO	-	Carbon Monoxide
DDF	-	Department of the Federal District
EEA	-	Energy and Environmental Analysis, Inc.
EPA	-	Environmental Protection Agency
FIRE	-	Factor Information Retrevial System
FTIR	-	Fourier Transform-Infrared
FTP	-	Federal Test Procedure
GHG	-	Greenhouse Gas
IMP	-	Mexican Petroleum Institute
INE	-	National Institute of Ecology
INEGI	-	Instituto Nacional de Estadística, Geografía e Informática
LIDAR	-	Light Detection and Ranging
LULC	-	Land Use/Land Cover
MARI	-	Mexico City Air Quality Research Initiative
NO	-	Nitrogen Oxide
NO_x	-	Oxides of Nitrogen

LIST OF ACRONYMS (CONTINUED)

PEMEX	-	Petróleos Mexicanos
PM_{10}	-	Particulate Matter Less than 10 Micrometers in Aerometric Diameter
$PM_{2.5}$	-	Particulate Matter Less than 2.5 Micrometers in Aerometric Diameter
QA	-	Quality Assurance
QC	-	Quality Control
SCC	-	Source Classification Codes
SIP	-	State Implementation Plan
SO_2	-	Sulfur Dioxide
TSP	-	Total Suspended Particulate
U.S.	-	United States
VKT	-	Vehicle Kilometers Traveled
VOC	-	Volatile Organic Compound
WGA	-	Western Governors' Association
WHO	-	World Health Organization

FINDINGS AND PRELIMINARY RECOMMENDATIONS

This document presents an analysis of emission estimating techniques (or methods) that could be applied to develop a comprehensive inventory for the country of Mexico. The analysis focuses on methods that can be used in the near term to develop initial estimates as well as more sophisticated methods that can be developed and used over time to refine the initial estimates.

Prior to conducting this analysis, the current inventory status in Mexico was examined. The materials presented in this document build upon the on-going inventory efforts in Mexico City and other urban areas.

Identification of Inventory Methods

The inventory methods discussed in the methods analysis were identified by examining techniques currently used in Mexico, Europe, Asia, and the United States (U.S.). Inventory techniques developed by the World Health Organization (WHO) and techniques used to develop global scale greenhouse gas (GHG) emissions inventories were also evaluated. Six different methods formed the basis of this analysis:

- Source sampling (direct and indirect);
- Modeling;
- Surveying;
- Use of census-based emission factors and activity data;
- Material balance (raw materials, fuel consumption); and
- Extrapolation.

In some cases, two or more of these methods were combined in order to produce hybrid methods to better address the needs of the Mexican inventory process.

Methodology Evaluation Approach

The analysis was performed using a set of criteria that examined the cost effectiveness, practicality, uncertainty, and upgrade potential for each method. Each inventory method was evaluated for its general application in Mexico and also on a source type basis. This detailed methods evaluation was performed in a matrix format by ranking each method using the four criteria. This approach results in the identification and analysis of several candidate methods for each source type.

Summary of Methods Evaluation Findings

Our understanding of the current status of emissions inventory development in Mexico, Europe, and Asia indicates that U.S. methods are typically applied throughout the world. Thus far, we have not identified any new or significantly different approaches for developing emissions inventories from the methods that are typically used in the U.S.

Our review of the *Rapid Source Inventory Techniques (Economopoulos, 1993)* developed in Greece for the WHO indicates a very simple emission factor approach is recommended for developing countries. The country of Mexico is capable of supporting a more sophisticated approach, yielding more precise estimates than can be developed with the WHO approach.

The available documentation for the WHO approach provides a tabular listing of emission factors without any supporting documentation. Therefore, the source and derivation of these emission factors is not clear to us at this time. In terms of ease of use, the WHO emission factors are generally equivalent to U.S.-based emission factors, although in some instances, the WHO factors may be easier to apply because some process operations have been aggregated into one emission factor. For example, several petroleum refinery sources are aggregated into one single emission factor. This aggregation, and the lack of emission factors for many processes, will tend to yield a higher level of uncertainty if only the WHO emission factors are used.

The approach to developing GHG inventories is intriguing, and in some cases, potentially beneficial to the development of the Mexico Inventory Program. Some of the concepts used in developing GHG inventories appear to be useful in the context of developing *emission estimation models*. The approaches taken in GHG inventory development also appear promising as inventory evaluation tools. We envision that most emission estimates in Mexico will be developed at the local and state level using source sampling, surveys, and census-based emission factors (i.e., a bottom-up approach). The top-down approaches used to develop GHG inventories are not considered as accurate, but they can be used to evaluate the reasonableness of emission estimates developed from bottom-up techniques.

The remainder of this section summarizes the findings for the general applicability to Mexico of each inventory method evaluated.

Source Sampling. For many large point sources, source sampling will be the most appropriate method for estimating emissions. As part of this effort, we evaluated the potential benefits of using indirect source measurement techniques, such as Fourier transform-infrared (FTIR) remote sensing. We examined this technology to see if it could possibly streamline and simplify the source sampling process. We determined that remote sensing provides numerous benefits when monitoring speciated emission estimates (e.g., air toxics) or volume sources that do not have stack emissions, such as open burning dumps. Remote sensing, however, has two important limitations when considered for routine monitoring of stack emissions. An FTIR system has a rather high purchase cost (~$180,000 per unit) and requires specialized training and expertise to use properly. Advantages include quick and efficient measurement of speciated hydrocarbons such that when applied on a large scale basis, capital costs are offset. Nonetheless, these constraints may limit the widespread use of this technology.

Emission Models. To aid in the methods evaluation, we continually asked ourselves: How could emission estimates be developed if there were no source sampling, survey, or statistical information available upon which to base emission calculations? For many source types, answering this question resulted in the concept of a "multivariate model." In this approach, emission estimates would be expressed as a function of a set of variables that help characterize a system. For example, satellite imagery data could be used to develop a predictive model for all non-industrial source emissions associated with typical day-to-day human activity (e.g., residential fuel consumption, residential solvent use, open burning, etc.). Non-industrial emissions could be characterized as a function of standard of living, population density, climate, and social practices. By combining micro-inventory and field survey techniques with socioeconomic information, predictive models could be developed with land use/land cover (LULC) data obtained from satellite imagery as the basis. This would result in an emissions flux that would be a function of the LULC type (e.g., agricultural land will have different emission characteristics than high density urban land). This approach could be further augmented using the concepts of fuzzy logic to help factor in geographic and standard of living differences.

A multivariate modeling approach appears most applicable to regions that have insufficient information to apply traditional inventory techniques and for source types where it is difficult to develop activity data, such as nonroad mobile sources and solvent utilization. This approach will require a greater amount of initial resources to develop, but it will be less resource intensive to apply and maintain. Section 3.0 provides further examples and detail on this new concept.

Even if a multivariate approach is not taken, serious consideration should be given to developing satellite imagery data for the entire country. These data can used to augment not only the air quality planning process but possibly other environmental programs as well. We currently estimate the cost of obtaining and processing satellite imagery data for the country of Mexico at $1.3 million.

Surveying. This is a useful tool so long as the information needed for emission calculations can be obtained through a survey. The National Institute of Ecology (INE) is currently using a survey approach to gather information that is used to develop a national point source inventory. This survey effort primarily collects combustion emissions, and in the Mexico City area and some other regions, source test results are reported in the survey responses. As the survey effort is expanded to include other source types and more geographic regions, emission factors will be required to estimate some emission estimates. The representativeness of survey-based emission estimates in Mexico for non-combustion source types is therefore highly dependent upon the applicability of current emission factors to Mexico. The extent to which current emission factors are applicable to Mexico is currently unknown and should be evaluated as a part of this overall effort. Recommendations to address this issue will be presented in the Task 6 Implementation Plan.

Use of Census-Based Emission Factors and Activity Data. This approach represents a quick and efficient method for developing emission estimates. This method also tends to have a higher level of uncertainty than other methods. When current census-based emission factors are applied in Mexico, the uncertainty is expected to be even larger because of socioeconomic and cultural differences between Mexico and the regions from which the available emission factors were developed. As stated above for surveying, additional research is needed to determine the applicability of the existing census-based emission factors to Mexico and refine them as necessary. This includes developing geographic-specific emission factors for different regions of Mexico.

Material Balance. Material balance calculations can also have a large degree of uncertainty compared to other methodologies. Nonetheless, there appear to be certain area source categories where a material balance may be the most cost effective and practical approach. A few potential examples for Mexico include national and/or regional fuel and solvent balances.

The use of material balances may also be a viable method for evaluating emission estimates developed with other methods, such as surveys. A material balance can be used to check the reasonableness of emission calculations performed using other methods.

Extrapolation. This is generally considered the least accurate method for estimating emissions. For several of the source types evaluated, extrapolation was considered as an emissions inventory development methodology with emissions extrapolated from one geographic region to another. Extrapolating emissions from the U.S. to Mexico has limited applicability because of socioeconomic and cultural differences between the two countries.

Care must also be taken in extrapolating emissions from one region in Mexico to another. The recently completed Mexico City Air Quality Research Initiative (MARI) determined through air quality modeling and data analysis techniques that the 1991 base year VOC inventory used for MARI was low by a factor of four (LANL and IMP, 1994). This conclusion was reached through air quality modeling and ambient monitoring data combined with data analysis techniques. Therefore, extrapolating emissions from Mexico City may result in an underestimation of emissions in other regions. This finding clearly indicates that careful consideration must be given to the development of adequate inventory methods and tools in order to more accurately reflect conditions in Mexico.

Methodology Proposal. With the exception of extrapolation, the methodology proposal uses each of the six methods detailed above. For some source types, two or more methods are combined resulting in hybrid methods that allow for better emissions estimates.

Several of the methods contained in this methodology proposal also rely on emission factors. For both point and area sources, the applicability of existing emission factors to Mexican sources is largely unknown. At this time, we know that emission factors used in Mexico City have been modified for asphalt paving and consumer solvents. We also suspect that the combustion of combustóleo will result in different emission characteristics that cannot be represented by existing emission factors. As part of the implementation plan, we recommend establishing a process to evaluate the existing emission factors with source test results that have already been conducted in Mexico. This process would be carried out under the project's Phase II activities.

Finally, it should be noted that the methods evaluation conducted under Task 4 was extended to provide a ranking for each inventory method/source type combination in the context of an inventory program by considering application of the method in the near- and long-term. We added this distinction to recognize that the inventory program can not initially apply the most desirable method for each and every source category. Resource and time constraints will require the application of simpler methods for certain source categories in the near-term that will be refined over the long-term as the inventory program matures. The methods proposal, therefore, is presented here in light of future updates so that the INE and other agencies in Mexico can build upon this effort.

In the near term, the methodology proposal relies extensively on the use of emission factors. As the emission factor evaluation is performed, simple adjustments to the factors should be developed, if possible. Developing these adjustments is the first step in developing multivariate emission models.

Point Source Methodology Proposal

Table 1 lists the recommended methods for each point source type. For many point sources, source sampling and/or surveying is the recommended approach. Source sampling every point source is impractical; therefore, source sampling resources should be used for the largest emission sources, such as electric utilities. Emission estimates for many of the sources that are not sampled can be developed using a facility survey and emission factor approach. The combination of source sampling and surveying is not new to Mexico. These activities have been on-going at INE for some time. To develop a complete point source inventory, we recommend increasing the amount of source sampling and surveying that is currently being performed.

Table 1

Proposed Methods for Point Sources

Major Category	Subcategory	Priority[a]	Near - Term Recommendation	Long - Term Recommendation
Electric Utility	Combustion by Fuel Type	1	Source Sampling / Direct	Source Sampling / Direct
Industrial and Commercial Fuel Combustion	By Fuel Type	1	Surveying / Emission Factors	Source Sampling / Direct
Chemical Manufacturing	Process Emissions	1	Surveying / Emission Factors	Source Sampling / Direct
	Combustion Emissions	1	Surveying / Emission Factors	Source Sampling / Direct
	Fugitives From Equipment Leaks	1	Survey / Multivariate Model	Source Sampling / Indirect
	Storage Tanks	1	Survey / Mechanistic Model	Survey / Mechanistic Model
	Miscellaneous Solvent Usage	3	Survey / Material Balance	Survey / Material Balance
Petroleum Refining	Process Emissions	1	Source Sampling / Direct	Source Sampling / Direct
	Combustion Emissions	1	Surveying / Emission Factors	Source Sampling / Direct
	Fugitives From Equipment Leaks	1	Survey / Multivariate Model	Source Sampling / Indirect
	Storage Tanks	1	Survey / Mechanistic Model	Survey / Mechanistic Model
	Miscellaneous Solvent Usage	3	Survey / Material Balance	Survey / Material Balance
Primary Metal Production	Process Emissions	1	Source Sampling / Direct	Source Sampling / Direct
	Combustion Emissions	1	Surveying / Emission Factors	Source Sampling / Direct

Table 1

(Continued)

Major Category	Subcategory	Priority[a]	Near - Term Recommendation	Long - Term Recommendation
	Fugitive Emissions	2	Survey / Material Balance	Survey / Material Balance
Secondary Metal Production	Process Emissions	2	Surveying / Emission Factors	Source Sampling / Direct
	Combustion Emissions	1	Surveying / Emission Factors	Source Sampling / Direct
Cement Production	Process Emissions	1	Surveying / Emission Factors	Source Sampling / Direct
	Combustion Emissions	1	Surveying / Emission Factors	Source Sampling / Direct
	Fugitive Emissions	2	Surveying / Emission Factors	Source Sampling / Indirect
Miscellaneous Mineral Products (e.g. lime and aggregate kilns)	Process Emissions	1	Surveying / Emission Factors	Source Sampling / Direct
	Combustion Emissions	1	Surveying / Emission Factors	Source Sampling / Direct
	Fugitive Emissions	2	Surveying / Emission Factors	Source Sampling / Indirect
Automotive Industry	Process Emissions	1	Surveying / Emission Factors	Source Sampling / Direct
	Combustion Emissions	1	Surveying / Emission Factors	Source Sampling / Direct
	Fugitive Emissions	2	Surveying / Emission Factors	Source Sampling / Indirect
Wood Pulping Operations	Process Emissions	1	Surveying / Emission Factors	Source Sampling / Direct
	Combustion Emissions	1	Surveying / Emission Factors	Source Sampling / Direct

Table 1

(Continued)

Oil and Gas Production	Process Emissions	1	Surveying / Emission Factors	Source Sampling / Direct
	Fugitive Emissions	1	Surveying / Emission Factors	Source Sampling / Indirect
	Combustion Emissions	1	Surveying / Emission Factors	Source Sampling / Direct
	Storage Tanks	1	Survey / Mechanistic Model	Survey / Mechanistic Model
Printing and Publishing	Process Emissions	1	Surveying / Emission Factors	Surveying / Emission Factors
	Fugitive Emissions	2	Survey / Material Balance	Survey / Material Balance
Surface Coating	Process Emissions	1	Survey / Material Balance	Survey / Material Balance
	Degreasing Emissions	1	Survey / Material Balance	Survey / Material Balance
	Fugitive Emissions	1	Survey / Material Balance	Survey / Material Balance
Bulk Fuel Terminals	Loading Operations	1	Surveying / Emission Factors	Surveying / Emission Factors
	Storage Tanks	1	Survey / Mechanistic Model	Survey / Mechanistic Model
Mining and Quarrying	Process Emissions	1	Surveying / Emission Factors	Source Sampling / Indirect
	Fugitive Emissions	2	Surveying / Emission Factors	Source Sampling / Indirect
Wood Products Manufacture	Process Emissions	2	Surveying / Emission Factors	Surveying / Emission Factors
	Combustion Emissions	2	Surveying / Emission Factors	Source Sampling / Direct
Sugar Production	Process Emissions	2	Surveying / Emission Factors	Source Sampling / Direct
	Combustion	2	Surveying / Emission Factors	Source Sampling / Direct

Table 1

(Continued)

	Emissions			
	Fugitive Emissions	2	Surveying / Emission Factors	Source Sampling / Indirect
Tanning and Leather Finishing	Process Emissions	2	Surveying / Emission Factors	Source Sampling / Direct
	Combustion Emissions	2	Surveying / Emission Factors	Source Sampling / Direct
	Fugitive Emissions	2	Surveying / Emission Factors	Source Sampling / Indirect
Glass Production	Process Emissions	2	Surveying / Emission Factors	Source Sampling / Direct
	Combustion Emissions	2	Surveying / Emission Factors	Source Sampling / Direct
	Fugitive Emissions	2	Surveying / Emission Factors	Source Sampling / Indirect
Rubber and Plastic Parts	Process Emissions	2	Surveying / Emission Factors	Surveying / Emission Factors
	Combustion Emissions	2	Surveying / Emission Factors	Source Sampling / Direct
Fabricated Metal Products	Process Emissions	2	Surveying / Emission Factors	Surveying / Emission Factors
	Combustion Emissions	1	Surveying / Emission Factors	Surveying / Emission Factors
Textile Products	Process Emissions	2	Surveying / Emission Factors	Surveying / Emission Factors
	Combustion Emissions	1	Surveying / Emission Factors	Source Sampling / Direct
Solid Waste Disposal	Landfill Gas Emissions	3	Survey / Mechanistic Model	Survey / Mechanistic Model
	Open Burning Dump	2	Source Sampling / Indirect	Source Sampling / Indirect

Table 1

(Continued)

	Municipal Waste Combustors	1	Source Sampling / Direct	Source Sampling / Direct
Miscellaneous Industrial Activities / Processes	Process Emissions	2	Surveying / Emission Factors	Surveying / Emission Factors
	Combustion Emissions	2	Surveying / Emission Factors	Surveying / Emission Factors
	Fugitive Emissions	2	Survey / Material Balance	Survey / Material Balance
Government Facilities	Combustion Emissions	2	Surveying / Emission Factors	Surveying / Emission Factors
	Fugitive Emissions	2	Survey / Material Balance	Survey / Material Balance
Food and Agriculture	Process Emissions	3	Surveying / Emission Factors	Surveying / Emission Factors
	Combustion Emissions	1	Surveying / Emission Factors	Source Sampling / Direct
Asphalt Plants	Process Emissions	3	Surveying / Emission Factors	Surveying / Emission Factors
	Combustion Emissions	1	Surveying / Emission Factors	Source Sampling / Direct

[a] A priority has been assigned to communicate the current, perceived importance of each source type.

N / A = Not applicable.

With the exception of extrapolation, the other emission estimation methods are also proposed for specific source types where these methods appear to be the best alternative for estimating emissions. At this time, we don't recommend the use of extrapolation. A brief summary of the application of the other methods to point sources is presented below:

- A **mechanistic modeling** approach is recommended for liquid organic storage tanks and landfills;

- A **multivariate model** is recommended for petrochemical fugitive emissions from leaking components such as valves and flanges; and

- **Material balances** should be used for estimating facility-level VOC emissions from surface coating and solvent usage emission sources.

Area Source Methodology Proposal

Table 2 presents the methodology proposal for stationary area sources. Generally, the methods recommended for the near-term (e.g., census-based emission factors, material balance, extrapolation) make use of readily available information such as population or employment figures or fuel consumption data. In contrast, the methods often recommended for the long-term (e.g., surveying and multivariate models) would require further data collection or data analysis efforts, taking a longer time to implement.

Table 2

Proposed Methods for Stationary Area Sources

Major Category	Subcategory	Priority[a]	Near - Term Recommendation	Long - Term Recommendation
Stationary Source Fuel Combustion -Industrial and Commercial	By fuel type	1	Material Balance / AP-42 Emission Factors	Material Balance / Emission Factors
Stationary Source Fuel Combustion -Residential Commercial Fuels	Commercial fuels by fuel type	1	Material Balance / AP-42 Emission Factors	Material Balance / Emission Factors
Stationary Source Fuel Combustion -Residential Biomass or Waste-Derived Fuels	Biomass or waste-derived fuels by fuel type	1	Surveying / AP-42 Emission Factors	Surveying / Multivariate Model
Paved Road Dust	N / A	1	Mobile VKT / AP-42 Methodology	Mobile VKT / Surveying / AP-42 Methodology
Unpaved Road Dust	N / A	1	Surveying / AP-42 Methodology	Surveying / AP-42 Methodology
Surface Coatings and Clean-up Solvents - Industrial	By industrial sector	1	Extrapolation / Mexican Point Source Inventory	Surveying / Multivariate Model
Industrial Surface Cleaning (Degreasing)	By industrial sector	1	Extrapolation / Mexican Point Source Inventory	Surveying / Multivariate Model
Dry Cleaning	By solvent type	1	Census-based Emission Factors	Surveying / Multivariate Model
Consumer Solvents	By product type	1	Census-based Emission Factors	Surveying / Multivariate Model
Storage and Transport (Storage Tanks, Loading / Unloading Operations, and Fugitive Component Leaks from Pipelines, Bulk Terminals, Service Stations, and Transport Vessels / Trucks)	By product type	1	Material Balance / Mechanistic Models and Emission Factors	Material Balance / Mechanistic Models and Emission Factors

Table 2

(Continued)

Major Category	Subcategory	Priority[a]	Near - Term Recommendation	Long - Term Recommendation
Agriculture Production	Livestock	1	Census-based Emission Factor	Surveying / Multivariate Model
Waste Management - On-Site Incineration	N / A	1	Material Balance	Surveying / Multivariate Model
Waste Disposal - Refuse Burning	N / A	1	Surveying	Surveying / Multivariate Model
Fires	Wildfires	1	Surveying / AP-42 Emission Factors	Multivariate Model
	Prescribed burning	1	Surveying / AP-42 Emission Factors	Multivariate Model
Public Baths	N / A	1	Census-based / AP-42 Emission Factors	Census-based Emission Factors
Industrial Processes	By industrial sector	2	Census-based Emission Factors / GHG Inventory Technologies	Surveying / Multivariate Model
Surface Coatings and Clean-up Solvents - Architectural Coatings	N / A	2	Census-based Emission Factors	Material Balance
Surface Coatings and Clean-up Solvents - Auto Refinishing	N / A	2	Census-based Emission Factors	Surveying / Multivariate Model
Graphic Arts	N / A	2	Census-based Emission Factors	Surveying / Multivariate Model
Asphalt Application	N / A	2	Material Balance / AP-42 Emission Factors	Material Balance / Emission Factors
Agriculture Production	Pesticide Application	2	Material Balance	Surveying / Multivariate Model
	Fertilizer Application	2	Material Balance	Surveying / Multivariate Model
	Agricultural Burning	2	Surveying	Surveying / Multivariate Model

Table 2

(Continued)

Major Category	Subcategory	Priority[a]	Near - Term Recommendation	Long - Term Recommendation
	Tilling	2	Surveying / Multivariate Model	Surveying / Multivariate Model
Fires	Structures	2	Surveying / AP-42 Emission Factors	Surveying / Emission Factors
Waste Management - Wastewater Treatment	N / A	2	Surveying / AP-42 Emission Factors	Surveying / Multivariate Model
Open Sewage	N / A	2		
Street Vending / Cooking	N / A	2		
Domestic Ammonia Emissions	N / A	2	Census-based Emission Factors	
Tortilla Factories	N / A	2	Census-based Emission Factors	Census-based Emission Factors
Brick Manufacturing	N / A	2	Surveying	Surveying / Multivariate Model
Building Construction	N / A	3	Surveying / AP-42 Emission Factors	Surveying / Multivariate Model
Surface Coatings and Clean-up Solvents - Traffic Markings	N / A	3	Census-based Emission Factors	Material Balance
Rubber and Plastics Fabrication	N / A	3	Extrapolation / Mexican Point Source Inventory	Surveying
Waste Management - Landfills	N / A	3	Material Balance / Mechanistic Model	Surveying / Mechanistic Model
Bakeries	N / A	3	Census-based Emission Factors	Census-based Emission Factors

[a] A priority has been assigned to communicate the current, perceived importance of each source type.

N / A = Not applicable.

A brief summary of the methodology recommendation for stationary area sources is presented below:

- **Census-based emission factors and activity data** are recommended as the near-term method for various non-industrial surface coating and solvent area source types.

- **Surveying** is recommended as a near-term method for stationary area sources where a census-based approach is not available or is likely to introduce a very high degree of uncertainty if applied in Mexico (e.g., unpaved road dust, agricultural burning, fires). Surveying is also a method used to support long-term modeling methods.

- **Material Balance** is recommended for industrial and commercial fuel consumption (i.e., stationary area combustion sources) and to support modeling of emissions from material storage and transport.

  For surface coating and solvent usage, material balances may prove to be a helpful evaluation tool to check the "reasonableness" of the other recommended methods. This is important since an underestimation of VOC emissions from these area source categories could cause significant bias in the countrywide VOC inventory.

- **Multivariate models** are recommended as the long-term method for the majority of the stationary area source types in order to encourage the development of models based on Mexico-specific data. This approach will serve as a means of evaluating and expanding the near-term methods to be more applicable to Mexico. In general, the near-term methods can serve as the initial foundation and be upgraded to a multivariate approach over time.

  These multivariate models should also be designed to account for regional differences that are important to developing stationary area source emission estimates. For example, it is expected that many area sources in Mexico are geographically non-homogeneous. For example, the rate at which dry cleaning solvents are used probably varies with geographic location. Consequently, the use of single per capita emission factors will not reflect regional differences.

- **Mechanistic models** are recommended for liquid organic storage and transport, and for landfills. Surveying or material balances are secondary methods needed to support the data requirements of the mechanistic models.

- **Extrapolation** is recommended only as a near-term method for industrial surface coating and solvent use. Eventually, most of these industrial emissions should be incorporated into the Mexican point source inventory.

- **Source sampling (direct or indirect)** is not recommended for any stationary area source types.

Nonroad Mobile Source Methodology Proposal

Table 3 presents the methodology proposal for nonroad mobile sources. The approach for airports, shipping, and railroads relies primarily on surveying to gather activity data. Survey data would then be combined with emission factors to estimate emissions.

Table 3

Proposed Methods for Nonroad Mobile Sources

Category	Priority[a]	Near - Term Recommendation	Long - Term Recommendation
Aircraft	2	Surveying / AP-42 Emission Factors	Surveying / AP-42 Emission Factors
Railroads	2	Surveying / AP-42 Emission Factors	Surveying / AP-42 Emission Factors
Commercial Marine Vessels	2	Surveying / AP-42 Emission Factors	Surveying / AP-42 Emission Factors
Agricultural Equipment	2	Survey / Multivariate Model	Survey / Multivariate Model
Construction Equipment	2	Survey / Multivariate Model	Survey / Multivariate Model
Industrial Equipment	2	Survey / Multivariate Model	Survey / Multivariate Model
Light Commercial Equipment	2	Survey / Multivariate Model	Survey / Multivariate Model
Lawn & Garden Equipment	3	Survey / Multivariate Model	Survey / Multivariate Model
Recreational Equipment	3	Survey / Multivariate Model	Survey / Multivariate Model
Recreational Boats	3	Survey / Multivariate Model	Survey / Multivariate Model

The proposed approach for nonroad equipment emissions relies on multivariate models in both the near- and long-term. Developing emission estimates for nonroad equipment is extremely difficult, regardless of geographic location. Multivariate models are needed in the near-term to estimate the activity data for this group of sources so that emission estimates can be developed. The Methodology Evaluation Report presents several examples of how this approach would be applied to this group of sources.

On-Road Mobile Source Methodology Proposal

On-road mobile source emissions are calculated based on estimates of vehicle activity and emission factors. The methods chosen depend upon the geographic scope of the inventory and the extent of the available data. Development of the on-road mobile source inventory for this effort will depend upon existing data.

Motor Vehicle Activity Data

To estimate vehicle activity, the following types of data are commonly used for inventory purposes:

- Detailed vehicle kilometers traveled (VKT) estimates such as those developed from transportation models, comprehensive traffic counting programs and surveying, and detailed registration records;
- Regional VKT estimates based on traffic counting programs;

- Regional VKT estimates developed from on-road fuel use; and
- Regional VKT estimates developed from population and vehicle registration data.

These data sources are listed in the order of perceived accuracy (high to low).

The availability of these data will vary geographically across Mexico. For each region in Mexico to be inventoried, an analysis will be required to determine which data are available to estimate vehicle activity. For example, detailed VKT data are available for the larger metropolitan areas, such as Mexico City and Monterrey. The larger metropolitan regions have the available resources to develop these data as part of their transportation planning efforts. If detailed or regional VKT estimates are not available, then fuel usage should be used to estimate vehicle activity.

Motor Vehicle Emission Factors

The second part of the motor vehicle emission estimation process requires the development of emission factors representative of vehicles operating in a given region. A variety of sources are available to provide vehicle emission factors for this effort. These include the following:

- MOBILE-MCMA, an emission factor model developed for Mexico City;
- MOBILE5C, an emission factor model developed by U.S. EPA's office of Mobile Sources for regions outside of the U.S.;
- COPERT, Computer Programme to Calculate Emissions from Road Traffic;
- *Rapid Source Inventory Techniques*, a listing of emission factors that can be used to quickly estimate emissions; and
- PART5, U.S. EPA's particulate emission factor program.

These techniques are discussed in detail in the methods evaluation.

Proposed Methodology for Motor Vehicle VOC, NO_x, and CO

Based on our analysis, we recommend using the same emission factor approach that was taken to develop the MOBILE-MCMA program. This approach relies on developing an emission control technology equivalence matrix that relates basic emission factors in the MOBILE model to the Mexican vehicle fleet. The MOBILE-MCMA model was recently updated as part of a study conducted in the Monterrey Metropolitan Area (MMA). The new version of this model is referred to as MOBILE-MMAp, where *p* indicates *preliminary*. Additional work is needed to refine the emission control technology equivalence matrix so that this model can be used with more confidence in other areas of Mexico.

Refining the emission control technology equivalence matrix matrices would consist of using inspection/maintenance data from Monterrey (at idle conditions) to better match the MOBILE model's basic emission factors to the Mexican vehicle fleet. Over time, this approach can be updated by replacing the U.S.-derived basic emission factors with Mexico specific data.

Proposed Methodology for Motor Vehicle Particulate Matter

A similar approach is proposed for motor vehicle particulate matter. Estimates for this pollutant can be developed using the U.S. EPA's PART5 model. This is also a technology-based model and will require similar changes to those discussed above for MOBILE.

Proposed Methodology for Motor Vehicle SO_2

Finally, we recommend that emission estimates for motor vehicle SO_2 be based on material balances. The quantity of fuel consumed and the average sulfur content of the fuel can be used to accurately estimate SO_2 emissions.

Natural Source Methodology Proposal

Table 4

Proposed Methods for Natural Sources

Major Category	Priority[a]	Near - Term Recommendation	Long - Term Recommendation
Biogenic VOC	1	Multivariate Model	Multivariate Model
Windblown Dust	1	Multivariate Model	Multivariate Model
Soil NO_x	2	Multivariate Model	Multivariate Model
Soil NH_3	2	Multivariate Model	Multivariate Model
Lightning	3	N / A	Mechanistic Model
Geogenic	3	N / A	Field Research

[a] A priority has been assigned to communicate the current, perceived importance of each source type. The priorities assigned to each source type will be refined over time as feedback is obtained from INE and more Mexico-specific information is gathered.

N / A = Not applicable.

The methodologies used to estimate emissions from natural sources traditionally rely on emission models, especially the techniques used for biogenic hydrocarbon emission estimates. Table 4 presents the recommended natural source estimation methods.

Estimating emissions for the natural source categories will rely extensively on land use/land cover (LULC) data. For example, land use describes the type of vegetation that may be present (e.g., natural versus urban) and also the type of vegetation present (e.g., row crop versus orchard). Development of natural source emission estimates for Mexico would be greatly enhanced through the application of satellite imagery data to develop LULC data. These data could be used directly to develop biogenic hydrocarbon, soil NO_x, soil NH_3, and wind blown dust emissions.

Further field research is also warranted so that a more refined biogenic emission estimate can be developed for Mexico. The applicability of the current biogenic emission models may have limited applicability in many regions of Mexico. The work performed to develop the biogenic hydrocarbon inventory for the Grand Canyon Visibility Transport Commission found that biogenic emission estimates for the southwestern U.S. appear to be overestimated. It is possible that the scrubland LULC category for the southern U.S. and northern Mexico should incorporate a lower biomass than is currently used in the biogenic emissions calculations. No other biomass data are available for this region.

In summary, a large effort will be required to develop the necessary data for natural source emission estimates. Satellite imagery would greatly enhance the process, but additional fundamental research will be required to develop other model parameters. This includes soil parameters for soil NO_x and NH_3 estimates and biomass data to support the modeling of biogenic hydrocarbons.

1.0 INTRODUCTION

The U.S. and of Mexico have common needs for emissions inventory information. The Grand Canyon Visibility Transport Commission established by the U.S. Congress is sponsoring projects to develop an emission inventory for areas, including Mexico, that potentially contribute to regional haze on the Colorado Plateau. Mexico is conducting several air quality planning efforts that will benefit from country-wide emissions information. In particular, INE is interested in developing a national methodology for the Mexican emission inventory program. The focus of this effort is on species that are traditionally included in an emissions inventory. These species include volatile organic compounds (VOC), oxides of nitrogen (NO_x), carbon monoxide (CO), oxides of sulfur (SO_x), and particulate matter (PM). Ammonia (NH_3) is also included because of its potential to form secondary aerosols that influence visibility. Air toxics and GHGs are not presently included.

The Western Governors' Association (WGA) is the administrative arm of the commission. As such, it receives funds and administers grants on behalf of the commission. In addition, WGA is vested in working with the Mexican government in several economic and technical areas, including the development of an emissions inventory methodology for Mexico. A work plan describing the development of an emissions inventory methodology for Mexico has been prepared (Radian, 1994).

As described in the work plan, development and implementation of the inventory methodology will proceed in two phases:

- Phase I--Development of a methodology and implementation plan for the Mexico inventory; and

- Phase II--Implementation of the first steps of the Phase I plan, such as development of a portion of the emission inventory and emission inventory training.

The resources needed to perform a traditional inventory for Mexico emission sources are considerable. As a result, the commission is sponsoring the development of a creative, emissions methodology in Phase I tailored for the country of Mexico.

In Phase I, the available Mexico data sets and inventory methodologies will be evaluated, followed by the preparation of a detailed inventory development plan. The Phase I work is divided into seven tasks, as follows:

- Task 1: Work Plan Development;
- Task 2: Information Surveying;
- Task 3: Critical Review of Data;
- Task 4: Critical Review of Emissions Methodologies;
- Task 5: Methodology Proposal;
- Task 6: Implementation Plan; and
- Task 7: Technology Transfer.

Information from the first four tasks will be used to prepare a recommended methodology in Task 5 for the development of the emissions inventory. Furthermore, it is INE intention that this methodology become the set of national methods for inventory development in Mexico. To guide the methodology development, the Binational Advisory Committee (BAC), consisting of representatives from the U.S. and Mexico, will work in consultation with the commission's Project Manager and the staff of INE. The BAC will provide technical advice to the WGA Project Manager and recommend approval of the final selection of inventory methods in Task 5. An implementation plan will then be prepared in Task 6 to carry out a portion of the methodology under the Phase II program.

This document presents the results of Task 4 and Task 5. The objective of Task 4 was to identify and evaluate candidate emissions inventory methods that could be applied in the country of Mexico. These methods were evaluated with respect to the near-term goal of developing country-wide emission estimates and a long-term goal to develop an emissions inventory *program* in Mexico. The objective of Task 5 was to recommend the most appropriate methods that met the requirements of these goals.

Developing a national inventory program will require a combination of approaches.

No single inventory method can be used throughout Mexico for all emission source categories. We started with the commonly accepted methods for developing stationary and mobile source emission estimates. For this evaluation, the list of available methodologies was expanded to include emissions modeling techniques and new emerging technologies for estimating emission estimates. This expansion helped to identify new, creative approaches for developing emission estimates. In some instances, the combination of one or more methods results in a new and creative approach for developing regional emissions inventories.

The remainder of this document is organized as follows:

- Section 2.0 discusses the technical approach, including the evaluation criteria;
- Section 3.0 describes each of the inventory methods considered in the point and area (including nonroad mobile) source evaluation and provides an analysis of the applicability of the methods to Mexico;
- Section 4.0 presents the results of a detailed methods evaluation for on-road motor vehicles;
- Section 5.0 contains the methods evaluation for natural sources; and
- Section 6.0 contains the bibliography.
- Appendix A contains the critical review of point source emissions methods;
- Appendix B contains the critical review of stationary area source emissions methods;
- Appendix C contains the critical review of nonroad mobile source emissions methods;
- Appendix D contains the critical review of on-road motor vehicle source emissions methods; and
- Appendix E contains the critical review of biogenic and natural source emissions methods.

2.0 TECHNICAL APPROACH

This section summarizes the approach used to perform the inventory methods evaluation. Performing the evaluation required developing a source type list, evaluation criteria, and a rating system.

2.1 Source Typing for Methods Evaluation

Developing a list of source types was the first step for performing the evaluation. General practice is to divide emission sources into four key source types: point, area, mobile, and natural sources. Point sources are typically industrial facilities such as power plants and cement kilns. Conversely, area sources are typically defined as those sources that individually emit relatively small quantities of air pollutants, but can cumulatively result in significant emissions. This may initially include smaller facilities not inventoried in the point source component of the inventory system as well as other sources whose emissions occur over a broad geographic area, such as architectural surface coatings or consumer solvents. Mobile sources consist of on-road motor vehicles and nonroad sources (e.g. construction equipment, trains, planes, ships, agricultural equipment, etc). Natural sources include sources such as biogenic hydrocarbon emissions from natural, urban, and agricultural biomass; windblown dust; and geogenic sources, such as natural oil seeps.

Based on previous experience, we recommend structuring the Mexico inventory program around the major source types described above. Specific recommendations for defining point and area sources will be provided in the Phase II materials developed under this study. An arbitrary emission threshold is frequently used in the U.S. This practice need not be duplicated in Mexico.

Tables 2-1 through 2-4 list the key source types for point, area, mobile, and natural sources. These tables list the source types for which we *evaluated* the various methodologies. In the context of this evaluation, the term source type represents many similar source categories (e.g., point source electric utility fuel combustion includes different types of internal and external combustion sources burning multiple fuels). We collapsed the source categories to the source types shown in Tables 2-1 through 2-4 to facilitate the methodology evaluation. For the list of natural sources, no further disaggregation is recommended.

The actual inventory program for Mexico will consist of many more specific point and area source categories than the general source types summarized here. In addition, the lists of source types presented in Tables 2-1 through 2-4 are not meant to represent an aggregation scheme that would be used for preparing emission summaries. As stated previously, the lists of source types in Tables 2-1 through 2-4 was developed for the sole purpose of facilitating the methods evaluation.

We also attempted to tailor the list of source types with present-day Mexico-specific conditions in mind, specifically looking for unique sources of emissions in Mexico that are not commonly found in the U.S. So far, four unique area source categories have been identified: tortilla manufacturing, open burning dumps, public baths, street vendors, and brick kilns. For example, there are numerous facilities throughout Mexico that produce tortillas. The emissions from this potential source category result from the combustion of fuels used in the ovens. At this time, it is not clear if a separate area source category should be created for tortilla factories or if the fuel combustion should be inventoried under the major area source types of industrial and commercial fuel combustion.

As another example, brick manufacturing appears to be a definite, unique category that should be included in the inventory as an area source category. We understand there are numerous, small brick kilns located throughout northern Mexico. Many of these units are domestic operations, making it impractical to include them in the point source inventory. Fuels used in the kilns include waste derived materials, such as trash and waste solvents.

The search for unique source types in Mexico continues. We expect that as the inventory program in Mexico develops, the list of emission source categories will be continually refined.

2.2 Evaluation Criteria

We evaluated each inventory method based on the objective of this study: to develop an inventory program that can be efficiently applied throughout Mexico while allowing for continual improvement and refinement as the program matures. With this objective in mind, the following evaluation criteria were used.

Cost Effectiveness. What is the relative inventory development cost per magnitude of pollutant inventoried? Costlier options may be more appropriate for the largest source categories (either point or area) located in the more populated geographical areas. For this criteria, we used a qualitative approach. Actually developing quantitative estimates would be highly resource intensive and of little practical utility.

Practicality. Which activity data are more readily available? Public domain, municipality-wide population and employment data may be more useful than facility-based employment data that are confidential and/or proprietary. Which industries and/or geographical areas will participate in a surveying effort? Industries that are closely affiliated with the government—such as the Mexican petroleum refining company, PEMEX—may be more accessible as survey participants. Which source types and geographical areas are best suited to extrapolation techniques? For example, extrapolating nonroad mobile source emissions from U.S. to Mexico based on a population ratio may not be appropriate because of different socioeconomic conditions between the two countries. Which emission factors should be used? Where differences in control technology exist, aggregated emission factors described in the *Rapid Source Inventory Techniques* guidance document (Economopoulos, 1993) may be preferred to U.S.-based emission factors.

Uncertainty. How much imprecision and what biases are associated with each methodology? Can the uncertainty or bias be quantified? For example, use of U.S.-based, controlled emission factors in Mexico may introduce bias into the emission estimates. If this methodology is used, the magnitude of this bias should be estimated and confidence limits for the emission estimates should be determined. Generally, more expensive methodologies have lower associated uncertainty that can be more readily quantified. For example, the uncertainty range associated with an emissions sampling device may already be established, whereas determining the uncertainty associated with the use of a material balance approach is highly subjective and qualitative in nature.

Developing uncertainty estimates requires the development of data that can be used in statistical models to quantify imprecision. These data are rarely available, especially when discussing the general uncertainty of a specific inventory methodology. Therefore, the uncertainty analysis for the methods evaluation was by nature qualitative. Our approach to evaluating the uncertainty for each method was guided by the following:

- Emission measurements often have known uncertainty limits.
- A statistically sound survey effort has an inherently low uncertainty if properly implemented.
- The uncertainty associated with the emission factors used in emission calculations can sometimes be obtained from literature and a knowledge of the source characteristics. The applicability of the emission factor to the source and the variation among sources determines the level of uncertainty in emission factors.
- The uncertainty associated with the activity data often can be determined based on an understanding of the method by which the activity data were collected. Census-and other survey-based activity data have higher associated uncertainties than activity data based on overall material production and sales or fuel consumption data.
- The uncertainty and/or bias associated with the use of extrapolation techniques is dependent upon the socioeconomic and emission differences between two or more geographical areas or source categories.

Upgrade potential. Which emission estimation methodologies can be readily refined to yield a higher resolution inventory? For example, if a surveying approach is used, select sources can be targeted for future source sampling. The survey effort can also be modified/extended to cover more source types and larger geographical areas. If proper planning is applied, this is a minor concern. In properly designed programs, inventories are constantly updated with special studies designed to generate more refined data. Reconciliation methods are readily available to allow refinement at the device, facility, or source category level.

Ultimately, the unique combination of emission source types and socioeconomic factors in a given geographical area will lead to the appropriate selection of emission estimation methodologies. In addition, the end uses of the emissions inventory must be considered in the methodology selection. For example, source sampling and/or surveying may be used originally for large combustion sources, but over time this technology would be extended to other sources.

Lastly, it should be noted that three of the evaluation criteria—cost effectiveness, practicality, and uncertainty—are not independent parameters. A method that is practical also tends to be cost effective. At the same time, highly detailed methods that can provide more precise emission estimates may not be cost effective (i.e., the cost per unit of emissions inventoried does not justify the level of precision obtained). Nonetheless, these criteria provide a framework to sufficiently distinguish between the various methods evaluated on a source type basis.

2.3 Rating System

The product of this effort is an evaluation of the inventory methods in the context of the available data in Mexico and the needs of INE. To facilitate the evaluation and communication of results, a simple rating system was developed and applied. Different rating systems could have been applied, such as a numerical scoring system. Given the subjective nature of this type of evaluation, using a numerical system would consume additional resources with little value added. Rather, we chose to apply a rating system consisting of *favorable*, *neutral*, or *unfavorable* (+/0/-) categories to convey our opinions about the applicability of the method to each source type.

The rating system described above was applied to each method/source type combination (see Appendices A through E for results). For each combination, ratings were applied independently of the considerations pertaining to the development of an inventory program for Mexico. In other words, the ratings for cost effectiveness, practicality, uncertainty, and upgrade potential reflect our opinions regarding the merits of each method relative to the other methods for that source type. For example, it may be determined that direct source sampling is the best method for estimating emissions for one point source type, and therefore given a "+" rating. For another source type, direct source sampling may only be given a "0" rating. We evaluated each method relative to the other methods identified for a given source type. Therefore, in one instance, direct source sampling may be considered highly favorable relative to the other methods; however, for another source type, direct source sampling may not be the preferred approach relative to other methods applicable to that source type.

We extended the analysis to provide a score for the method/source type combination in the context of an inventory program by considering application of the method in the near- and long-term. The methods, therefore, were evaluated in light of future updates so that INE and other agencies in Mexico can build upon this effort. We added this second analysis to recognize that the inventory program can not initially apply the most desirable method for each and every source category. Resource and time constraints will require the application of simpler methods for certain source categories in the near-term that will be refined over the long-term as the inventory program matures.

Table 2-1

Point Source Types Used for Methods Evaluation

Major Category	Subcategories	Priority[a]	Pollutant	Comments
Electric Utility	Combustion by Fuel Type	1	CO, NO_x, SO_x, VOC, PM, and NH_3	Category consists of internal and external combustion devices used to produce electricity.
Chemical Manufacturing	Process Emissions	1	VOC and NH_3	Typically VOCs generated during the manufacture of organic chemicals. Ammonia is emitted from some chemical processes, such as fertilizer manufacturing.
	Combustion Emissions	1	CO, NO_x, SO_x, VOC, PM, and NH_3	Fuels burned to supply energy to the chemical manufacturing process.
	Fugitives From Equipment Leaks	1	VOC	Subcategory includes VOC emissions from such devices as pipeline valves and flanges, and compressor seals.
	Storage Tanks	1	VOC	Floating and fixed roof storage tanks release VOC emissions from tank breathing and the filling of the tank.
	Miscellaneous Solvent Usage	3	VOC	Organic solvents are used for equipment maintenance and can be an important source of VOC emissions.
Petroleum Refining	Process Emissions	1	VOC and NH_3	Example process emissions include fluid catalytic cracking units and vacuum distillate column condensers.
	Combustion Emissions	1	CO, NO_x, SO_x, VOC, PM, and NH_3	Fuels burned to supply energy to the refining process.
	Fugitives From Equipment Leaks	1	VOC	Subcategory includes VOC emissions from such devices as pipeline valves and flanges, and compressor seals.
	Storage Tanks	1	VOC	Floating and fixed roof storage tanks release VOC emissions from tank breathing and the filling of the tank.
	Miscellaneous Solvent Usage	3	VOC	Organic solvents are for used equipment maintenance and can be an important source of VOC emissions.

Table 2-1

(Continued)

Primary Metal Production	Process Emissions	1	SO_x and PM	Subcategory includes numerous operations that occur during the smelting and refining of metals such as copper, lead, iron / steel, zinc, etc. Process emissions primarily consist of crushing and grinding of raw materials followed by pyrometallurgical and casting operations to produce metal ingots.
	Combustion Emissions	1	CO, NO_x, SO_x, VOC, PM, and NH_3	Fuel burned to supply energy to the smelting and refining processes.
	Fugitive Emissions	2	PM	Subcategory includes TSP emissions from such devices as storage piles and entrained dust from unpaved roads.
Secondary Metal Production	Process Emissions	2	VOC and PM	Emissions from finishing process that produce VOCs and TSP.
	Combustion Emissions	1	CO, NO_x, SO_x, VOC, PM, and NH_3	Fuel burned to supply energy to secondary metal finishing processes.
Cement Production	Process Emissions	1	PM	Emission sources include material handling and crushing and grinding of both raw and finished materials.
	Combustion Emissions	1	CO, NO_x, SO_x, VOC, PM, and NH_3	Fuel burned to supply energy to the kiln.
	Fugitive Emissions	2	PM	Fugitive sources include piles and entrained dust from equipment operation on unpaved surfaces.
Miscellaneous Mineral Products (e.g. lime and aggregate kilns)	Process Emissions	1	PM	Emission sources include material handling and crushing and grinding of both raw and finished materials.
	Combustion Emissions	1	CO, NO_x, SO_x, VOC, PM, and NH_3	Fuel burned to supply energy to the kiln.
	Fugitive Emissions	2	PM	Fugitive sources include piles and entrained dust from equipment operation on unpaved surfaces.

Table 2-1

(Continued)

Automotive Industry	Process Emissions	1	VOC	Emission sources include surface coating and other processes that emit VOCs.
	Combustion Emissions	1	CO, NO_x, SO_x, VOC, PM, and NH_3	Fuel burned to supply energy for production of automobiles and associated parts.
	Fugitive Emissions	2	VOC	A variety of solvents are used in addition to the coating material. These solvents are used for such activities as wipe cleaning and thinning of coating materials.
Wood Pulping Operations	Process Emissions	1	SO_x, VOC, and PM	Manufacture of pulp involves numerous process operations such as digesters, evaporators, and oxidation towers that produce VOC, TSP, and sulfur compounds.
	Combustion Emissions	1	CO, NO_x, SO_x, VOC, PM, and NH_3	Large quantities of fuel are consumed in the pulping process to provide heat to process operations and to recover chemicals used in the pulping process. In addition to liquid and gaseous fuels, large quantities of wood may also be burned.
Oil and Gas Production	Process Emissions	1	VOC	This subcategory applies mostly to the processing of natural gas. Example processes include gas sweetening and stripping operations.
	Fugitive Emissions	1	VOC	Subcategory includes VOC emissions from such devices as well heads and sumps/pits. It also includes pipeline valves and flanges and compressor seals.
	Combustion Emissions	1	CO, NO_x, SO_x, VOC, PM, and NH_3	Liquid and gaseous fuels are burned to supply energy to the oil and gas process.
	Storage Tanks	1	VOC	Typically fixed roof storage tanks are used to store crude oil in the field. Releases of VOC emissions from the tank are a result of tank breathing and filling.

Table 2-1

(Continued)

Printing and Publishing	Process Emissions	1	VOC	Operations used in the printing industry (letter press, flexographic, lithographic, and gravure) produce VOC emissions.
	Fugitive Emissions	2	VOC	In addition to the printing operations, miscellaneous solvents are also used in the printing industry for thinning of inks and cleaning of equipment.
Surface Coating	Process Emissions	1	VOC	Application of coating materials results in significant VOC emissions.
	Degreasing Emissions	1	VOC	Degreasers are frequently used at facilities involved in coating operations. Solvent evaporation from the degreaser results in VOC emissions.
	Fugitive Emissions	1	VOC	A variety of solvents are used in addition to the coating material. These solvents are used for such activities as wipe cleaning and thinning of coating materials.
Bulk Fuel Terminals	Loading Operations	1	VOC	Loading and unloading of fuels into marine vessels, rail cars, and trucks results in VOC emissions. Also includes VOC emissions generated by spills.
	Storage Tanks	1	VOC	Floating and fixed roof storage tanks used at bulk terminals release VOC emissions from tank breathing and the filling of the tank.
Mining and Quarrying	Process Emissions	1	PM	There are many different mining operations that emit TSP, such as drilling/blasting, loading, and hauling.
	Fugitive Emissions	2	PM	Fugitive sources include piles and entrained dust from equipment operation on unpaved surfaces.
Wood Products Manufacture	Process Emissions	2	VOC and PM	The manufacture of finished lumber and plywood, etc. involves several processes such as pressure treating, drying, and sawing. VOCs generated in finishing process.
	Combustion Emissions	2	CO, NO_x, SO_x, VOC, PM, and NH_3	Various fuels, including wood, are used to provide the energy needed during the manufacturing process.

Table 2-1

(Continued)

Sugar Production	Process Emissions	2	PM	Processing of sugar results in some TSP emissions.
	Combustion Emissions	2	CO, NO_x, SO_x, VOC, PM, and NH_3	Fuel burned to supply energy for sugar processing.
	Fugitive Emissions	2	PM	Possible fugitive VOC and TSP emissions from degreasing, maintenance or cleaning activities.
Tanning and Leather Finishing	Process Emissions	2	VOC	Substantial VOC emissions result from the tanning and finishing processes.
	Combustion Emissions	2	CO, NO_x, SO_x, VOC, PM, and NH_3	Fuel burned to supply energy for tanning and finishing processes.
	Fugitive Emissions	2	VOC	Possible fugitive VOC emissions from processing activities.
Glass Production	Process Emissions	2	VOC and PM	Some TSP emission from the various glass manufacturing processes.
	Combustion Emissions	2	CO, NO_x, SO_x, VOC, PM, and NH_3	Fuel burned to supply energy for glass manufacturing processes.
	Fugitive Emissions	2	VOC and PM	Possible fugitive VOC and TSP emissions from manufacturing processes.
Rubber and Plastic Parts	Process Emissions	2	VOC	Category includes such devices as tire manufacturing, fabricated plastic products, fiberglass resin products, and plastic foam products. These manufacturing operations use a variety of processes that mostly emit VOC.
	Combustion Emissions	2	CO, NO_x, SO_x, VOC, PM, and NH_3	Fuel burned to supply energy to rubber and plastic fabrication processes.

Table 2-1

(Continued)

Fabricated Metal Products	Process Emissions	2	PM	Manufacture of fabricated metal products use process operations such as electroplating, conversion coating, abrasive blasting, and metal deposition. VOCs generated in the finishing process.
	Combustion Emissions	1	CO, NO_x, SO_x, VOC, PM, and NH_3	Various fuels are burned in process heaters.
Textile Products	Process Emissions	2	VOC	Various chemicals/solvents are used in the production of textiles that may result in VOC emissions.
	Combustion Emissions	1	CO, NO_x, SO_x, VOC, PM, and NH_3	Fuel burned to supply energy to textile manufacturing process.
Solid Waste Disposal	Landfill Gas Emissions	3	VOC	Solvents placed in landfills and biological decomposition of materials in landfills results in VOC emissions.
	Municipal Waste Combustors	1	CO, NO_x, SO_x, VOC, and PM	Combustion of municipal waste in incinerators at waste management facilities releases combustion pollutants and air toxics.
	Open Burning Dump	2	CO, NO_x, SO_x, VOC, and PM	Combustion pollutants are emitted during this process.
Miscellaneous Industrial Activities/Processes	Process Emissions	2	CO, NO_x, SO_x, VOC, and PM	There will be a number of industrial activities that don't fit into a traditional source category, such as semiconductor manufacturing. These facilities have process emissions that should be included in a point source inventory.
	Combustion Emissions	2	CO, NO_x, SO_x, VOC, PM, and NH_3	Fuels maybe burned to support process operations. Fuels are also used frequently for space heating.
	Fugitive Emissions	2	VOC	Many miscellaneous facilities use solvents for such things as degreasing and wipe cleaning.

Table 2-1

(Continued)

Government Facilities	Combustion Emissions	2	CO, NO_x, SO_x, VOC, PM, and NH_3	Research and development, military, and other institutional facilities often burn fuels for space heating, or to a lesser extent, for process operations.
	Fugitive Emissions	2	VOC	Many facilities use solvents for such activities as degreasing and wipe cleaning. This can be a large source of VOC emissions.
Food and Agriculture	Process Emissions	3	VOC and PM	Category includes numerous food and agriculture related processes that generate primarily TSP and VOC. Examples include: alfalfa dehydration, coffee roasting, grain elevators, beer production, vegetable oil processing, etc.
	Combustion Emissions	1	CO, NO_x, SO_x, VOC, PM, and NH_3	Fuels burned to supply energy to processing of agricultural products.
Asphalt Plants	Process Emissions	3	PM	Emission sources in this category include such groups as screens, bins, and mixers; heaters; and dryers.
	Combustion Emissions	1	CO, NO_x, SO_x, VOC, PM, and NH_3	Fuel burned to supply energy to the asphalt plant.

[a] A priority has been assigned to communicate the current, perceived importance of each source type. The priorities assigned to each source type will be refined over time as feedback is obtained from INE and more Mexico-specific information is gathered.

Table 2-2

Stationary Area Source Types Used for Methods Evaluation

Major Category	Subcategory	Priority[a]	Pollutant	Comments
Stationary Source Fuel Combustion - Industrial and Commercial	By fuel type	1	CO, NO_x, SO_x, VOC, PM, and NH_3	Subcategories include fuels such as coal, combustoleo, natural gas, and waste-derived fuels. This will be an important category initially, until many of the smaller sources are incorporated into the point source inventory.
Stationary Source Fuel Combustion - Residential Commercial Fuels	Commercial fuels by fuel type	1	CO, NO_x, SO_x, VOC, PM, and NH_3	Subcategories include fuels such as coal, combustoleo, natural gas, etc.
Stationary Source Fuel Combustion - Residential Biomass or Waste-Derived Fuels	Biomass or waste-derived fuels by fuel type	1	CO, NO_x, SO_x, VOC, PM, and NH_3	Subcategories include fuels such as wood, waste oil, tires, etc.
Paved Road Dust	N/A	1	PM	An important source of particulate matter.
Unpaved Road Dust	N/A	1	PM	An important source of particulate matter.
Surface Coatings and Clean-up Solvents - Industrial	By industrial sector	1	VOC	Subcategories include textile products, machinery & equipment, etc. This will be an important category initially until many of the smaller sources are incorporated into the point source inventory.
Industrial Surface Cleaning (Degreasing)	By industrial sector	1	VOC	Subcategories include fabricated metal products, industrial machinery & equipment, auto repair services, etc. This will be an important category initially until many of the smaller sources

Table 2-2

(Continued)

Major Category	Subcategory	Priority[a]	Pollutant	Comments
				are incorporated into the point source inventory.
Dry Cleaning	By solvent type	1	VOC	Subcategories include perchloroethylene, special naphthas, and other solvents.
Consumer Solvents	By product type	1	VOC	Subcategories include personal care products, household products, pesticides, etc.
Storage and Transport (Storage Tanks, Loading/Unloading Operations, and Fugitive Component Leaks from Pipelines, Bulk Terminals, Service Stations, and Transport Vessels/Trucks)	By product type	1	VOC	Subcategories include petroleum products (crude oil, gasoline, diesel, etc.) and may also include organic, inorganic, and bulk materials.
Agriculture Production	Livestock	1	PM and NH_3	Feedlots are a major source of NH_3 and a source of particulate matter.
Waste Management - On-Site Incineration	N/A	1	CO, NO_x, SO_x, VOC, and PM	Includes incineration of all industrial waste types.
Waste Disposal - Refuse Burning	N/A	1	CO, NO_x, SO_x, VOC, and PM	Includes agricultural and other types of open burning.
Fires	Wildfires	1	CO, NO_x, SO_x, VOC, and PM	May be a significant source of particulate matter.
	Prescribed burning	1	CO, NO_x, SO_x, VOC, and PM	May be a significant source of particulate matter.
Public Baths	N/A	1	CO, NO_x, SO_x, VOC, and PM	Magnitude of emissions is uncertain.
Industrial Processes	By industrial sector	2	CO, NO_x, SO_x, VOC, and PM	Subcategories include chemical manufacturing, rubber/plastics, food and kindred products (tortilla factories), brick manufacturing, etc. This could be an important category

Table 2-2

(Continued)

Major Category	Subcategory	Priority[a]	Pollutant	Comments
				initially, until many of the smaller sources are incorporated into the point source inventory.
Surface Coatings and Clean-up Solvents - Architectural Coatings	N/A	2	VOC	Architectural coatings are thought to be a significant source of VOC emissions in urban areas of Mexico.
Surface Coatings and Clean-up Solvents - Auto Refinishing	N/A	2	VOC	Auto refinishing is thought to be a significant source of VOC emissions in urban areas of Mexico.
Graphic Arts	N/A	2	VOC	Minor VOC source.
Asphalt Application	N/A	2	VOC	Includes application of various types of asphalt materials.
Agriculture Production	Pesticide Application	2	VOC	May be an important VOC source.
	Fertilizer Application	2	NH_3	May be an important NH_3 source.
	Crops	2	PM	May be an important PM source.
Waste Management - Wastewater Treatment	N/A	2	VOC and NH_3	Minor source of VOC, but a significant source of NH_3.
Open Sewage	N/A	2	VOC and NH_3	Most likely a minor source of VOC. Possibly a significant source of NH_3.
Street Vending/Cooking	N/A	2	CO, NO_x, SO_x, VOC, and PM	Magnitude of emissions is uncertain.
Domestic Ammonia Emissions	N/A	2	NH_3	Includes domesticated dogs and cats, human respiration, human perspiration, household ammonia use, cigarette smoke, and untreated human waste.
Fires	Structures	2	CO, NO_x, SO_x, VOC, and PM	Minor source of particulate matter.
Building Construction	N/A	3	PM	Building construction and demolition produce fugitive TSP emissions through processes such as site preparation and

Table 2-2

(Continued)

Major Category	Subcategory	Priority[a]	Pollutant	Comments
				mechanical/explosive dismemberment.
Surface Coatings and Clean-up Solvents - Traffic Markings	N/A	3	VOC	Traffic markings are thought to be a minor source of VOC emissions in Mexico.
Rubber and Plastics Fabrication	N/A	3	VOC	Minor source of VOC.
Waste Management - Landfills	N/A	3	VOC	Minor source of VOC.
Bakeries	N/A	3	VOC	Minor source of VOC.

[a] A priority has been assigned to communicate the current, perceived importance of each source type. The priorities assigned to each source type will be refined over time as feedback is obtained from INE and more Mexico-specific information is gathered.

Table 2-3

Mobile Source Categorization Used for Methods Evaluation

Category	Priority[a]	Pollutant	Comments
On-Road Motor Vehicles	1	CO, NO_x, SO_x, VOC, PM, and NH_3	Category includes light-duty gas vehicles, light-duty diesel vehicles, light-duty gas trucks, light-duty diesel trucks, heavy-duty gas vehicles, heavy-duty diesel vehicles, and motorcycles.
Aircraft	2	CO, NO_x, SO_x, VOC, PM, and NH_3	Category includes commercial, military, and private aircraft.
Railroads	2	CO, NO_x, SO_x, VOC, PM, and NH_3	Category consists of diesel locomotives used only in switching and line haul application. Electric locomotives use electricity generated at stationary power plants (point sources), so these are not included as a nonroad source.
Commercial Marine Vessels	2	CO, NO_x, SO_x, VOC, PM, and NH_3	Commercial marine vessels include fishing vessels, harbor vessels, cruise ships, ferries, commercial ships, etc.
Agricultural Equipment	2	CO, NO_x, SO_x, VOC, PM, and NH_3	Agricultural equipment category includes tractors, combines, sprayers, harvesters, agricultural hydropower equipment, etc.
Construction Equipment	2	CO, NO_x, SO_x, VOC, PM, and NH_3	Category consists of pavers, rollers, excavators, cement mixers, cranes, off-highway trucks, bulldozers, backhoes, etc.
Industrial Equipment	2	CO, NO_x, SO_x, VOC, PM, and NH_3	Industrial equipment category consists of aerial lifts, forklifts, sweepers, abrasive blasters, industrial scrubbers / blowers / vacuums, airport service equipment, etc.
Light Commercial Equipment	2	CO, NO_x, SO_x, VOC, PM, and NH_3	Category includes generators, pumps, compressors, welders, etc.
Lawn & Garden Equipment	3	CO, NO_x, SO_x, VOC, PM, and NH_3	Category consists of lawnmowers, tillers, chainsaws, chippers, etc.
Recreational	3	CO, NO_x, SO_x,	Recreational equipment category includes all-terrain vehicles, off-road

Table 2-3

(Continued)

Equipment		VOC, PM, and NH_3	motorcycles, golf carts, etc.
Recreational Boats	3	CO, NO_x, SO_x, VOC, PM, and NH_3	Category includes inboard motors and outboard motors on recreational motorboats. This category also includes auxiliary motors on sailboats.

Table 2-4

Natural Source Categorization Used for Methods Evaluation

Major Category	Priority[a]	Pollutant	Comments
Biogenic VOC	1	VOC	Category includes isoprene, terpene, and other VOC emissions from natural, agricultural, and urban vegetative biomass.
Windblown Dust	1	PM	Wind erosion of crustal material can be a significant source of particulate matter. Although emissions originate primarily from disturbed lands (e.g., agricultural areas), emissions can also occur from undisturbed lands.
Soil NO_x	2	NO_x	Microbial nitrification and denitrification cycles in soil under certain conditions can result in significant releases of NO_x. NO is the principle nitrogen species emitted by soils (overall under certain conditions NO_2 comprises less than 10% of soil NO_x emissions).
Soil NH_3	2	NH_3	Through the natural ammonification cycle, soil surfaces can emit important amounts of NH_3.
Lightning	3	NO_x	Several studies have shown lightning to be a source of NO_x. On a regional basis, emissions are typically low compared to anthropogenic emissions.
Geogenic	3	SO_x, VOC, and PM	There are a number of geogenic sources that can be important sources of air emissions under certain conditions. Examples include volcanoes and natural oil and gas seeps that can emit sulfur, particulate matter and VOCs.

[a] A priority has been assigned to communicate the current, perceived importance of each source type. The priorities assigned to each source type will be refined over time as feedback is obtained from INE and more Mexico-specific information is gathered.

3.0 POINT AND AREA SOURCE INVENTORY METHODOLOGIES

This section summarizes inventory development methods for point and area sources and discusses their applicability to Mexico. Point and area (including nonroad mobile) inventory methods are discussed in Section 3.1. Detailed evaluation of the methods for each source type can be found in Appendices A through C.

3.1 Point and Area Source Methods Discussion

The following point and area source methods are discussed in this section:

- Source sampling (direct and indirect);
- Modeling;
- Surveying;
- Use of census-based emission factors and activity data;
- Material balance (raw materials, fuel consumption); and
- Extrapolation.

3.1.1 Source Sampling

This methodology is the most accurate and expensive option. It should only be considered for the most critical and undercharacterized (e.g., Mexico sources for which current emission factors have limited applicability) emission sources. Source sampling can be *direct* or *indirect* (Mobley and Saeger, 1993). These two approaches are discussed below.

Direct Source Sampling. This technique often refers to the use of in-stack sampling equipment. Direct sampling methods have been developed to measure stack gas concentrations for numerous pollutants, including speciated hydrocarbons. The resulting concentration data are then used to calculate emission estimates. Several of the methods require collecting samples that are sent to a laboratory for analysis. Real time data can be obtained through the use of a continuous emissions monitoring (CEM) device to measure stack emissions.

CEMs also measure other important stack parameters, such as flue gas flow rate and temperature. Direct source sampling is already effectively used in Mexico for compliance evaluation and recently to support the development of point source emission estimates. Continued development and use of direct source sampling equipment is highly recommended.

Indirect Source Sampling. This term refers to the use of a remote measurement technique, such as FTIR spectroscopy to measure gas concentrations in the open air (see Figure 3-1). This method is especially useful for characterizing emissions from numerous and dispersed sources like fugitive emissions from chemical plants or refineries (Mobley and Saeger, 1993; Spellicy et al., 1991).

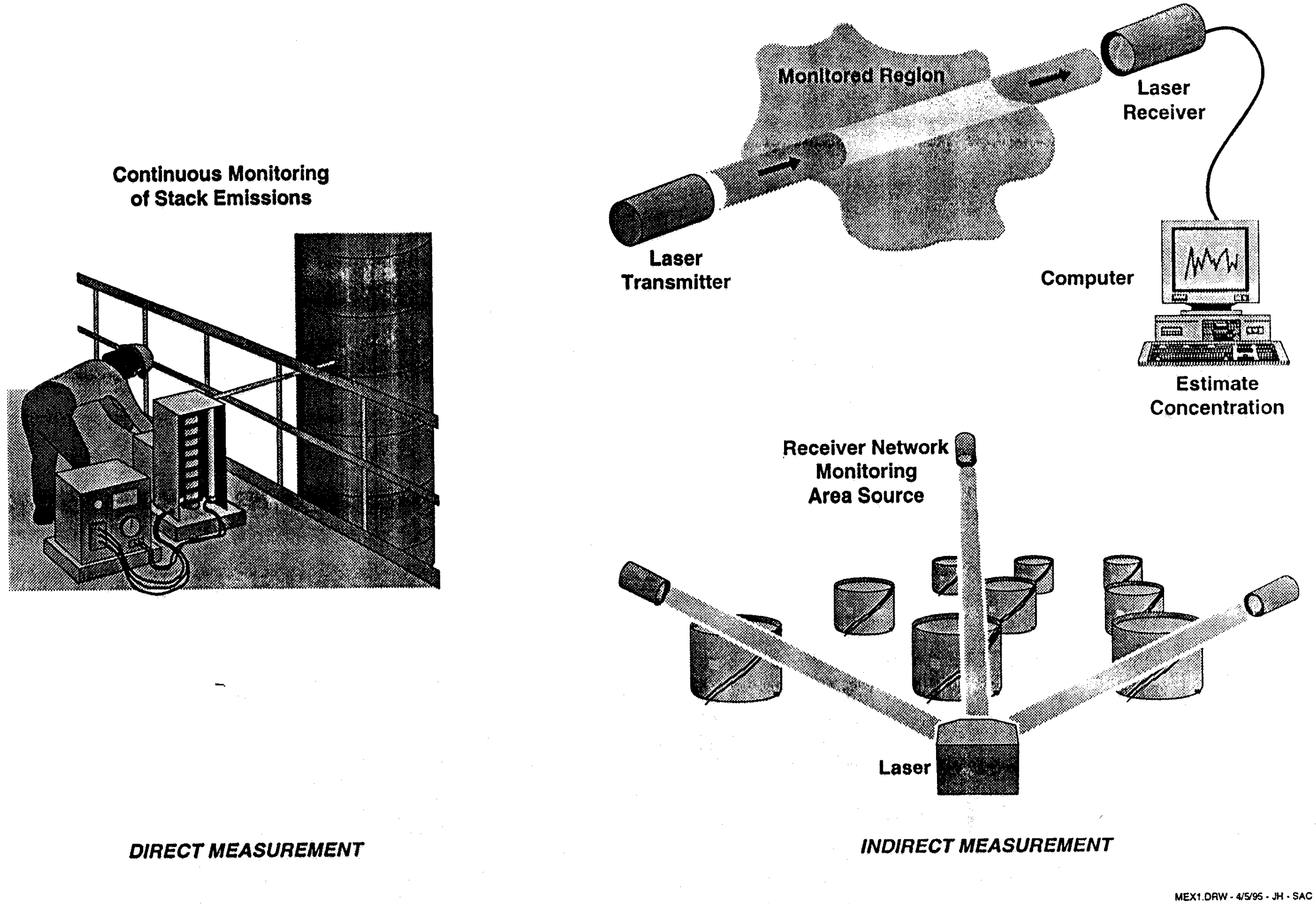


Figure 3-1. Comparison of Direct versus Indirect Emissions Measurement

Since Mexico is in its early stages of developing an inventory program, there is an opportunity to establish methods and procedures that are based on advanced technology without the need to apply current technology that may soon be out dated. Special consideration was given to indirect sampling as a means of creatively and more cost effectively developing emission estimates. Our findings are presented below.

Remote sensing is typically used in one the following ways:

- Development of emission fluxes from volume sources such as waste impoundments, landfills, or open burning dumps;
- Early warning systems for accidental releases of extremely hazardous substances;
- Fence line monitoring of air toxics; and
- Application as an extractive sampling device in a traditional stack sampling approach (i.e., a cart-mounted unit is used to measure gas concentrations extracted from a stack using standard stack sampling equipment).

We also considered the use of remote sensing as a potential emissions verification tool for a defined geographic region. This application has not yet been demonstrated.

Advantages of an FTIR system include: the ability to more easily monitor many constituents (e.g., air toxics) simultaneously on a real time basis, the ability to monitor acid gases, and low application costs relative to direct sampling. Disadvantages include: detection limit problems resulting from carbon dioxide and water, an inability to measure particulate, an inability to identify contributing sources, and a relatively high capital equipment cost (~ $180,000 per unit). Application of FTIR technology has been most successful when applied as a continuous monitoring device for accidental releases of extremely hazardous chemicals and monitoring of species for which the U.S. EPA has not developed a specific monitoring method (e.g., acid gases emitted from semiconductor facilities).

All of the technologies being applied to open-air atmospheric monitoring today are well established and have been in use in the scientific community for years. What is new, however, is their application to nonlaboratory environments. The U.S. 1990 Clean Air Act Amendments have provided greater impetus to apply this technology to atmospheric monitoring (Spellicy, 1991; Spellicy, 1993). The Europeans are also applying remote sensing technology; their applications are also for fence line monitoring for both routine and non-routine releases of emissions.

Use of light detection and ranging (LIDAR) remote sensing technology has been proposed for Ciudad Juárez by Los Alamos National Laboratory (Streit, 1995). This technology would be used to develop the wind fields needed for an air quality grid model and to identify areas of elevated particulate matter. This technology senses aerosols and can only determine relative differences between one region and another. For Ciudad Juárez, LIDAR was going to be used to identify areas with unpaved roads. Cost for the application of LIDAR in Juárez for this study was estimated at $3 million. This proposal was not considered to be cost effective.

Indirect sampling techniques are most applicable to volume sources where emissions are not emitted from defined stacks, such as waste impoundments. In these instances, indirect measurements can be combined with dispersion models to develop emission fluxes. Therefore, we see this technology as a possible means of refining and/or developing new emission factors for volume sources such as open burning, mobile sources, soil NO_x, and biogenic hydrocarbons. In these applications, indirect sampling would not be used to develop emission estimates; rather, it would be used to develop refined emission factors and emission estimating models specific to Mexico.

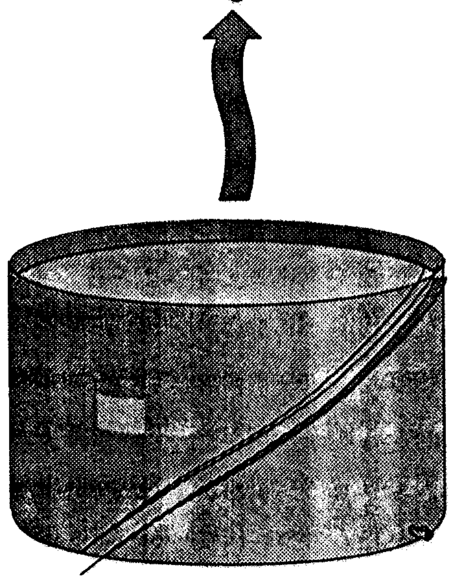
Another possible use of indirect sampling techniques may be in the area of verification and evaluation of regional emission estimates. By combining indirect sampling measurements with data analysis techniques, an emissions verification tool could possibly be developed. This would include the magnitude, temporal, and spatial characteristics of emission sources within a geographic region. Discussing this application with remote sensing experts suggests that this technology may be more applicable to examining the temporal and spatial characteristics of emission estimates rather than verifying the magnitude of emission estimates developed with traditional means. At this time, using remote sensing to verify emissions of a geographic region may only provide order of magnitude estimates, thus reducing its effectiveness in this application.

In summary, remote sensing can be used to develop better emission estimating tools for important volume sources. Discussions are under way at the U.S. Environmental Protection Agency (EPA) to use this technology as a technique to better characterize GHG emissions from open burning dumps and open sewage lines. For criteria pollutant emissions from defined stacks, standard source sampling is a practical choice for Mexico. Direct sampling equipment has a much lower capital cost and requires much less expertise to operate. Utilization of remote sensing equipment in Mexico may be limited to universities and properly trained staff at INE. Nonetheless, wide spread use of remote sensing would result in lower application costs and provide for more efficient collection of emissions data.

3.1.2 Emissions Models

Most emission estimates are developed assuming a linear relationship (i.e., an "emission factor") between the emission rate and a unit of activity (e.g., quantity of fuel consumed, population, employment, production rates, etc.). Although infrequently used, a more complex modeling approach is also applicable to many source types. This section describes the development and application of mechanistic, adaptive, and multivariate models that can be used to develop emission estimates.

Mechanistic Models. Under this modeling framework, "first principles" are used to develop algorithms that use the laws of chemistry and physics to describe the emission rate for a particular source category. Given the large number of source categories that are inventoried, this approach has only received modest use. The current U.S. EPA emission estimating algorithm for fixed roof storage tanks is the best example of this type of approach (see Figure 3-2). The fixed roof storage tank model applies heat transfer and other principles to model VOC emissions from the storage of organic liquids. A mechanistic approach has also been taken to describe the increased emissions that occur during hard accelerations of on-road motor vehicles (i.e., power enrichment).



VOC emitted from vapor expansion and contraction due to changes in temperature and pressure.

Emissions $= f(V_V, W_V, \Delta P_V, P_{VA}, P_A, \Delta T_V, T_{LA})$

Where:

V_V = vapor space volume of tank

W_V = vapor density of stored liquid

ΔP_V = daily vapor range of stored liquid

P_{VA} = vapor pressure at daily average liquid surface temperature

P_A = atmospheric pressure

ΔT_V = daily vapor temperature range of stored liquid

T_{LA} = daily average liquid surface temperature

Figure 3-2. Example of Mechanistic Modeling

A mechanistic model can potentially provide a more precise estimate if it is sufficiently robust. For Mexico, developing additional mechanistic models on a source category basis is impractical. Over time, additional models of this type will be developed. We recommend that Mexico apply these models as they become available, taking advantage of inventory research conducted elsewhere.

Adaptive Models. This is a relatively new technology that has received increased attention since the passage of the U.S. Clean Air Act Amendments and the requirement for continuous emissions monitoring of stack emissions at certain sources. Several companies have developed software systems that can be used to replace costly CEMs. These software systems are sometimes referred to as soft CEMs.

Soft CEMs rely on adaptive modeling software that integrate neural network, fuzzy logic, and chaotic systems into one software package (Collins and Terhune, 1994). During the setup stage, the software is trained with historic operating and emissions data (see Figure 3-3). Operating parameters are then monitored and used by the software system to predict emissions at a cost less than the application of a true CEM. Accuracy of the soft CEM is equivalent to a true CEM when properly trained.

Adaptive models are now being used or considered as emissions estimating techniques for both mobile and area sources. Radian staff have used adaptive modeling to model

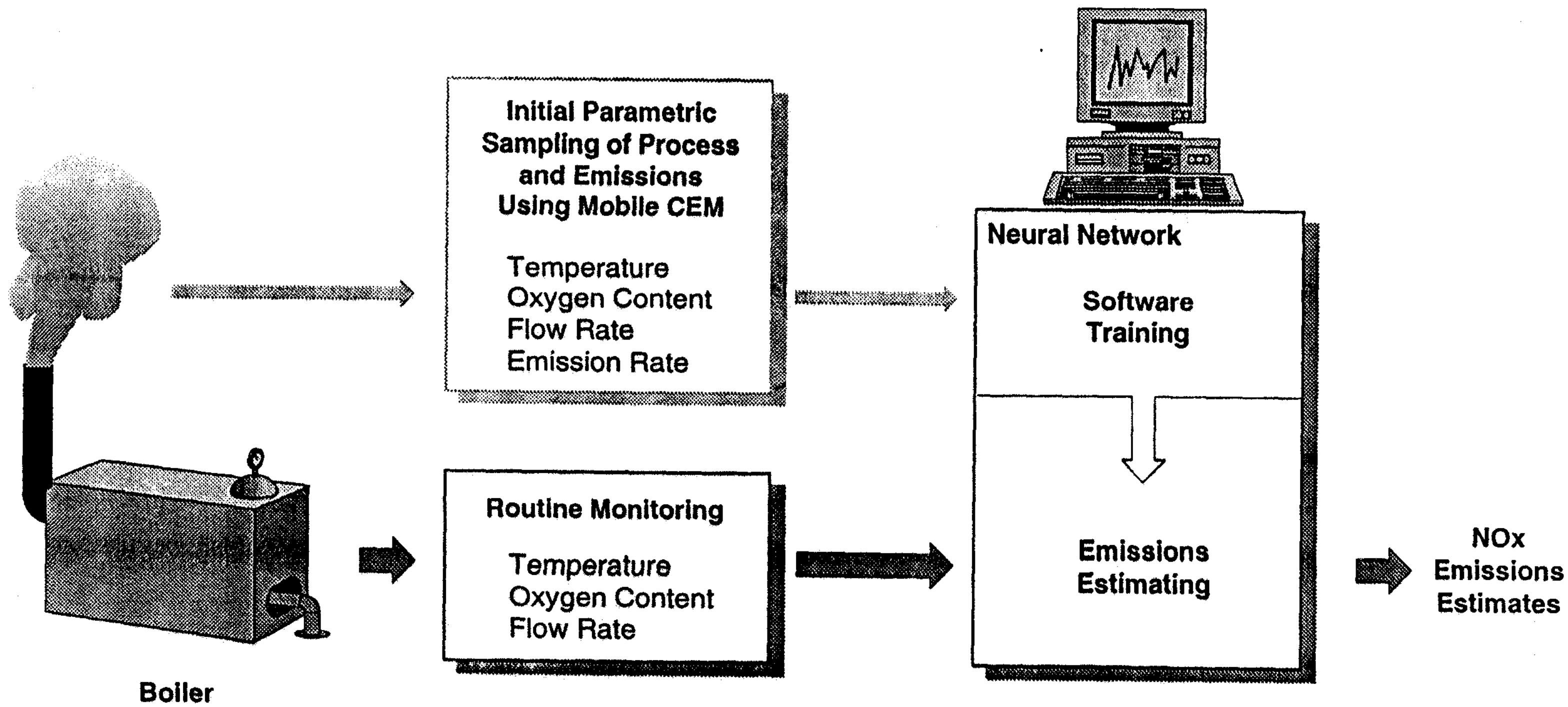


Figure 3-3. Example of Adaptive Model

oxygen levels for a fleet of cars by using just one car. In another effort, Waters et al. (1994) report that a fuzzy logic model is being developed to better estimate emissions from automobile refinishing. According to Waters et al., fuzzy logic is an approximate reasoning technique used in processing inexact information:

> "For example, if climate is a factor in an area's emission levels, then it could be classified as *dry, moderate, or rainy*. The type of area might also be loosely classified into three fuzzy sets *rural, suburban, and urban*. A typical fuzzy rule, based on expert opinion, may be expressed as "If the climate is *dry* AND the area is *rural* THEN emissions are *low*." Another rule may state "If the climate is *wet* AND the area is *urban* then emissions are *high*." These rules describe the increased likelihood of accidents and auto refinishing in a congested area with poor weather and vice versa. The fuzzy system uses the degree of membership of an input in a given set to determine to what degree the output belongs in any set (e.g., *low*, *medium*, *high*). This type of reasoning can augment the emissions prediction based on optimally correlated data."

This type of approach may be applicable for several area source categories in Mexico, especially where there are strong geographic differences in emissions magnitude for a particular source type. For example, dry cleaning emissions in urban Mexico City are expected to be different on a per capita basis compared to many rural areas in the country. At this time, we have not identified any specific regional emissions inventory applications of adaptive software that relies on neural network technology. It should also be noted that the purchase cost of adaptive software can be quite expensive, approaching $100,000.

Multivariate Emissions Models. This is a new term developed specifically for this project. In this approach, emission estimates are expressed in terms of a set of variables that help characterize a system. In some ways, this new approach can be thought of as a combination of traditional inventory approaches combined in an extrapolation framework. Therefore, this approach differs significantly from adaptive modeling software that uses complex mathematical concepts. A few examples are provided below.

At the outset of this study, several members of the Binational Advisory Committee expressed interest in using satellite imagery as a way of creatively estimating emissions.

Traditional use of this technology for emissions inventory development has been primarily limited to the development of biogenic emission estimates. Land use/land cover (LULC) data are used to support the estimate of the quantity and location of biomass needed in biogenic hydrocarbon emission calculations. We also explored the possibility of using this technology to identify other emission sources from satellite imagery, such as the occurrence of wild and prescribed fires as well as other geographic related area source categories such as unpaved road dust. As a potential example of the application of this technology, spatial interpretation studies could be undertaken to identify burned areas. The cost to acquire and process Landsat Thematic Mapper data is approximately $1.3 million. Therefore, the cost effectiveness of using these data in such a limited approach is not very practical. For other sources, such as unpaved roads, it may not be possible to identify this LULC type satellite imagery given the spatial resolution of the data (~ 30 meter pixels).

To improve cost effectiveness of satellite imagery as an emissions estimating tool, these data could be expanded into a modeling framework, where the LULC data are used not only to estimate biogenic but also anthropogenic emissions using a predictive model with the LULC data as the basis (Van Curren, 1995). For example, non-point emissions in a region are a function of the standard of living, population density, climate, and social practices. Using micro-inventory techniques combined with socioeconomic information, predictive models could be developed using LULC data as the basis. In essence, an emissions flux would be developed that relies on LULC data as the basis for the emission estimate. This approach could be used to account for many different area and mobile source categories in a quick and efficient modeling framework that could be updated and refined over time. This approach is most applicable for regions that have insufficient records and statistics to apply traditional inventory techniques. The concept of fuzzy logic could also be incorporated into this approach to augment the emission estimating technique. This may be especially important for Mexico were important emission differences are expected across geographic regions.

As a second example, multivariate models could be developed for individual area source categories, such as solvent use and agricultural equipment. Regardless of location, it is difficult to obtain the data needed to estimate emissions for these two area source categories. Stratified random surveys could be used to collect the needed data to develop the model. In this approach, a survey program would be designed to sample a subset of the source population with the results statistically extrapolated to the remaining population. Such an approach has been attempted for Southern California (Wyane, et al., 1989) and is currently being developed for the state of California (Roe and Jones, 1994). This concept has also been used to estimate agricultural equipment emissions in California's San Joaquin Valley where equipment use (and hence emissions) are considered to be a function of crop type and acreage. Figure 3-4 illustrates this concept for agricultural equipment.

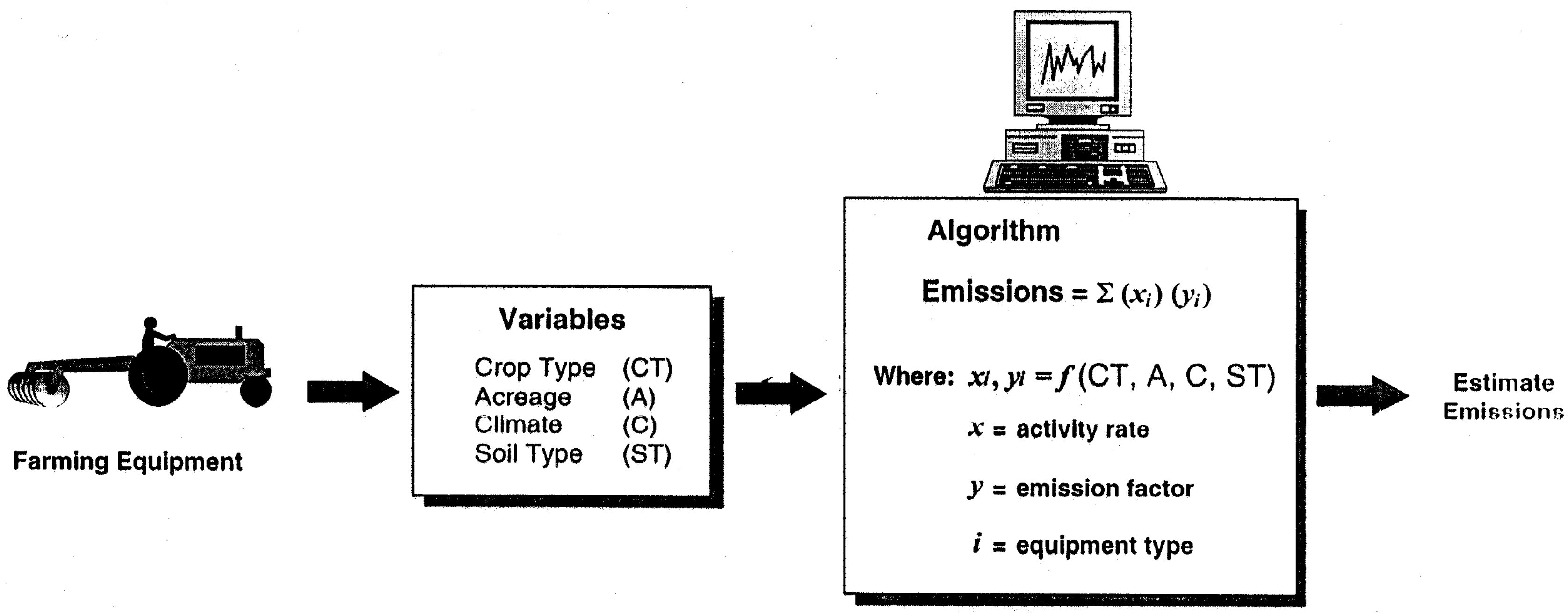


Figure 3-4. Example of Multivariate Emissions Model

Multivariate models may be also applicable to point sources. Consider petroleum refinery VOC fugitive emissions from leaking valves, flanges, and compressors. In the U.S., highly detailed and sophisticated emission techniques have been developed that require detailed component counts and, in some cases source screening data. Initially obtaining this level of detail in Mexico may be difficult. Therefore, a model could be developed to estimate emissions based on certain parameters that are easily obtained for each refinery. For example, refinery fugitive component emissions could be considered to be a function of the material throughput, age, product mix, and the use of an inspection/maintenance program at the refinery.

From the above examples, it can be seen that the use of multivariate models will have higher initial costs than other methods because of the model development step. However, ease of application and reduced future inventory maintenance costs make this a very attractive approach. Another key advantage is that the models would be developed for Mexico, and therefore, Mexico-specific emissions would be estimated. We believe that multivariate models could simplify the emission inventory development process in Mexico, and we have integrated this concept into the methodology proposal for those sources where this approach makes the most sense.

3.1.3 Surveying

A surveying methodology can be used to collect activity data to characterize emissions from certain source types (e.g., electrical utilities, commercial solvent usage, etc.) or in certain regions (e.g., highly industrialized areas). Surveying is applicable to both point and dispersed area sources. A successful survey effort obtains activity data (e.g., fuel consumption or material throughput) to combine with emission factors for calculating emissions and verifying emissions calculated (or measured) based upon the use of a different method. Figure 3-5 illustrates this concept.

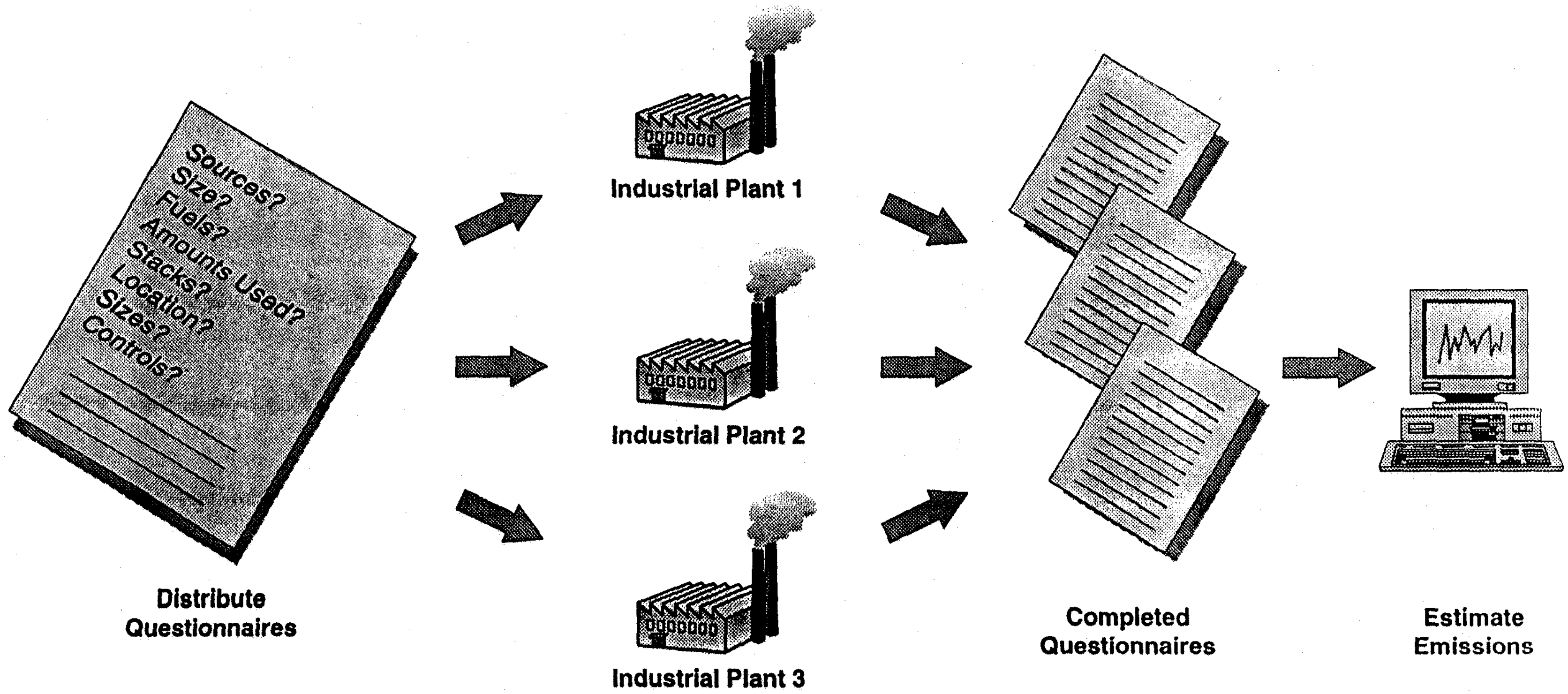


Figure 3-5. Example of Surveying

Much thought and planning must be dedicated to the design of a new questionnaire or modification of an existing one. The success rate of a surveying effort is largely dependent on whether the survey is backed by regulatory agency support and also on the conciseness, ease of use, and generality of the survey questionnaire. In addition, the questionnaire responses must be subjected to thorough quality assurance (QA) and quality control (QC) reviews to eliminate "bad" data (e.g., supersonic stack exit gas velocities). The cost of a surveying effort is a function of the completeness and specificity of the questionnaire, the extent of the target audience, and the thoroughness of the QA/QC and follow-on activities.

Survey methods for point sources are already being used in Mexico. Staff at INE use questionnaires to gather information for their national point source inventory. Questionnaires are also being used in Monterrey and Mexico City to gather point source data. Continued use of surveys is envisioned in the Mexico Inventory Program.

3.1.4 Census-Based Emission Factors and Activity Data

The emissions from area sources can be estimated using a variety of available data (e.g., survey data discussed in the previous section). This often involves the application of an emission factor representing the quantity of pollutant released as a result of some activity. U.S.-specific per capita emission factors for various activities are available from several sources including the U.S. EPA's FIRE emission factor data base, *AP-42 Compilation of Air Pollutant Emission Factors* and its Supplements F and G, the SIP guidance document, and AIRS/AMS *Short List of AMS SCCs and Emission Factors*. Non-U.S.-specific emission factors for various source aggregates are available from the *Rapid Source Inventory Techniques* guidance document developed for the WHO (Economopoulos, 1993) and various GHG inventory guidance documents (see e.g., IPCC, 1993a and b).

In the universe of emission factors and activity data, arguably the most "user-friendly" choices are those that are based on census data. Example census data include population, housing, and number of employees. Examples of source types that have census-based emission factors are dry cleaning, surface cleaning, and solvent use. In Mexico, population and housing data, and employment data by economic sector and municipality are available in printed and electronic format from the Instituto Nacional de Estadística, Geografía e Informática

(INEGI). Facility-specific, manufacturing employment data (by economic sector) are also available in electronic format from Cámara de la Industria de la Transformación (CAINTRA). The latter database is proprietary and available at a cost of $1,300. The use of census-based emission factors is especially attractive for dispersed and numerous emission source types that cannot be readily characterized by a knowledge of process rates, fuel consumption rates, and/or material feed rates. Care must be taken, however, to account for socioeconomic and control differences when transferring census-based emission factors from one country to another. For example, there is a census-based emission factor for consumer solvents (2.86 kilograms/year/person). For the Mexico City area source inventory, Department of the Federal District (DDF) has adjusted this emission factor down to 2.49 kilograms/year/person.

For many area source categories, the application of census-based emission factors is an appropriate method for estimating emissions in Mexico. As stated above, care must be taken to make sure that these factors are representative of Mexican conditions. Many of the existing factors may not represent conditions in Mexico. The census-based factors developed for the WHO could possibly be more applicable, but their derivation is not clearly documented. The *Rapid Source Inventory Techniques* guidance document is simply a tabular listing of emission factors with no supporting documentation. Although not census-based, Table 3-1 illustrates the presentation of the WHO emission factors for petroleum refining. It's possible that the census-based emission factors used in GHG inventories may be more applicable to Mexico than U.S. factors. Consequently, more evaluation is needed to determine which factors are most appropriate for Mexico.

3.1.5 Material Balance

In some instances, a material balance approach can be used to approximate the emissions. Material balances can be used directly, for example, by assuming that all the sulfur content of a fuel is emitted as SO_2. Alternately, a material balance can be used to establish an empirical equation taking into account the relationship between combustion reactants and products. Material balances can also be used in conjunction with non-census-based emission factors to estimate emissions, such as those based on the difference between the raw material and the product when the emission factor for a process is per unit of material consumed. In essence, material balances are often used in calculating emissions when activity data such as production and sales data and fuel composition data are used.

For example, material balances could be performed for area source emission calculations involving fuel manufacture, distribution, and consumption (see Figure 3-6). A material balance for fuel distribution and consumption was recently applied in the United States (De Luchi, 1993). A similar approach appears even more feasible in Mexico because fuel manufacture, distribution, and consumption are under government leadership. A national material balance for solvents for surface coating materials may also be the best method for estimating VOC emissions from this group of sources. We are currently exploring this potential application.

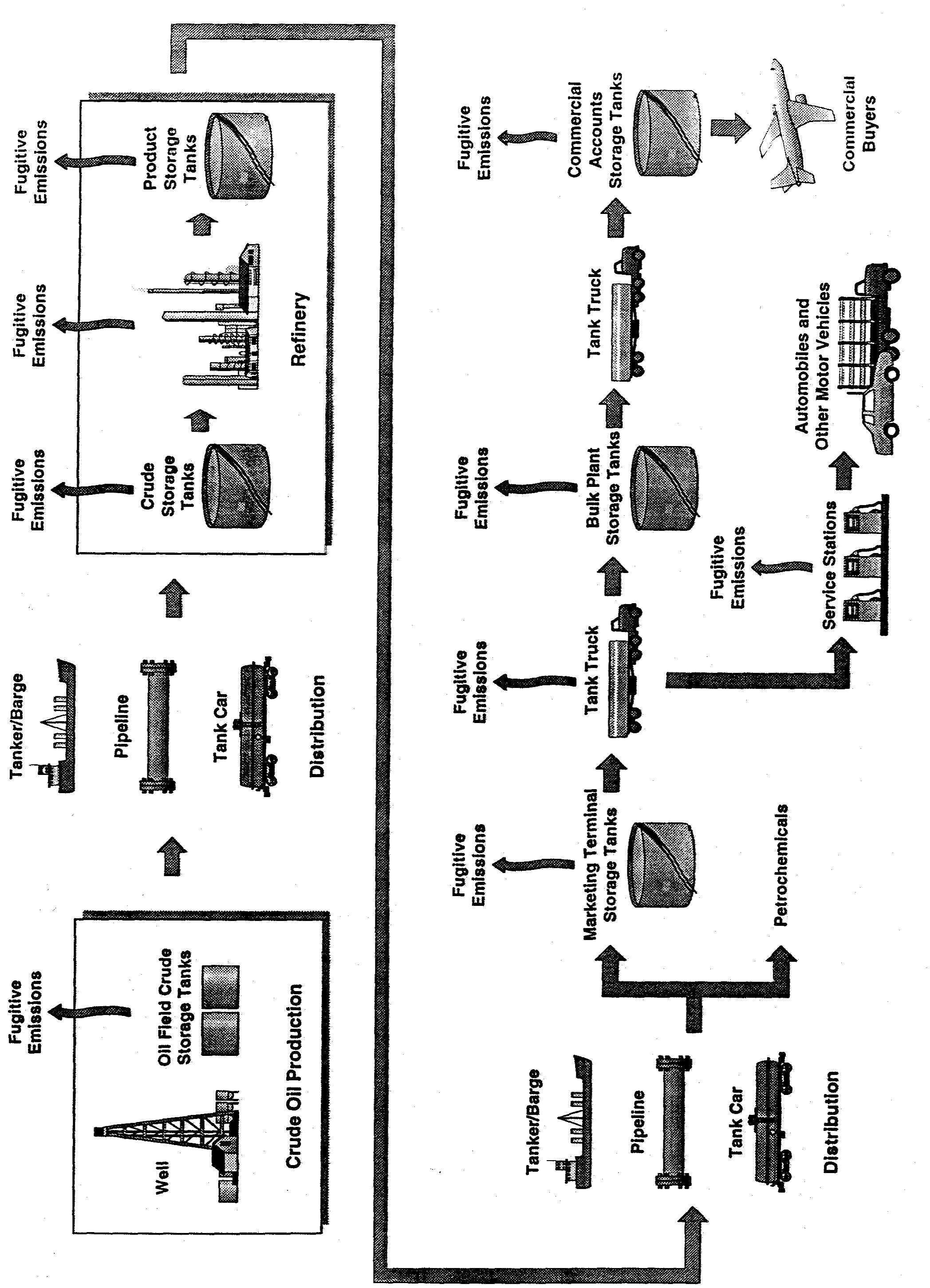


Figure 3-6. Example of Material Balance Highlighting Fugitive Emissions

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With the exception of the fuel and solvent use examples presented above, we see limited use of material balance calculations in Mexico as a primary method for estimating emissions. Rather, we envision the use of material balances as a top down method to evaluate the reasonableness emission estimates generated using other techniques.

3.1.6 Extrapolation

Extrapolation techniques can be used both to calculate emissions directly and to verify the emission estimates calculated using another approach. For example, source sampling data from one type of process or one facility can be extrapolated to other source types or facilities. In other cases, if it can be argued that the socioeconomic conditions between two or more geographical regions are comparable, then the available area source emissions data for one region can be extrapolated to the remaining regions based on population/employment data. Figure 3-7 illustrates the concepts of emissions extrapolation. Emissions inventories compiled in the U.S. and in Europe can be used in this manner. Within Mexico, emissions inventories that have been compiled for Mexico City and that are being developed for other areas (e.g., Monterrey metropolitan area) can be used as a basis for QA and/or development of portions of the "new" emissions inventories for other regions.

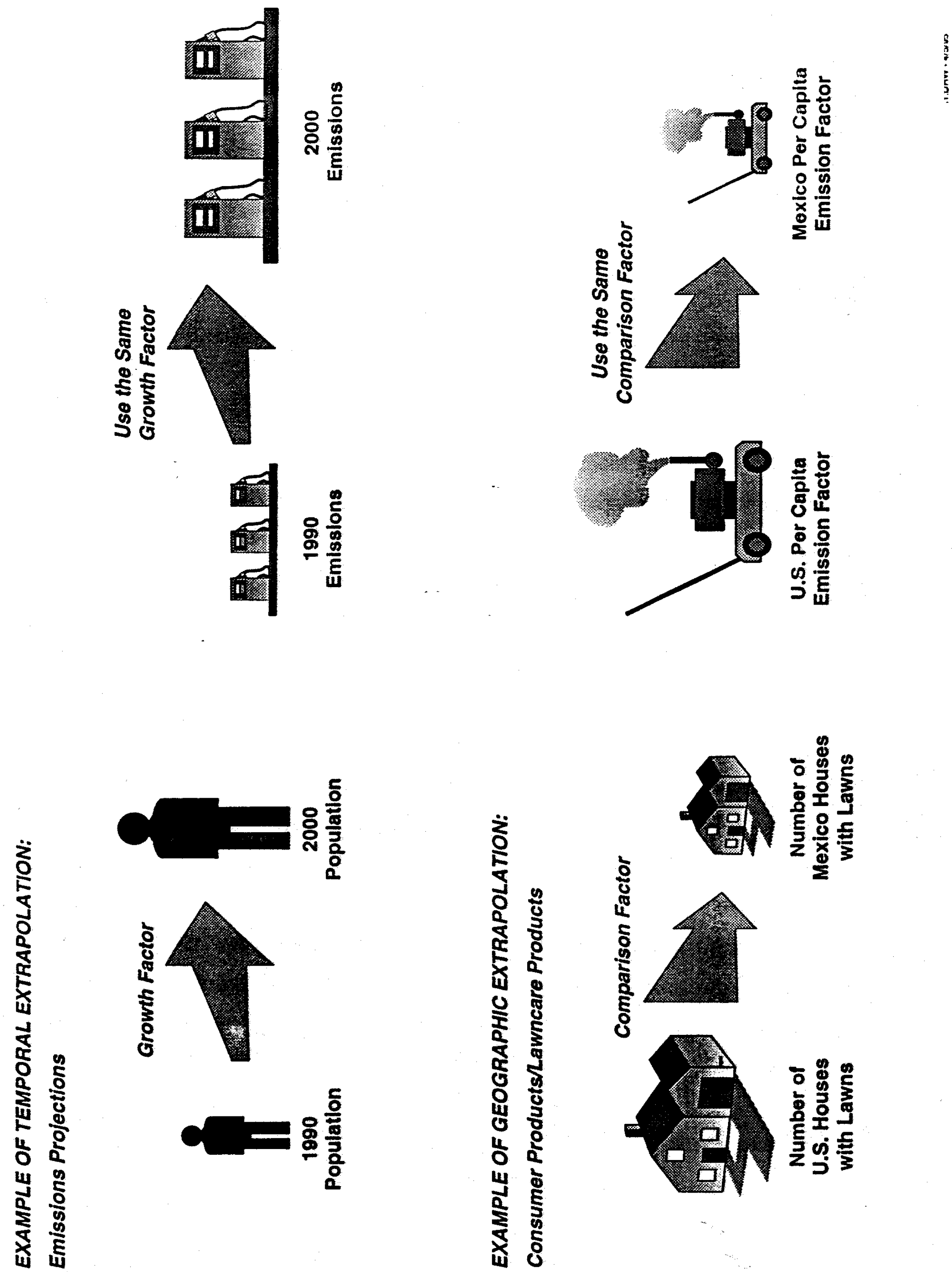

Figure 3-7. Examples of Extrapolation

We view straight extrapolation of emissions from one geographic region to another as the least desirable approach for emissions estimation. Such an approach may not properly account for important differences between two regions and may propagate biases from one inventory to another. For example, the recently completed Mexico City Air Quality Research Initiative (MARI) determined through air quality modeling, ambient monitoring, and data analysis techniques that the VOC inventory used for MARI is underestimated by a factor of four (LANL and IMP, 1994). To our knowledge, causes of this underprediction are currently unknown, although motor vehicle emissions and gasoline evaporation are strongly suspected (Striet, 1995). Recent air quality monitoring results also suggest that emissions from propane tanks used for cooking may also be a significant source of uninventoried VOC.

When combined in a modeling framework, however, extrapolation of emissions to regions where there is insufficient statistical information to estimate emissions using traditional approaches will be a practical and cost effective approach. This concept is discussed in greater detail above under the concept of "Multivariate Models."

3.2 Point and Area Source Methods Evaluation

A detailed methods evaluation was performed for each of the point and area source types listed in Section 2.0. The results of the evaluation are presented in tabular format to facilitate the review of this material. The evaluation results for point, area, and nonroad mobile sources are presented in Appendices A through C, respectively.

Two of the methods considered in this analysis rely on the use of emission factors (i.e., survey and census data combined with emission factors). At this time, we are aware of two different sets of emission factors available to make emission calculations. The first set are the standard emission factors used in the U.S., such as those found in AP-42. The other set of factors is contained in the *Rapid Source Inventory Techniques* guidance document (Economopoulos, 1993). At this time, the applicability of either set of these factors to Mexico is unknown. Therefore, another method that could be added to Appendices A through C is the concept of "pooled source testing" to develop Mexico-specific emission factors. We have not listed this as an approach in the following material because it is a refinement of the data that would be used in a method that is currently being evaluated. Nonetheless, an evaluation of existing emission factors is warranted, but beyond the current scope of the project's Phase I activities. The implementation plan (Task 6) will address this issue in more detail.

Table 3-1

Rapid Source Inventory Techniques Emission Factors for Petroleum Refining[a]

Process	Subprocess	Unit (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U
Misc. Operations[b]	N / A	m^3 of crude					0.4
Fluid Catalytic Cracking (FCC)	Uncontrolled	m^3 of FCC feed	0.695	1.413	0.204	39.2	0.63
	CO Boiler	m^3 of FCC feed	0.695	1.413	0.204		
	ESP & CO Boiler	m^3 of FCC feed	0.126	1.413	0.204		
Desulfurization of Source Gas[c]	N / A	kg of Sulfur in Gas	2(100-e) / 100				
		kg of Sulfur Recovered	2(100-e) / e				
Rail Tank & Tank Trucks Filling	Gasoline Loading Splash Loading	m^3 of Gasoline					1.43
		tn of Gasoline					1.94
	Submerged Loading [d] Normal Service	m^3 of Gasoline					0.59
		tn of Gasoline					0.80
	Vapor Balance Serv.	m^3 of Gasoline					0.98
		tn of Gasoline					1.33
	Vapor Controlled	m^3 of Gasoline					0.05
		tn of Gasoline					0.07
	Jet Naphtha Loading Splash Loading	m^3 of Gasoline					0.43
		tn of Gasoline					0.58

Table 3-1

(Continued)

Rail Tank & Tank Trucks Filling (Cont.)	Submerged Loading Normal Service	m^3 of Naphtha					0.18
		tn of Naphtha					0.24
	Vapor Balance Serv.	m^3 of Naphtha					0.30
Loading of Barges	Gasoline	m^3 of Gasoline					0.41
		tn of Gasoline					0.55
	Crude Oil	m^3 of Crude Oil					0.12
		tn of Crude Oil					0.137
	Jet Naphtha	m^3 Jet Nephtha					0.15
		tn of Naphtha					0.20
Loading of Ships / Ocean Barges	Gasoline	m^3 of Gasoline					0.215
		tn of Gasoline					0.291
	Crude Oil	m^3 of Crude Oil					0.073
		tn of Crude Oil					0.083
	Jet Naphtha	m^3 Jet Naphtha					0.06
		tn of Naphtha					0.08

[a] Emissions due to fuel burning are not accounted for and should be computed separately (see SIC No. 410).

[b] VOC emissions from typical sources within a refinery, such as storage tanks, API separators, blowdowns, fugitive sources etc. are included. The listed factor is based on detailed VOC emissions estimates in several refineries.

[c] "e" is the percent efficiency of the sulfur recovery plant. Typical values are for 2-stage plant controlled 92-95%, for 3-stage plant uncontrolled 95-97.5%. 4-stage plant uncontrolled 96-99%, and for controlled plant 99-099.9%.

[d] In the Vapor Balance Service the cargo truck retrieves the vapors displaced during the underground tank filling in service stations (see below, SIC 620). This operation increases the VOC concentration in the air within the empty truck and causes higher VOC emissions when the truck is filled. It should be noted in this regard that most of

Table 3-1

(Continued)

the VOC emissions reduction achieved through the balanced vapor filling of the service stations submerged tanks is offset by the resultant increased emission in the Truck Filling Station, unless of course a vapor recovery system is used in the latter. Reproduced from Economopoulus, 1993.

4.0 ON-ROAD MOBILE SOURCE INVENTORY METHODOLOGIES

On-road mobile source emissions are calculated based on estimates of vehicle activity and emission factors. The methods chosen depend upon the geographic scope of the inventory and the extent of the available data. Development of the on-road mobile source inventory for this effort will depend upon existing data.

4.1 Motor Vehicle Activity Data

To estimate vehicle activity, the following types of data are commonly used for inventory purposes:

- Detailed vehicle kilometers traveled (VKT) estimates;
- Regional VKT estimates;
- Regional estimates of on-road fuel use; and
- Regional population and vehicle registration data.

Each of these sources varies in accuracy and in the level of the assumptions required for its use. Table D-1 in Appendix D presents a detailed evaluation of these data sources. Each method is discussed below.

4.1.1 Detailed Urban VKT Estimates

These data represent the most accurate estimate of vehicle activity and are used extensively in emission factor models. In order to arrive at such data, it is necessary to determine the urban fleet's travel fraction. The travel fraction is based upon the breakdown of the entire fleet into individual model years, as well as the decomposition of total fleet VKT into VKT by model years. In general, the development of detailed urban VKT estimates requires the use of transportation models, comprehensive traffic counting programs and surveying, and detailed registration records. As a result, these data are usually only prepared for larger metropolitan regions which have the available resources to develop such data. Radian used data of this type in estimating vehicle emission for Mexico City (Klausmeier and Menendez, 1991). Detailed VKT estimates are also available for Monterrey and Ciudad Juárez. In general, the large metropolitan areas are expected to have transportation agencies which can provide detailed VKT estimates.

4.1.2 Regional VKT Estimates

Unlike detailed urban VKT estimates which focus on a single metropolitan area, these estimates cover a much larger geographical area, such as an entire state. They are usually based on traffic counting programs, but are usually less detailed than the urban VKT estimates. In order to use regional VKT estimates with emission factor models, various assumptions must be made in order to characterize vehicle activity. Some of these assumptions may involve the application of known vehicle fleet characteristics from one region to the vehicle fleet of another region. Unfortunately, such an application could result in substantial error and uncertainty. One possible problem is the level of non-registered vehicles. Although this is an issue that must be addressed with all vehicle fleets, this will be more of a problem in some regions than in others. Also, because of the influence of U.S. vehicles, the characteristics of the Mexican fleet in the border region could be significantly different from the fleet in the southern regions of Mexico.

4.1.3 Regional Estimates of On-Road Fuel Use

In some areas there are no direct estimates of VKT available. In these areas, the most common technique to estimate vehicle activity is to use fuel consumption data. Such data can be obtained on a regional basis from federal or state governments through fuel tax receipts. Also, these data can be obtained from the petroleum industry through the Mexican Petroleum Institute (IMP).

Regional VKT is estimated from fuel usage data and fuel economy data from the following equation:

$$VKT_{gasoline,diesel} = \frac{Regional\ On\text{-}Road\ Fuel\ Use_{gasoline,diesel}}{Fleet\ Average\ Fuel\ Economy_{gasoline\ diesel\ vehicle}}$$

Fleet Average Fuel Economy = Σ(Fuel Economy$_{vehicle\ type}$*Registration Fraction$_{vehicle\ type}$*Mileage Accumulation Rate$_{vehicle\ type}$) / Σ(Registration Fraction$_{vehicle\ type}$*Mileage Accumulation

$Rate_{vehicle\ type})$

Fuel use data are separated by fuel type (gasoline or diesel) for a region. It is important at this stage to distinguish off-road fuel use for industrial, construction, recreational activities from the on-road fuel use. The on-road fuel use represents usage for the entire fleet, and across all types of light and heavy duty passenger cars and trucks. To estimate regional VKT, the fuel use is divided by the fleet average fuel economy. Fuel economy for each vehicle type (light duty passenger cars, light duty trucks, heavy duty trucks) can be estimated from a number of local data sources, usually survey results or data recorded during emissions test qualification. Local data sources are preferred as they help account for differing local driving conditions. Finally, regional registration data and mileage accumulation estimates are used to develop the fleet average fuel economy estimate.

The estimate of the fleet average fuel economy can be subject to significant uncertainty, resulting from imprecision or assumptions in the three parameters used in the calculation. In particular, mileage accumulation rate data are often not available in the necessary detail and must be estimated using other data sources.

Fuel use estimates may also be used as a means of checking VKT estimates developed using transportation models and traffic counting programs. It should be recognized, however, there are a number of problems associated with this type of comparison. The same concerns regarding development of fuel economy estimates apply in this case as well.

4.1.4 Regional Population and Vehicle Registration Data

This method uses population or vehicle registration data. These data are combined with per capita or per vehicle emission factors to estimate emissions. This is the least accurate method of estimating vehicle activity and requires the largest number of assumptions. This method is useful as a quality control measure to check the accuracy of emissions estimated by one of the other methods described above.

4.2 Motor Vehicle Emission Factors

The second part of the motor vehicle emission estimation process requires the development of emission factors representative of vehicles operating in a given region. A variety of sources are available to provide vehicle emission factors for this effort. These include the following:

- MOBILE-MCMA, an emission factor model developed for Mexico City;
- MOBILE5C, an emission factor model developed by U.S. EPA's office of Mobile Sources for regions outside of the U.S.
- COPERT, Computer Programme to Calculate Emissions from Road Traffic;
- *Rapid Source Inventory Techniques,* a listing of emission factors that can be used to quickly estimate emissions; and
- PART5, U.S. EPA's particulate emission factor program.

The first two sources provide emission factors only for VOC, CO, and NO_x. The last source provides emission factors for particulate emissions. Emissions of SO_2 are generally estimated through material balances using overall estimates of fuel consumption and knowledge of fuel sulfur levels. Table D-2 presents a detailed analysis of these different sources. Additional discussion of these sources is provided below.

4.2.1 Emission Factor Models

U.S. EPA's MOBILE model has been adapted on two different occasions to Mexico. One of the first efforts was by Radian in which the MOBILE-MCMA model was developed. This model was developed by Radian for use in estimating emissions for Mexico City metropolitan area (Klausmeier and Menendez, 1991). It is based on the U.S. EPA's MOBILE4 model, but contains significant revisions and local data to reflect actual Mexico City conditions. This model represents the most comprehensive estimate of Mexico City emission factors for on-road vehicles. It will introduce a bias, however, when applied to other regions because it is based on an out dated version of the MOBILE model that tends to under predict emissions. In addition, MOBILE-MCA was designed to reflect the higher altitude of Mexico City.

The U.S. EPA has also recognized the need to develop a motor vehicle emission factor model for use in border studies. The control technology mix of the 49-state U.S. vehicle fleet has changed over time as manufacturers have met changing emission standards. Those 49-state emission standards have not coincided with Mexican standards and control technology and, consequently, the MOBILE5a source code and default data which describes the 49-state vehicle fleet by technology are not appropriate for use with other vehicle fleets.

Energy and Environmental Analysis, Inc. (EEA) was assigned the task of developing a version of MOBILE5 which can be used in Ciudad Juárez and El Paso. This "Mexican border version" of MOBILE5 could have been developed by replacing the U.S. specific default data with data that reflect the characteristics of the Ciudad Juárez vehicle fleet. However, this methodology would have resulted in a version of MOBILE5 that is useful only for Juárez, and if emission factors for other border towns (or Mexican interior towns) were desired, other versions of MOBILE5 or its successor would have to be developed. At EPA's suggestion, EEA has instead developed code for a new version of MOBILE5 (referred to as MOBILE5c) that can be used anywhere, be it non-California U.S., California, Mexico, or any foreign country.

Although flexible, our review of the MOBILE5c code indicates that the user must supply the basic emission factor database that drives the model, thus requiring a significant level of effort on the part of the user. At this time, the approach for developing MOBILE-MCMA appears to be the most appropriate. In this approach, an emission control technology equivalence matrix is developed and used in the model. In other words, the basic emission factors associated with the MOBILE5a model are mapped to the Mexican vehicle fleet to reflect the age of the fleet and level of emission controls. A preliminary, updated version of this code has been developed for application in Monterrey and is based on MOBILE5a. The name of this new model is MOBILE-MMAp (i.e., Monterrey Metropolitan Area—preliminary). Further refinement of this model is needed so that it can be applied with confidence elsewhere in Mexico. This refinement consists of using inspection/ maintenance data from Monterrey (at idle conditions) to refine the preliminary emission control technology equivalence matrix. Further refinement would consist of developing basic emission factors from a Mexico-specific testing data base.

Because the country of Mexico is in its early stages of developing an inventory program, there is an opportunity to establish methods and procedures that are based on advanced technology. Consideration was therefore given to using a modal modeling approach. Existing modeling techniques are based on composite emissions data collected over a defined driving cycle (typically a cycle such as the Federal Test Procedure or FTP). However, this requires an assumption that the cycle is representative of real-world driving behavior. In the modal modeling approach, emission factors are developed for discrete driving events or modes, such as engine starts, level cruise, acceleration, and full throttle acceleration. Emissions can then be "assembled" for any cycle by combining the emissions from a series of these discrete modes. In the future, this may become the preferred approach for estimating emissions from motor vehicles in the U.S.

Although we believe a modal modeling approach would be superior to the current method of estimating emissions, the measurement program required to develop the database needed to support this approach would be extremely high, on the order of millions of dollars. Given this high cost, we do not recommend pursuing this approach in Mexico at this time. Rather, Mexico would be better served to wait and take advantage of any research and development efforts conducted in the U.S and other countries, or combine Mexican efforts with other countries.

4.2.2 COPERT

This model was developed by the Commission of the European Communities (CEC). The development of this model occurred within the framework of the CORINAIR sub-activity of the CEC-sponsored CORINE project (Coordination of Information for the Environment). It reflects a somewhat different approach to emission factor estimation. COPERT uses an iterative method that calculates total fuel consumption and emissions without requiring extensive traffic data. Fuel consumption estimates are then compared to statistical fuel data in order to refine emissions estimates. It is thought that COPERT is more readily adapted to areas with different emission standards than the U.S. EPA's MOBILE5a model (Samaras and Zachariadis, 1993).

Although it appears that COPERT might be an option for estimating motor vehicle emissions in Mexico, the MOBILE-type emission factor models seem to be a more appropriate choice. First of all, COPERT does not include the effects of fuel volatility, altitude, and high engine load. All of these effects could be significant in the Mexico motor vehicle emissions inventory. COPERT also provides only rough estimates of evaporative emissions, whereas

MOBILE-type emission factor models include much more refined estimates. Finally, because the first version of COPERT appeared in 1989, its methodology and related data are not as developed as MOBILE which was first developed in 1978.

4.2.3 Rapid Source Inventory Techniques

This guidance document was developed in Greece for the WHO and contains two different methods for calculating mobile source emissions (Economopoulos, 1993). The first method uses simple mobile source emission factors based on the quantity of fuel consumed. These emission factors are distinguished by engine size and driving location. Because of the predominance of emissions from light duty gasoline powered vehicles, the *RAPID Source Inventory Techniques* document provides an additional method for calculating emissions from motor vehicles. This second method uses graphs and equations from the COPERT computer model (detailed above) which have been extended to include vehicles with catalytic technology.

We do not believe that the emissions estimating methodologies described in *Rapid Source Inventory Techniques* are appropriate for the development of Mexico's emission inventory. The simple mobile source emission factors fail to add adequate detail, while the second method is inappropriate for the same reasons outlined in the section describing the COPERT computer model, namely: insufficient treatment of evaporative emissions, inability to describe local conditions, and underdeveloped data.

4.2.4 PART5

This is the latest generation of the U.S. EPA's particulate emission factor model. It can be used to generate emission factors specific to vehicle types. It can also estimate size-specific emission factors for PM_{10} and $PM_{2.5}$ emissions. This model is also "technology" driven and therefore would have to be modified in the same manner as the MOBILE5a model. Modifying the PART5 code and developing the emission control technology equivalence matrix is relatively straightforward. It should be noted, however, that the emission estimates generated for diesel vehicles are based on an extremely limited database (approximately eight vehicles). Consequently, when this small database is extrapolated to different driving conditions, such as a change in speed, highly uncertain results are generated.

5.0 NATURAL SOURCE INVENTORY METHODOLOGIES

The methodologies used to estimate emissions from natural sources traditionally rely on emission models, especially the techniques used for biogenic hydrocarbon emission estimates. Appendix E presents the available natural source estimation methods.

Estimating emissions for the natural source categories will rely extensively on land use/land cover data (LULC). For example, land use describes the type of vegetation that may be present (e.g., natural versus urban) and also the type of vegetation present (e.g., row crop versus orchard). Development of natural source emission estimates for Mexico would be greatly enhanced through the application of satellite imagery data to develop LULC data. These data could be used directly to develop biogenic hydrocarbon, soil NO_x, and wind blown dust emissions.

Further field research is also warranted so that a more refined biogenic emission estimate can be developed for Mexico. The applicability of the current biogenic emission models may have limited applicability in many regions of Mexico. The work performed to develop the biogenic hydrocarbon inventory for the Grand Canyon Visibility Transport Commission found that biogenic emission estimates for the southwestern U.S. appear to be overestimated. It is possible that the scrubland LULC category for the southern U.S. and northern Mexico should incorporate a lower biomass than is currently used in the biogenic emissions calculations. No other biomass data are available for this region.

In summary, a large effort will be required to develop the necessary data for natural source emission estimates. Satellite imagery would greatly enhance the process, but additional fundamental research will be required to develop other model parameters. This includes soil parameters for soil NO_x estimates and biomass data to support the modeling of biogenic hydrocarbons.

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APPENDIX A

CRITICAL REVIEW OF POINT SOURCE EMISSIONS METHODS

Table A-1

Critical Review of Point Source Emissions Methods

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
Electric Utility Fuel Combustion	Source Sampling / Direct	+	0	+	N / A	+	+	With the small number of facilities in this category, source sampling is a relatively practical and cost effective way to develop emission estimates for this category of sources.
	Surveying / AP-42 Emission Factors	+	+	0	+	0	0	Emissions from utilities have been well studied in the U.S. Further evaluation is needed to determine if these emission factors are applicable to Mexico.
	Surveying / WHO Emission Factors	+	+	0	+	0	0	WHO emission factors have about the same level of source coverage as those in AP 42.
Industrial and Commercial Fuel Combustion	Source Sampling / Direct	+	0	+	N / A	0	+	For the largest sources, source sampling is a practical and cost effective way to develop emission estimates.
	Surveying / AP-42 Emission Factors	+	+	0	+	+	+	Emissions from industrial and commercial boilers have been well studied in the U.S. For the sources not source tested, surveying and application of emission factors is an appropriate approach. Further evaluation is needed to

Table A-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
								determine if these emission factors are applicable to Mexico.
Industrial and Commercial Fuel Combustion (Cont.)	Surveying / WHO Emission Factors	+	+	0	+	+	+	WHO emission factors have about the same level of source coverage as those in AP 42.
	Material Balance	+	+	--	+	+	+	Initially, not all facilities can be either tested or surveyed. Emissions from remaining facilities can be estimated using a material balance. Fuel balances for Mexico appear to be reasonably straight forward because of the central control and distribution of fuels. Emissions calculated using a material balance approach would be placed in the area source inventory.
Chemical Manufacturing (process emissions)	Source Sampling / Direct	0	0	+	N / A	0	+	For the largest sources, source sampling is a practical and cost effective way to develop emission estimates.
Chemical Manufacturing (process emissions) (Cont.)	Surveying / AP-42 Emission Factors	+	0	--	0	0	0	Sources that are not characterized through source sampling could be inventoried through surveying and application of

Table A-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
								emission factors. Given site specific factors, chemical manufacturing emission factors have a high degree of variability. U.S. Emission factors for this category of sources may have limited applicability in Mexico.
	Surveying / WHO Emission Factors	+	0	--	0	--	--	Same comments as above. Further evaluation is needed to determine extent of process coverage for WHO emission factors. Same level of information is needed to apply WHO factors for this category of sources as is needed for AP-42 emission factors.
Petroleum Refining (process emissions)	Source Sampling / Direct	0	0	+	N / A	+	+	For the largest sources, source sampling is a practical and cost effective way to develop emission estimates.
Petroleum Refining (process emissions) (Cont.)	Surveying / AP-42 Emission Factors	0	0	0	0	+	+	Sources that are not characterized through source sampling could be inventoried through surveying and application of emission factors. Given site specific factors, petroleum emission factors have a high degree of variability.

Table A-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
	Surveying/WHO Emission Factors	+	+	--	--	0	--	WHO provides simplified emission factors that group processes, fugitives and tanks together. These emission factors would be easier to apply than AP-42 factors, but they would have a higher level of uncertainty.
Chemical and Refinery Fugitive Equipment Leaks	Source Sampling/Direct	--	--	+	N/A	--	0	It's possible to conduct a site specific screening and bagging study at each facility. This approach is resource intensive and not very practical in the near term.
Chemical and Refinery Fugitive Equipment Leaks (Cont.)	Source Sampling/Indirect	0	0	0/+	N/A	0	+	On-site screening measurements can be collected at each facility and used in conjunction with leak/no leak emission factors, stratified emission factors, or correlation equations. Leak/no leak factors are the least rigorous and correlation equations are the most rigorous of this group. Screening methods vary by choice of factors.
	Surveying/AP-42 Emission Factors	0	0	--	--	+	0	Through surveys, the number of components at each refinery would be collected and combined with the emission factors. In the

Table A-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
								U.S., this approach tends to overestimate emissions.
	Surveying / WHO Emission Factors	+	+	--	--	+	--	The WHO emission factors are based on volume of crude oil processed. Available emission factor combines numerous emission sources such as fugitives, tanks, etc. into one factor. This approach will yield a highly uncertain emission estimate.
Chemical and Refinery Fugitive Equipment Leaks (Cont.)	Extrapolation	+	+	--	--	--	--	Using U.S. inventory data, factors based on quantity of crude could be developed for fugitives and applied in Mexico. This factor would be similar to the WHO factor, but based on current U.S. emission estimates. Uncertainty resulting from application of this factor would still be quite high.
	Surveying / Multivariate Model	0	+	0	0	+	0	From U.S. emissions data, develop and apply multivariate emissions model. Variables would be material throughput, refinery age, product mix, and use of inspection / maintenance program.
Organic Liquid	Mechanistic	0	0	+	+	0	+	Mechanistic model

Table A-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
Storage Tanks	Emissions Model							represents the best estimating tool currently available. The model could either applied by each facility and the calculated emissions reported, or each facility could be surveyed to obtain the required model parameters and emissions calculated at a central location.
Organic Liquid Storage Tanks (Cont.)	Extrapolation	+	+	--	--	--	--	Data from U.S. emission inventories could be used to develop average emission factors/rates that could be extrapolated to Mexico. While this would provide a quick and efficient approach, a tremendous amount of uncertainty would be associated with the emissions.
Primary Metal Production	Source Sampling/Direct	+	+	+	N/A	+	+	The small number of facilities in this category make source sampling a practical and cost effective way to develop emission estimates for this category of sources.
	Surveying/AP-42 Emission Factors	+	+	0	+	0	0	Smelter process operations tend to be variable, making it hard to develop accurate

Table A-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
								emission factors.
	Surveying / WHO Emission Factors	+	+	--	--	0	--	WHO emission factors are more generalized, making them easier to apply, but at the same time giving them a higher level of uncertainty.
Primary Metal Production (Cont.)	Material Balance	+	+	+	+	+	+	For some facilities and pollutants, a material balance would provide precise emission estimates. For example, SO_2 emissions from uncontrolled copper smelters can be easily estimated using a material balance.
Secondary Metal Production	Source Sampling / Direct	--	--	+	N / A	--	0	Metal recycling facilities are generally small emission sources. Source testing resources should be reserved for other source types.
	Surveying / AP-42 Emission Factors	+	+	--	+	+	0	A variety of emission factors are available from AP-42.
	Surveying / WHO Emission Factors	0	0	--	--	--	--	Only generalized emission factors are available for secondary copper.
Cement Production and Miscellaneous Mineral Products (e.g. lime and aggregate	Source Sampling / Direct	+	0	+	N / A	+	+	With the small number of facilities in this category, source sampling is a relatively practical and cost effective way to develop emission estimates for this category of sources.

Table A-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
kilns)								
	Surveying/AP-42 Emission Factors	+	+	0	+	0	0	Emissions from kilns have been well studied in the U.S. Further evaluation is needed to determine if these emission factors are applicable to Mexico.
Cement Production and Miscellaneous Mineral Products (e.g. lime and aggregate kilns) (Cont.)	Surveying/WHO Emission Factors	+	+	0	+	0	0	Emission factors for kilns are included in the WHO method. Coverage of emission sources appears to be similar to AP-42. Further evaluation is needed to determine if these emission factors are applicable to Mexico and if they would be more practical than AP-42 factors.
Automotive Industry	Source Sampling/Direct	+	0	+	N/A	0	+	With the small number of facilities in this category, source sampling is a relatively practical and cost effect way to develop emission estimates for this category of sources.
	Surveying/AP-42 Emission Factors	+	+	0	+	+	0	Emissions from the automotive industry and related industries have been well studied in the U.S. Current emission factors would provide a reasonable estimate of emissions.

Table A-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
	Surveying/WHO Emission Factors	0	0	--	0	--	--	WHO emission factors are somewhat limited for this source category.
Wood Pulping Operations	Source Sampling/Direct	+	0	+	N/A	0	+	With the small number of facilities in this category, source sampling is a relatively practical and cost effective way to develop emission estimates for this category of sources. Further evaluation is needed to see if this category even exists in Mexico.
	Surveying/AP-42 Emission Factors	+	+	0	+	+	0	Pulp mill emissions have been well studied in the U.S. Current emission factors would provide a reasonable estimate of emissions.
Oil and Gas Production	Source Sampling/Direct	--	--	+	N/A	0	0	It would not be practical to test every source. However, emission factors for this category of sources are limited. Additional source testing needed to develop more reliable factors.
	Source Sampling/Indirect	+	+	+	N/A	+	+	Many of the sources in this category are fugitive in nature. Indirect source sampling could be used to better characterize these emissions and develop better emission factors.

Table A-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
	Surveying / AP-42 Emission Factors	0	0	--	+	0	+	Limited factors are available. More research is needed in this area.
Oil and Gas Production (Cont.)	Surveying / WHO Emission Factors	--	--	--	--	--	--	Emission factors available only for desulfurization of natural gas. Application of this method would omit a number of source types and therefore create a bias in the inventory.
Printing and Publishing	Source Sampling	--	--	+	N / A	--	--	Source testing could be used to develop emission estimates, but it would not be a very cost effective approach. Source testing resources should be devoted to other source types.
	Surveying / AP-42 Emission Factors	+	+	0	+	+	+	Reasonable emission estimates can be developed with existing factors.
	Surveying / WHO Emission Factors	+	+	--	+	0	0	Factors available for most process operations. Method ignores miscellaneous solvent use, which would create a bias.
	Survey / Material Balance	+	+	+	+	+	+	This method should be used for fugitive solvent emissions.
Surface Coating	Source Sampling	--	--	0	N / A	--	--	Source testing could be used to develop emission estimates, but it would not

Table A-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
								be a very cost effective approach. Fugitive solvent emissions would also be difficult to measure. Source testing resources should be devoted to other source types.
	Surveying / AP-42 Emission Factors	0	--	--	0	--	--	Product specific emission factors are available, but they have a high degree of uncertainty due to large variations in VOC content of coating materials. U.S. data may also have limited applicability in Mexico (i.e., difference is VOC content). Emission factor approach also likely to exclude clean--up and other solvent use at coating facilities. Thus, the estimates could be biased low.
	Surveying / WHO Emission Factors	0	0	--	--	--	--	Simplified, non-product specific emission factors are available, but a large amount of uncertainty would be introduced into the estimates from their use. Similar concerns about biasing emission estimates low.
Surface Coating (Cont.)	Material Balance	0	0	+	+	0	+	Performing material balances at the facility level provides the most accurate emission

Table A-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
(Cont.)								estimate. However, this is a very resource intensive approach.
Bulk Fuel Terminals	--	--	--	--	--	--	--	See discussion under liquid organic storage tanks at the beginning of this table.
Mining and Quarrying	Source Sampling/Indirect	0	0	+	N/A	0	0	Mining operations consist of area sources that are not amenable to direct source testing. However, indirect sampling and analysis techniques could be used to evaluate the applicability of the available emission factors.
	Surveying/AP-42 Emission Factors	+	+	0	+	+	+	Emission factors for a variety of mining operations have been developed for use in the U.S. These factors could be applied in Mexico.
	Surveying/WHO Emission Factors	0	0	--	0	--	--	Limited factors are available, primarily for crushing and grinding. Other process operations and fugitive dust sources are not addressed.
Wood Products Manufacture	Source Sampling	--	0	+	N/A	--	0	Source testing could be used to develop emission estimates, but it would not be a very cost effective approach. Source testing resources should be devoted to other larger emitting

Table A-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
								source types.
	Surveying / AP-42 Emission Factors	+	+	0	+	+	+	Surveying data combined with emission factors would be the most cost effective way to develop emission estimates for this category of sources.
Sugar Production	Source Sampling	--	0	+	N / A	--	0	Source testing could be used to develop emission estimates, but it would not be a very cost effective approach. Source testing resources should be devoted to other larger emitting source types.
	Surveying / AP-42 Emission Factors	+	+	0	+	+	+	Surveying data combined with available emission factors would be the most cost effective way to develop emission estimates for this category of sources. Emission factors are somewhat limited.

Table A-1

(Continued)

Tanning and Leather Finishing	Source Sampling/Direct	+	+	+	N/A	+	+	The small number of facilities in this category make source sampling a practical and cost effective way to develop emission estimates for this category of sources.
	Surveying/ Emission Factors	0	0	--	--	--	--	Emission factors for this source category are extremely limited.
Glass Production	Source Sampling	--	0	+	N/A	--	0	Source testing could be used to develop emission estimates, but it would not be a very cost effective approach. Source testing resources should be devoted to other larger emitting source types.
	Surveying/AP-42 Emission Factors	+	+	0	+	+	+	Surveying data combined with emission factors would be the most cost effective way to develop emission estimates for this category of sources.
	Surveying/WHO Emission Factors	+	+	--	+	0	0	Factors available for some process operations. Method ignores miscellaneous solvent use, which would create an inventory bias.
Rubber and Plastic Parts	Source Sampling	--	0	+	N/A	--	0	Source testing could be used to develop emission estimates, but it would not be a very cost effective approach. Source testing resources should be devoted

Table A-1

(Continued)

								to other larger emitting source types.
	Surveying / AP-42 Emission Factors	+	+	0	+	+	+	Surveying data combined with emission factors would be the most cost effective way to develop emission estimates for this category of sources.
Fabricated Metal Products	Source Sampling	--	--	+	N / A	--	--	Source testing could be used to develop emission estimates, but it would not be a very cost effective approach. Source testing resources should be devoted to other larger emitting source types.
	Surveying	--	0	0	0	0	0	Process emissions from this category of sources are minimal. Initial focus should be on combustion emissions. See discussion on industrial fuel combustion at the beginning of this table.
Textile Products	Source Sampling	--	--	+	N / A	0	0	Further evaluation of this source category is needed. If there are numerous operations, and the available emission factors are limited, then source testing is warranted.
	Surveying / Emission factors	+	+	0	+	+	+	Activity data collected through surveys could be used to characterize emissions with the available factors. (This source

Table A-1

(Continued)

								category is not addressed in the WHO emission factors.)
Landfill Gas Emissions	Source Sampling/Indirect	--	+	+	N/A	_	_	Landfills are minor VOC emission sources. Source testing resources should be devoted to more important point source categories.
	Surveying/AP-42 Emission Factors	+	+	0	+	0	0	Available emission factors can be used to estimate emissions.
	Surveying/WHO Emission Factors	N/A	N/A	N/A	N/A	N/A	N/A	Source type not addressed.
	Survey/Mechanistic Model	0	+	+	+	+	+	Survey data would be used in existing model to calculate emissions.

Table A-1

(Continued)

Open Burning Dumps	Source Sampling/Indirect	+	+	0	N/A	+	+	It would not be practical to sample every burning dump, but remote sensing should be used to refine the exiting emission factors.
	Surveying/AP-42 Emission Factors	+	+	_	+	+	+	Existing emission factors are easy to apply once activity data are obtained. Uncertainty expected to be large.
	Surveying/WHO Emission Factors	+	+	--	+	+	+	Same comment as above.
Municipal Waste Combustion at Waste Management Facilities	Source Sampling/Direct	+	+	+	N/A	+	+	With the small number of facilities in this category, source sampling is a practical and cost effective way to develop emission estimates for this category of sources.
	Surveying/AP-42 Emission Factors	+	+	0	+	0	0	An emission factor approach could be used in the near term with emission estimates upgraded through source testing.
	Surveying/WHO Emission Factors	+	+	0	+	0	0	Availability of emission factors appears to mirror those factors developed in the U.S.

Table A-1

(Continued)

Food and Agriculture	Source Sampling / Direct	--	0	+	N / A	--	--	Use sampling resources for higher priority sources.
	Surveying / AP-42 Emission Factors	+	+	0	+	+	+	Survey data combined with emission factors is the most practical way to develop emissions for this source type.
Asphalt Plants	Source Sampling	--	0	+	N / A	--	0	Source testing could be used to develop emission estimates, but it would not be a very cost effective approach. Source testing resources should be devoted to other larger emitting source types.
	Surveying / AP-42 Emission Factors	+	+	0	+	+	0	Available U.S. emission factors could be used to estimate emissions from this source type.
	Surveying / WHO Emission Factors	+	+	0	+	+	0	Coverage of WHO emission factors is similar to the U.S. factors. Further evaluation is needed to determine which set would be more applicable.

APPENDIX B

CRITICAL REVIEW OF STATIONARY AREA SOURCE EMISSIONS METHODS

Table B-1

Critical Review of Stationary Area Source Methods

Category	Method	Cost Effectivenes s	Practicality	Uncertainty	Upgrade Potentia l	Near Term Rating	Long Term Rating	Comments
Stationary Source Fuel Combustion - Industrial and Commercial	Material Balance / AP-42 Emission Factors	+	+	0	0	+	0	Collect total fuel usage by fuel type and geographic region (city, state, etc.) from PEMEX. Must reconcile with point sources. Material balance approach also is a useful tool to evaluate estimates made with other methods.
	Surveying / AP-42 Emission Factors	0	0	0	0	0	0	Conduct a stratified, random sampling survey to collect fuel usage in regions where fuel usage data are not available from PEMEX. Use these data to develop per capita or per-employee fuel consumption factors.
Stationary Source Fuel Combustion - Residential Commercial Fuels	Material Balance / AP-42 Emission Factors.	+	+	0	0	+	0	Collect total fuel usage by fuel type and geographic region (city, state, etc.) from PEMEX. Use heating degree day to help spatially disaggregate fuel consumption geographically.
Stationary Source Fuel	Surveying / AP-42 Emission Factors	0	0	0	0	0	0	Conduct a stratified, random sampling survey

Table B-1

(Continued)

Category	Method	Cost Effectivenes s	Practicality	Uncertainty	Upgrade Potentia l	Near Term Rating	Long Term Rating	Comments
Combustion - Residential Commercial Fuels (Cont.)								to collect fuel usage in regions where fuel usage data are not available from PEMEX and use these data to develop per capita or per-employee fuel consumption factors. This could be expanded into a multivariate modeling approach. For example, use heating degree day and other survey data to estimate emissions.
Stationary Source Fuel Combustion - Residential Biomass or Waste-Derived Fuels	Surveying / AP-42 Emission Factors	+	+	0	0	+	0	Conduct a stratified, random sampling survey to collect fuel usage data and use these data to develop per capita fuel consumption factors. Use heating degree day to help spatially disaggregate fuel consumption geographically.
Stationary Source Fuel Combustion - Residential Biomass or Waste-Derived Fuels (Cont.)	Surveying / Multivariate Model	0	0	+	+	0	+	Conduct a stratified, random sampling survey to collect fuel usage data and other variables (e.g., standard of living, climate, population density) to develop a multivariate model that

Table B-1

(Continued)

Category	Method	Cost Effectivenes s	Practicality	Uncertainty	Upgrade Potentia l	Near Term Rating	Long Term Rating	Comments
(Cont.)								incorporates fuzzy logic.
Paved Road Dust	Mobile VKT / AP-42 Methodology	+	+	0	0	+	0	Use VKT data from the mobile source inventory and combine with U.S. default values for silt loading and mean vehicle weight.
	Mobile VKT / Extrapolation / AP-42 Methodology	0	0	+	+	0	+	Use VKT data from the mobile source inventory. Develop Mexico-specific default values for silt loading (possibly by industry or public road type) and mean vehicle weight by extrapolating to Mexico using existing data.
Paved Road Dust (Cont.)	Mobile VKT / Surveying / AP-42 Methodology	--	--	+	+	--	+	Use VKT data from the mobile source inventory. Conduct a stratified, random sampling survey of public road conditions and vehicles to develop Mexico-specific default values for silt loading and mean vehicle weight. AP-42 public road silt loadings are provided by daily traffic level (i.e., high or low) and averaging period (i.e., annual, January-June, or

Table B-1

(Continued)

Category	Method	Cost Effectivenes s	Practicality	Uncertainty	Upgrade Potentia l	Near Term Rating	Long Term Rating	Comments
								July-December).
Unpaved Road Dust	Extrapolation / AP-42 Methodology	+	+	--	0	+	0	Use paved road VKT data from the mobile source inventory and extrapolate to estimate unpaved road VKT. Use as much Mexico-specific data as possible (soil characteristics, wind speeds etc.) to develop Mexico-specific default values.
	Surveying / AP-42 Methodology	+	--	+	+	--	+	Conduct a survey to estimate unpaved road VKT. Conduct a survey to gather Mexico-specific soil characteristics and wind speed data.
Surface Coatings and Clean-up Solvents - Industrial	Census-based Emission Factors	+	+	--	0	+	--	Use per-employee emission factors with employment data or per capital emission factors with population data. Adjust for average VOC content differences between the U.S. and Mexico.
	Extrapolation / Mexican Point Source Inventory	+	0	0	+	+	0	Use Mexican point source inventory emissions and employment figures to develop per-employee emission factors for the various industrial

Table B-1

(Continued)

Category	Method	Cost Effectivenes s	Practicality	Uncertainty	Upgrade Potentia l	Near Term Rating	Long Term Rating	Comments
								sectors.
	Material Balance	0	0	0	0	0	0	Use Mexico-wide material balance of industrial surface coatings to develop regional estimates. Approach would provide accurate state-wide totals, but uncertainty would increase as smaller regions were considered.
	Surveying	0	0	0	+	0	+	Conduct a stratified, random sampling survey to collect coating usage and use these data to develop simple emission factors for the various industrial sectors.
Surface Coatings and Clean-up Solvents - Industrial (Cont.)	Surveying / Multivariate Model	--	--	+	+	--	+	Conduct a stratified, random sampling survey to collect coating usage and other variables (e.g., population density, number of employees, production rate) to develop a multivariate model.
Industrial Surface Cleaning (Degreasing)	Census-based Emission Factors	+	+	0	0	+	--	Use census-based emission factors (i.e., per-employee emission factors with employment data or per capital

Table B-1

(Continued)

Category	Method	Cost Effectivenes s	Practicality	Uncertainty	Upgrade Potentia l	Near Term Rating	Long Term Rating	Comments
								emission factors with population data).
	Census-based Emission Factors / Population Data	+	+	0	0	+	--	Use census-based emission factors (i.e., AP-42 per capita emission factors with population data).
	Extrapolation / Mexican Point Source Inventory	+	0	0	+	+	0	Use Mexican point source inventory emissions and employment figures to develop per-employee emission factors for the various industrial sectors.
	Material Balance	0	0	0	0	0	0	Use Mexico-wide material balance of industrial degreasing solvents to develop regional estimates.
Industrial Surface Cleaning (Degreasing) (Cont.)	Surveying	0	0	0	+	0	+	Conduct a stratified, random sampling survey to collect coating usage and use these data to develop simple emission factors for the various industrial sectors.
	Surveying / Multivariate Model	--	--	+	+	--	+	Conduct a stratified, random sampling survey to collect coating usage and other variables (e.g., population density, number of employees, production rate) to

Table B-1

(Continued)

Category	Method	Cost Effectivenes s	Practicality	Uncertainty	Upgrade Potentia l	Near Term Rating	Long Term Rating	Comments
								develop a multivariate model.
Dry Cleaning	Census-based Emission Factors	+	+	--	0	+	--	Use census-based emission factors (i.e., AP-42 per-employee emission factors with employment data per capita emission factors with population data). Need to identify differences in the mix of solvents used for dry cleaning in the U.S. and Mexico.
	Material Balance	0	0	0	0	0	0	Use Mexico-wide material balance of dry cleaning solvents to develop per-employee or per capita emission factors.
Dry Cleaning (Cont.)	Surveying	0	0	+	+	0	+	Conduct a stratified, random sampling survey of a limited number of dry cleaning establishments to collect solvent usage data and develop per-employee or per capita emission factors.
	Surveying / Multivariate Model	--	--	+	+	--	+	Conduct a stratified, random sampling survey to collect solvent usage and other variables (e.g., population density,

Table B-1

(Continued)

Category	Method	Cost Effectivenes s	Practicality	Uncertainty	Upgrade Potentia l	Near Term Rating	Long Term Rating	Comments
								standard of living, number of employees) to develop a multivariate model.
Consumer Solvents	Census-based Emission Factors	+	+	--	0	0	--	Use per capita emission factor with population data. Review the basis for this value and try to account for differences in cultural practices between the U.S. and Mexico (e.g., minimal use of lawn care products by homeowners in Mexico).
	Extrapolation / Mexican Census-based Emission Factors	+	+	0	0	+	0	Use Mexico City area source inventory census-based emission factor (i.e., 2.49 kg / person / yr) with population data.
Consumer Solvents (Cont.)	Material Balance	0	0	0	0	0	+	Use Mexico-wide material balance of consumer solvents to develop per capita emission factors. For national estimates, this approach would provide reasonable estimates, but uncertainty would increase when applied to smaller regions. Special methods would be needed to spatially

Table B-1

(Continued)

Category	Method	Cost Effectivenes s	Practicality	Uncertainty	Upgrade Potentia l	Near Term Rating	Long Term Rating	Comments
								disaggregate emissions to smaller regions so that socioeconomic differences could be taken into account.
	Surveying / Multivariate Model	--	--	+	+	--	+	Conduct a stratified, random sampling survey to collect consumer solvent usage and other variables (e.g., population density, standard of living, etc.).
Product Storage and Transport (Petroleum Products, Organic and Inorganic Liquids, and Bulk Materials)	Material Balance / Mechanistic Models and Emission Factors	+	+	+	+	+	+	Use data available from PEMEX to estimate total gasoline consumption and combine with AP-42 emission equations (i.e., mechanistic models) to estimate emissions from storage tanks and loading and unloading operations at pipelines, bulk terminals, service stations, airports, and vessels.
	Surveying / U.S. EPA Emission Factors	0	--	0	+	0	0	Conduct a stratified, random sampling survey to estimate the number of each type of fugitive component associated with pipelines and bulk terminals and combine these data with U.S. EPA emission factors.

Table B-1

(Continued)

Product Storage and Transport (Petroleum Products, Organic and Inorganic Liquids, and Bulk Materials) (Cont.)	Model	0	0	0	0	0	0	Use VKT from the mobile source inventory and fuel economy factors to estimate total gasoline consumption. Develop a Stage II vehicle refueling emission factor developed from MOBILE or other similar emission factor model.
	Census-based Emission Factors	0	--	--	--	0	--	Where region-specific fuel usage data are not available, use a per capita or per-vehicle consumption factor developed for all of Mexico and apply to regional population or vehicle registration figures. For national estimates, this approach would provide reasonable estimates, but uncertainty would increase when applied to smaller regions.

Table B-1

(Continued)

Agricultural Production - Livestock	Census-based Emission Factors	+	+	--	0	+	0	Use per-head emission factors with animal population data. Adjust for livestock type differences between the U.S. and Mexico.
	Surveying / Multivariate Model	--	--	+	+	--	+	Conduct a stratified, random sampling survey to animal population data and other variables (e.g., commercial vs. household livestock, detailed livestock characterization) to develop a multivariate model.
Waste Management - On-site Incineration	Material Balance	+	+	0	0	+	0	Use material balance to estimate the total quantity of waste generated and combine with emission factors.
	Census-based Emission Factors	+	0	--	0	0	--	Very rough U.S. factors are available to estimate quantity of waste burned in on-site incineration on a per capita basis. However, the use of on-site incineration as a waste management technology may be more / less common in Mexico.
Waste Management - On-site Incineration (Cont.)	Surveying	0	0	0	0	0	0	Conduct a survey of on-site incineration operations to develop Mexico-specific per capita activity data.

Table B-1

(Continued)

								Also, conduct source testing of "typical" on-site incinerators burning "typical" wastes to develop emission factors.
	Surveying / Multivariate Model	--	--	+	+	--	+	Conduct a stratified, random sampling survey of on-site incineration operations to collect the amount and types of waste burned and other variables (e.g., employment statistics, etc.) to develop a multivariate model.
Waste Disposal - Refuse Burning	Surveying	0	0	0	0	0	0	Conduct a survey of open burning dumps to develop Mexico-specific per capita emission factors. Also, conduct remote sensing (e.g., FTIR spectroscopy) of "typical" open burning dumps to develop emission factors.
	Surveying / Multivariate Model	--	--	+	+	--	+	Perform survey / micro-inventory efforts to develop a multivariate model for application in regions were statistical data are not available.
Fires - Wildfires	Surveying / AP-42 Emission Factors	0	0	+	+	0	+	Survey forestry experts in Mexico to estimate the total acreage burned and average fuel loading factors.
	Extrapolation / AP-42	+	+	--	0	0	0	Collect total forested

Table B-1

(Continued)

	Emission Factors							acreage and extrapolate U.S. ratio of acreage burned:forested acreage to Mexico. Combine with AP-42 emission factors. Limit U.S. data to region with climate similar to Mexico (e.g., southwestern U.S.).
	Multivariate Model	--	--	0	+	--	+	Develop algorithm based on LULC data from a satellite imagery that estimates typical wildfire emission rates.

Table B-1

(Continued)

Fires - Prescribed Burning	Surveying / AP-42 Emission Factors	0	0	+	+	0	+	Survey forestry experts in Mexico to estimate the total acreage burned and average fuel loading factors.
	Extrapolation / AP-42 Emission Factors	+	+	0	0	+	0	Collect total forested acreage and extrapolate U.S. ratio of acreage burned:forested acreage to Mexico. Combine with AP-42 emission factors. Limit U.S. data to region with climate similar to Mexico (e.g., Southwestern U.S.).
	Multivariate Model	--	--	0	+	--	+	Develop algorithm based on LULC data from satellite imagery that estimates typical prescribed fire emission activity.

Table B-1

(Continued)

Public Baths	Census-based / AP-42 Emission Factors	+	+	+	+	+	+	Data from PEMEX and INEGI have been used previously to estimate emissions for this source category.
	Material balance / AP-42 Emission Factors	+	+	0	0	0	0	Rather than considering this as a separate category, include it with other commercial fuel consumption. Estimate emissions using material balance data obtained from PEMEX.
Industrial Processes (not included in point source inventory)	Extrapolation / Mexican Point Source Inventory	+	0	--	+	0	--	Use Mexican point source inventory emissions and employment figures to develop per-employee emission factors for the smaller facilities in various industrial sectors. High degree of uncertainty because emissions may not correlate well with number of employees.
	Surveying / Emission Factors	--	--	+	0	--	+	Survey to collect emissions from small facilities and use these data to develop per-employee emission factors.
Industrial Processes (Cont.)	Extrapolation / U.S. Point Source Inventory	+	+	--	0	0	--	Use U.S. point source inventory emissions to develop per-employee

Table B-1

(Continued)

								emission factors for the various industrial sectors. Approach would yield a rapid method for developing estimates, but estimates would not be specific to Mexico. Must adjust for differences in level of automation (affects number of employees) or control technologies used.
	Surveying / Multivariate Model	--	--	0	+	--	+	Conduct a stratified, random sampling of emissions and other variables (e.g., SIC, number of employees, materials produced, $$ revenue, value added) to develop a multivariate model.
Industrial Processes (Cont.)	Extrapolation / Plant Models	0	0	0	0	0	0	Create "typical" plant models. Assume a certain number and distribution of devices, and then add together the various device emission factors to develop plant-wide emission factors. Might develop "typical" plant of various sizes (e.g., small, medium, and large).
	Census-based Emission Factors / GHG Inventory	+	+	0	0	+	0	Viable approach for many source types

Table B-1

(Continued)

	Techniques							where plantwide emission factors can be developed and applied to publicly available industrial production statistics.
Architectural Coatings	Census-based Emission Factors	+	+	0	0	+	--	Apply AP-42 per capita emission factors with population data. Adjust for average VOC content and socioeconomic differences between the U.S. and Mexico.
	Surveying	--	--	+	+	--	0	Conduct a stratified, random sampling survey to collect coating usage from contractors and use these data to develop Mexico-specific per capita or per-building emission factors.
Architectural Coatings (Cont.)	Material Balance	0	0	0	0	0	0	Use Mexico-wide material balance of architectural coatings to develop per capita emission factors. Material balance approach also may be useful as a QA tool to evaluate emissions calculated by other methods.
Auto Refinishing	Census-based Emission Factors	+	+	0	0	+	--	Use census-based emission factors (i.e, per-employee emission factors with employment data or per capita

Table B-1

(Continued)

								emission factors with population data). Adjust for average VOC content socioeconomic differences between the U.S. and Mexico. May need to adjust for technology differences (e.g., level of automation, spray efficiency / thickness, etc.).
	Surveying	0	0	+	+	0	+	Conduct a stratified, random sampling survey to collect coating usage from a limited number of auto refinishing shops and use these data to develop per-employee or per capita emission factors.
Auto Refinishing (Cont.)	Surveying / Multivariate Model	--	--	+	+	--	+	Conduct a stratified, random sampling survey to collect coating usage and other variables (e.g., percent of population that are car owners, frequency of refinishing or custom paint jobs, size of the used car market) to develop a multivariate model.
Graphic Arts	Census-based Emission Factors	+	+	--	0	+	--	Use census-based emission factors (i.e., AP-42 per capita emission factors with population data). Adjust for average VOC content

Table B-1

(Continued)

								differences between inks in the U.S. and Mexico. Per capita emission factors developed in the U.S. likely to introduce high degree of uncertainty.
	Material Balance	0	0	0	0	0	0	Use Mexico-wide material balance of graphic arts solvents to develop per-employee or per capita emission factors.
Graphic Arts (Cont.)	Surveying	0	0	+	+	0	+	Conduct a stratified, random sampling survey of a limited number of graphic arts establishments to collect solvent usage data and develop per-employee or per capita emission factors.
	Surveying / Multivariate Model	--	--	+	+	--	+	Conduct a stratified, random sampling survey to collect solvent usage and other variables (e.g., population density, standard of living, number of employees) to develop a multivariate model.
Solvent Use - Asphalt Application	Material Balance / AP-42 Emission Factors	+	+	0	0	+	0	Use material balance to estimate total paving material usage for cutback asphalt and emulsified asphalt and combine with AP-42

Table B-1

(Continued)

								emission factors. Total paving material estimates may be available from PEMEX data or Federal Highway Agency information.
Solvent Use - Asphalt Application (Cont.)	Census-based Emission Factors	+	+	0	0	+	--	Use census-based emission factors (i.e., per capita emission factors for cutback asphalt and emulsified asphalt) and apply to all Mexican asphalt application types.
Solvent Use - Agricultural Pesticide Application	Surveying	0	--	+	+	--	0	Survey Mexican agricultural department offices or conduct a stratified, random sampling survey of farmer pesticide usage. Depending on data availability, develop crop-specific acreage emission factors or region-specific per-acre emission factors.
	Material Balance	0	0	0	0	0	0	Use Mexico-wide material balance of agricultural pesticide consumption to develop a national per-acre or crop-specific per-acre emission factors.
	Extrapolation	+	+	--	--	0	--	Use U.S. national average per-acre emission factor and extrapolate to Mexico.

Table B-1

(Continued)

Solvent Use - Agricultural Pesticide Application (Cont.)	Surveying / Multivariate Model	--	--	+	+	--	+	Conduct a stratified, random sampling survey to collect pesticide usage and other variables (e.g., crop type, farm size, climate, etc.) to develop a multivariate model.
Solvent Use - Agricultural Fertilizer Application	Surveying	0	--	+	+	--	0	Survey Mexican agricultural department offices or conduct a stratified, random sampling survey of farmer fertilizer usage. Depending on data availability, develop crop-specific acreage emission factors or region-specific per-acre emission factors.
	Material Balance	0	0	0	0	0	0	Use Mexico-wide material balance of agricultural fertilizer consumption to develop a national per-acre or crop-specific per-acre emission factors.
	Extrapolation	+	+	--	--	0	--	Use U.S. national average per-acre emission factor and extrapolate to Mexico.
Solvent Use - Agricultural Fertilizer Application (Cont.)	Surveying / Multivariate Model	--	--	+	+	--	+	Conduct a stratified, random sampling survey to collect fertilizer usage and other variables (e.g., crop type, soil type, farm size, climate, etc.) to develop a multivariate

Table B-1

(Continued)

								model.
Agriculture Production - Agricultural Burning	Extrapolate / U.S. EPA Emission Factors	+	+	--	--	0	--	Assume U.S. agricultural burning practices apply to Mexico to determine acres of land burned in Mexico by crop type.
	Extrapolation / WHO Emission Factors	+	+	--	--	+	--	Use extrapolation to estimate the total quantity of waste burned or the total area of cropland (m^2) and combine with crop type-specific (i.e., field, vine, weeds, orchard, forest residue) WHO emission factors.
	Surveying	+	+	0	0	+	0	Survey agricultural experts in Mexico to develop crop-specific waste quantity estimates and combine with existing emission factors.
Agriculture Production - Agricultural Burning (Cont.)	Surveying / Multivariate Model	--	--	+	+	--	+	Survey agricultural operations / experts to collect the quantity and type of wastes burned and other variables (e.g., crop type, climate, acreage, traditional farming methods) to develop a multivariate model.
Agricultural Production - Tilling	Surveying / Multivariate Model	0	0	+	+	0	+	Conduct a stratified, random sampling survey of agricultural tilling operations to collect variables (e.g., crop type,

Table B-1

(Continued)

								acreage, days of precipitation, traditional farming methods, mobile agricultural equipment) to develop a multivariate model. Will need to distinguish between subsistence and commercial farming.
Fires - Structures	Surveying / AP-42 Emission Factors	0	0	0	0	0	0	Survey fire departments in major Mexican cities to estimate the total number of fires and average fuel loading factors (i.e., quantity of material burned per fire).
Waste Management - Wastewater Treatment	Surveying / AP-42 Emission Factors	0	0	0	0	+	0	Conduct surveys to estimate the quantity of wastewater treated and combine with AP-42 emission factors.
	Multivariate Model	+	+	0	0	0	+	Expand survey efforts to develop model based on a number of variables such as population, employment, etc.
Open Sewage	Surveying	0	0	0	+	0	+	Conduct a stratified, random sampling survey to collect sewage generation data and develop simple emission factors.
	Surveying / Multivariate Model	--	--	+	+	--	+	Conduct a stratified random sampling survey to collect sewage generation data and

Table B-1

(Continued)

									other variables (e.g., population density, standard of living)

Table B-1

(Continued)

Street Vending / Cooking	Surveying	0	0	0	+	0	+	Conduct a stratified, random sampling survey of a limited number of street vendors to collect fuel usage data and develop simple emission factors.
	Surveying / Multivariate Model	--	--	+	+	--	+	Conduct a stratified random sampling survey to collect fuel usage and other variables (e.g., population density, industrial / commercial concentration, food consumption patterns) to develop a multivariate model.
Domestic Ammonia Emissions	Census-based Emission Factors	+	+	0	0	+	+	Apply existing ammonia per capita emission factors with population and other census data.
Tortilla Factories	Extrapolation / Mexico Point Source Inventory	+	0	0	+	+	0	Use Mexican point source inventory emissions and employment figures to develop per-employee emission factors. The Mexico City inventory only tracks fuel combustion emissions from tortilla factories. There may not be any tortilla factories currently included in the

Table B-1

(Continued)

								point source inventory.
	Surveying / Emission Factors	--	0	+	+	0	+	Conduct a stratified, random sampling survey to collect fuel usage and other material usage to develop census-based per-employee, per capita or per tortilla material consumption factors.
Brick Manufacturing	Surveying	+	+	+	0	+	0	Survey small facilities to collect emissions data.
	Surveying / Multivariate Model	0	0	+	+	0	+	Conduct a stratified, random sampling survey to collect emissions and other variables (e.g., fuel use, population density, number of employees, brick production) to develop a multivariate model.
Building Construction	Surveying / AP-42 Emission Factors	0	0	0	0	+	0	Conduct surveys to estimate the amount of construction activity and combine with AP-42 emission factors.
	Surveying / Multivariate Model	+	+	0	0	0	+	Conduct a stratified, random sampling survey of construction operations to collect variables (e.g., construction practices, types of construction equipment, acreage, soil types) to develop a multivariate model.
Traffic	Census-based Emission	+	+	0	0	+	--	Use census-based

Table B-1

(Continued)

Markings	Factors							emission factors (i.e., per-employee emission factors with employment data or per capita emission factors with population data). Adjust for average VOC content and socioeconomic differences between the U.S. and Mexico.
Traffic Markings (Cont.)	Material Balance	0	0	0	0	0	0	Use Mexico-wide material balance of traffic marking surface coatings to develop per-employee or per capita emission factors. Total traffic marking coatings estimates may be available from PEMEX data or Federal Highway Agency information.
Solvent Use - Rubber and Plastics Fabrication	Extrapolation / Mexican Point Source Inventory	+	0	0	+	+	0	Use Mexican point source inventory emissions and production-worker (non-sales) employment figures to develop per-production worker emission factors.
	Surveying	--	--	+	+	--	+	Conduct a stratified, random sampling survey of rubber and plastics plants and use these data to develop simple emission factors.
	Material Balance	0	0	0	0	0	0	Use Mexico-wide material balance of

Table B-1

(Continued)

								solvents used for rubber and plastics fabrication to develop per-employee or per capita emission factors. May spatially disaggregate by employment data.
Waste Management - Landfills	Material Balance / Mechanistic Model	+	+	0	0	+	0	Use material balance to estimate the total quantity of waste disposed and combine with the AP-42 mechanistic model (based on biodegradation).
	Survey / Mechanistic Model	0	0	+	+	0	+	Use surveys to gather data required to run mechanistic model.
Bakeries	Census-based Emission Factors	+	+	0	0	+	0	None.

APPENDIX C

CRITICAL REVIEW OF NONROAD MOBILE SOURCE EMISSIONS METHODS

Table C-1

Critical Review of Nonroad Mobile Source Methods

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
Aircraft	Source Sampling / Direct	--	--	0	0	--	--	Development of emission factors is possible using source sampling, but this would not be a very cost effective approach. Source sampling should be used for much more dominant source types.
	Surveying / AP-42 Emission Factors	+	+	0	+	+	0	Emissions from aircraft have been studied in the U.S. Emission factors need to be modified if there are significant differences in aircraft types, usage, and fuels.
Railroads	Source Sampling / Direct	--	0	+	0	--	--	Development of emission factors is possible using source sampling, but this would not be a very cost effective approach. Source sampling should be used for much more dominant source types.
Railroads (Cont.)	Surveying / AP-42 Emission Factors	+	+	--	+	+	0	Emission factors in AP-42 are based on limited sets of data. As a result, large uncertainty is possible. Emission factors need to be modified if there are significant differences in locomotive types, usage,

Table C-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
								and fuels.
Commercial Marine Vessels	Source Testing / Direct	--	0	+	+	--	--	Development of emission factors is possible using source sampling, but this would not be a very cost effective approach. Source sampling should be used for much more dominant source types.
	Survey / AP-42 Emission Factors	0	0	0	+	+	+	Survey individual ports to develop origin and destination data. Also request in port activities as part of survey.
	Extrapolation	0	+	0	+	0	0	Scale U.S. EPA nonroad engine equipment populations and usage data by appropriate Mexican activity indicators to determine emissions.
Agricultural Equipment	Extrapolation	+	+	--	0	0	--	Scale U.S. EPA nonroad engine equipment populations and usage data by appropriate Mexican activity indicators to determine emissions.
	Surveying	0	0	0	+	0	0	Conduct a stratified, random sampling survey of agricultural equipment usage to

Table C-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
								develop Mexico-specific emission estimates.
	Surveying / Multivariate Model	--	--	+	+	--	+	Conduct a stratified, random sampling survey of agricultural equipment to collect variables (e.g., crop type, acreage, usage patterns) to develop a multivariate model using LULC data.
Construction Equipment	Extrapolation	+	+	0	+	0	--	Scale U.S. EPA nonroad engine equipment populations and usage data by appropriate Mexican activity indicators to determine emissions.
Construction Equipment (Cont.)	Surveying	0	0	+	+	+	0	Conduct a stratified, random sampling survey of construction equipment usage to develop Mexico-specific emission estimates.
	Surveying / Multivariate Model	--	--	+	+	--	+	Conduct a stratified, random sampling survey of construction equipment to collect variables (e.g., standard of living, population density, local construction activity) to develop a multivariate

Table C-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
								model.
Industrial Equipment	Extrapolation	+	+	0	+	0	--	Scale U.S. EPA nonroad engine equipment populations and usage data by appropriate Mexican activity indicators to determine emissions.
	Surveying	0	0	+	+	+	0	Conduct a stratified, random sampling survey of industrial equipment usage to develop Mexico-specific emission estimates.
Industrial Equipment (Cont.)	Surveying / Multivariate Model	--	--	+	+	--	+	Conduct a stratified, random sampling survey of industrial equipment to collect variables (e.g., standard of living, "industrial density", industrial activity) to develop a multivariate model.
Light Commercial Equipment	Extrapolation / Population Data	+	+	--	--	+	--	Use U.S. EPA nonroad engine emission estimates and extrapolate for Mexico based on population. Unquantified differences between the two countries could lead to large uncertainty.

Table C-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
	Extrapolation	0	0	0	+	0	0	Scale U.S. EPA nonroad engine equipment populations and usage data by appropriate Mexican activity indicators to determine emissions.
	Surveying	0	0	+	+	0	+	Conduct a stratified, random sampling survey of light commercial equipment usage to develop Mexico-specific emission estimates.
Light Commercial Equipment (Cont.)	Surveying / Multivariate Model	--	--	+	+	--	+	Conduct a stratified, random sampling survey of commercial equipment to collect variables (e.g., standard of living, "commercial density", commercial activity) to develop a multivariate model.
Lawn and Garden Equipment	Extrapolation	+	+	--	0	0	0	Scale U.S. EPA nonroad engine equipment populations and usage data by appropriate Mexican activity indicators to determine emissions.
	Surveying	0	0	+	0	+	0	Conduct a stratified, random sampling survey of lawn and garden

Table C-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
								equipment usage to develop Mexico-specific emission estimates.
	Surveying / Multivariate Model	--	--	+	+	--	+	Conduct a stratified, random sampling survey of lawn and garden equipment to collect variables (e.g., population density, standard of living, home / apartment ratio, park density) to develop a multivariate model.
Recreational Equipment	Extrapolation / Population Data	+	+	--	--	0	--	Use U.S. EPA non-road engine emission estimates and extrapolate for Mexico based on population. Unquantified differences between the two countries could lead to large uncertainty.
	Extrapolation	+	+	0	0	0	--	Scale U.S. EPA non-road engine equipment populations and usage data by appropriate Mexican activity indicators to determine emissions.
	Surveying	--	--	+	+	--	0	Conduct a stratified, random sampling survey of recreational

Table C-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
								equipment usage to develop Mexico-specific emission estimates.
	Surveying / Parametric Model	--	--	+	+	--	+	Conduct a stratified, random sampling survey of recreation equipment to collect variables (e.g., population density, standard of living) to develop a parametric model.
Recreational Marine Equipment	Extrapolation / Population Data	+	+	--	--	0	--	Use U.S. EPA non-road engine emission estimates and extrapolate for Mexico based on population. Unquantified differences between the two countries could lead to large uncertainty.
	Extrapolation	0	+	0	+	0	0	Scale U.S. EPA non-road engine equipment populations and usage data by appropriate Mexican activity indicators to determine emissions.
	Surveying	--	--	+	+	+	0	Conduct a stratified, random sampling survey of recreational equipment usage to develop Mexico-specific

Table C-1

(Continued)

Category	Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
								emission estimates.
	Surveying / Multivariate Model	--	--	+	+	--	+	Conduct a stratified, random sampling survey of recreation marine equipment to collect variables (e.g., standard of living, local water surface area) to develop a multivariate model.

APPENDIX D

CRITICAL REVIEW OF ON-ROAD MOTOR VEHICLE SOURCE EMISSIONS METHODS

Table D-1

Critical Review of On-Road Motor Vehicle Source Emission Factor Methods

Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
Rapid Assessment Inventory Technique	+	+	--	--	0	--	Two sets of generic emission factors. One set of factors requires simple VKT estimates and the other requires fuel consumption estimates. Local variability is not accounted for in these emission factors.
Use modified U.S. per capita or per vehicle emission factors with population or vehicle registration data.	0	0	--	--	0	--	U.S. emission factors must be modified to account for socioeconomic, cultural, and technological differences in Mexico. Currently, these emission factors and modification factors do not exist.
MOBILE-MCMA	0	0	0	+	0	+	Emission factors are based on Mexico City input parameters. These factors are not applicable for the entire country. Refinement of the model is required for application outside Mexico City. Refinement is taking place under projects conducted in Monterrey and Ciudad Juárez.
MOBILE5c	--	--	+	+	--	0	Model can be modified to reflect local conditions, however extensive testing and data development is required to determine some of the input parameters. Default parameters may not properly represent local conditions.
Modal Model Approach	--	--	+	+	--	0	This model currently does not exist. Instead of being a modified MOBILE model, it would be a new model that would more accurately represent mobile emissions in Mexico. It might model such things as different driving modes

Table D-1

(Continued)

Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
							and Mexico's unique vehicle mix. Very expensive to develop.
PART5	0	0	--	+	0	+	This method can only be used for determination of PM emissions. Emission factors are based on United States input parameters. Structure of this model is similar to MOBILE5A, so this model could possibly be modified to represent conditions in Mexico, much like MOBILE-MCMA is a modified version of MOBILE5A. Uncertainty of PART5 is higher than that for the MOBILE models because data sets are not as robust.
Sulfur Fuel Balance	+	+	+	0	+	+	This method can only be used for determination of SO_x emissions. Uncertainty from this method results mainly from uncertain fuel sulfur levels.

Table D-2

Critical Review of Methods for Estimating Vehicle Kilometers Traveled (VKT) or other On-road Motor Vehicle Source Activity Data

Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
Population / Vehicle Registration Data	+	+	0	--	+	--	These data are used only with per capita or per vehicle emission factors. These data are typically available through the national census and transportation organization.
Fuel Consumption Data	+	0	0	0	+	+	VKT can be indirectly calculated through fuel consumption. Fuel consumption data are usually derived from fuel distribution information. This is especially easy when the distribution system is concentrated among only a few entities. In the absence of fuel distribution information, fuel consumption can be calculated by fuel tax data. In the near term, fuel consumption data is useful when VKT is unavailable. As VKT information develops, fuel consumption data can serve as a reasonableness check.
"Simple" VKT Data	0	0	0	+	0	+	"Simple" VKT usually is estimated for a relatively large geographical area. Although simple VKT is commonly based on traffic counting programs, these programs tend to be geographically limited. Consequently, some assumptions must be used to "expand" the coverage of simple VKT.
"Complex" VKT Data	--	--	+	+	--	+	"Complex" VKT is usually only

Table D-2

(Continued)

Method	Cost Effectiveness	Practicality	Uncertainty	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
							determined for large metropolitan areas. Detailed VKT information is necessary in such urban areas with large numbers of mobile sources. Because these areas are relatively small, detailed VKT data can be determined by traffic control programs or transportation models.

APPENDIX E

CRITICAL REVIEW OF BIOGENIC AND NATURAL SOURCE EMISSIONS METHODS

Table E-1

Critical Review of Biogenic and Natural Source Emissions Methodologies

Category	Method	Cost Effectivenes s	Practicality	Uncertaint y	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
Biogenic VOC	Extrapolate U.S. Emissions	+	0	--	--	0	--	Initial biogenic emission estimates for Mexico could be extrapolated from U.S. estimates. Emission fluxes for specific LULC types would be develop from U.S. results and applied to Mexico. This approach would likely rely on hard copy maps and be highly labor intensive. However, we have seen this approach applied in California's Los Angeles Air Basin and in Taiwan.
	BEIS (Pierce et al., 1990)	0	0	0	--	0	--	U.S. EPA's BEIS model could be used to model biogenic emissions for the country of Mexico. Data demands for this model are modest; however, computational approach used in this model is somewhat outdated. Electronic file containing LULC data must be developed for use in Mexico.
Biogenic VOC (Cont.)	BIOME (Mayenkar et al., 1992)	--	--	+	+	--	+	This is a flexible modeling system designed to develop biogenic emission estimates from the bottom-up using plant species-specific emission factors rather than foliar mass emission factors such as those used in BEIS. System is written in SAS®

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(Continued)

Category	Method	Cost Effectivenes s	Practicality	Uncertaint y	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
								and ARC/INFO® and therefore can be easily updated and tailored to Mexico. System currently uses Tingy algorithms for temporal adjustments; system should be updated to use the Guenther algorithms. Large effort would be required to develop LULC data and assemble/assign emission factors for LULC data.
Biogenic VOC (Cont.)	BEISII (Geron et al., 1994)	--	--	+	+	--	+	This new modeling system uses tree genus-specific emission factors in a FORTRAN modeling framework. Model was specifically designed for the eastern U.S. to match U.S. Forest Service LULC data. Application of this model in the southeast U.S. results in significantly higher biogenic emission rates (3 to 10 times higher) than previous modeling efforts. This model could be adapted to Mexico. Data development step would be similar to that of using BIOME. System currently uses Guenther temporal adjustment algorithms.
Windblown Dust	Extrapolate U.S. Emission	0	--	--	--	--	--	Extrapolation could be used to quickly develop emission estimates, but results would

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(Continued)

Category	Method	Cost Effectivenes s	Practicality	Uncertaint y	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
	Rates							have a very large degree of uncertainty.
	Multivariat e Model	0	0	+	+	+	+	U.S. EPA is currently developing a refined approach for wind blown dust from agricultural lands. Modeling framework should be applicable to Mexico.
Soil NO_x	Extrapolate U.S. Emission Rates	0	--	--	--	--	--	Very few soil NO_x emission estimates have been developed in the U.S.; there is not much to extrapolate from. Resulting uncertainty from this approach would be large.
	Multivariat e Model	0	0	0	+	+	+	There has only been limited research in this area. Soil NO_x models are not yet well developed.
Soil NH_3	Extrapolate U.S. Emission Rates	0	--	--	--	--	--	Very few soil NO_x emission estimates have been developed in the U.S.; there is not much to extrapolate from. Resulting uncertainty from this approach would be large.
	Multivariat e Model	0	0	0	+	+	+	There has only been limited research in this area. Soil NH_3 models are not yet well developed.
Lightning	Mechanisti	+	+	+	+	+	+	Reasonably simple mechanisms

Table E-1

(Continued)

Category	Method	Cost Effectivenes s	Practicality	Uncertaint y	Upgrade Potential	Near Term Rating	Long Term Rating	Comments
	c Model							have been developed that could be applied in Mexico.
Geogenic	N / A	N / A	N / A	N / A	N / A	N / A	N / A	Geogenic emissions are site specific and must be quantified through special studies.