Abt Associates Inc.

Estimation of Cocaine Availability, 1996-1999

Final Report

September 2000

Cambridge, MA
Lexington, MA
Hadley, MA
Bethesda, MD
Washington, DC
Chicago, IL
Cairo, Egypt
Johannesburg, South Africa

Prepared for
Office of National Drug Control Policy
750 17th St. NW
Washington, DC

Abt Associates Inc.
1110 Vermont Avenue, NW
Suite 610
Washington, DC 20005-3522

Prepared by
Mary Layne
Patrick Johnston
William Rhodes

Contents

Acknowledgements iii

Executive Summary 1

1. Introduction 1

2. The STAR Model 1
Overview 1
STAR Stage and Transition Details 4
Stage 1 Through Stage 5: Cocaine Production Stages 4
Stage 1: Previous Year's Net Cultivation 4
Stage 2: Net Cultivation in Current Year 4
Stage 3: Net Leaf 5
Stage 4: Base Availability 5
Stage 5: Cocaine Availability at Labs 5
Discussion of Data Incorporated into Stage 1 Through Stage 5 5
Stage 6: Cocaine Departing South America 7
Stage 7: Availability at U.S.-Bound Transshipment Corridors and Non-U.S./Latin American Markets 9
Event-Based Data on Cocaine Movements in the Transit Zone 10
Stage 8: Cocaine Availability at U.S. Border Entry Regions 12
Stage 9: Cocaine Availability at Domestic Retail Areas 22

3. Limitations of the STAR Model and Directions for Improvement 26

4. Applications of the STAR Model 27
Global Accounting Approach 29
Modified Global Accounting Approach 31
U.S.-Residual Approach 33
Consumption Approach 35
Hybrid Approach 37

5. Conclusion 40

References 41

Appendix A: Summary Tables for STAR Production Stages 43

Appendix B: Sources For Enhanced Seizure Data 50
Information in FDSS Data 50
Information in EPIC BLISS Data 52
Information in Customs Seizure Data 54
Information in Coast Guard Seizure Data 57

Appendix C: Technical Details of the Border Allocation Model 58
Transportation Costs 58

Transportation Cost Smoothing Model 60
Outliers 61
Technical Details of Border Allocation Model 63
Limitations of the Model 65

Appendix D: Technical Details of U.S. Domestic Allocation Model 67
Limitations of the Model 68

Appendix E: Transition Tables For 1996 69

Appendix F: Transition Tables For 1997 70

Appendix G: Transition Tables For 1998 71

Acknowledgements

The following people provided thoughtful comments on the draft version of the paper: Adrian Wolfberg, Defense Intelligence Agency; Scott Decker, Professor of Criminology and Criminal Justice, University of Missouri-St. Louis; Dr. Michael Cala, Policy Analyst, Office of National Drug Control Policy; Senior Special Agent Frederick Stacey, U.S. Customs Service; and Anne-Marie Bruen, Associate, Abt Associates. John Lavin, Senior Programming Analyst, Abt Associates provided expert GIS programming support and Caben Chester, Analyst, Abt Associates contributed able research support.

Executive Summary

The 1998 National Drug Control Strategy specified five Goals and thirty-two supporting objectives that will guide the Government's anti-drug program over the next decade. The Strategy's five Goals are summarized as: *Reduce the supply of and the demand for illicit drugs 50 percent by year-2007*. The Nation's ability to meet this summary goal depends partly on its ability to reduce drug availability through source country programs, transit zone interdiction, and domestic law enforcement.

In addition to that summary statement, the Office of National Drug Control Policy has set 97 performance targets and 127 associated measures. Twelve of these performance targets have been designated as Impact Targets. They provide a report card for the effectiveness of anti-drug programs.

Five additional targets involve supply-side activity. These targets are instrumental toward increasing the price of illicit drugs, reducing the supply of illicit drugs, or both. They are important because reduced availability and higher prices should promote less drug use.

- By 2002, reduce drug availability in the United States by 25 percent as compared with the estimated 1996 base year. By 2007, reduce illicit drug availability in the U.S. by 50 percent from the base year.
- By 2002, reduce the rate of outflow of illicit drugs from the source zone by 15 percent as compared to the 1996 base year. By 2007, reduce the outflow rate by a total of 30 percent measured against the base year.
- By 2002, reduce the rate at which illegal drugs successfully enter the United States from the transit and arrival zones by 10 percent as compared to the 1996 base year. By 2007, reduce this rate by 20 percent as measured against the base year
- Domestic production – By 2002, reduce the production of methamphetamine and the cultivation of marijuana in the United States by at least 20 percent as compared to the 1996 base year and by 2007, reduce by 50 percent the production of methamphetamine and the cultivation of marijuana as compared to the base year.
- Domestic trafficker success – By 2002, reduce by 10 percent the rate at which illicit drugs of U.S. venue reach the U.S. consumer, as compared with the 1996 base year. By 2007, reduce this rate by 20 percent over the base year

Having adopted this report card for monitoring the success of the Nation's anti-drug programs, ONDCP faces a problem of measuring the achievement of the performance targets. For example, to measure the reduction in the rate at which cocaine successfully enters the United States, ONDCP needs reliable estimate of the flow of cocaine across U.S. borders. Developing such estimates is conceptually simple but, operationally, extremely difficult.

ONDCP has made remarkable strides at developing cocaine estimates. This report discusses a new model – the Sequential Transition and Reduction (STAR) model. The STAR model tracks the flow of cocaine hydrochloride (HCl) from the cultivation of coca in source country growing regions, to the consumption of cocaine in the U.S. – although it could just as easily track

backwards from U.S. consumption to potential production estimates. It can incorporate various values – or *scenarios* -- and project the impact forward to U.S. consumption, backward to potential production, or to any point in between. It contains a *micro* level component that makes cocaine flow projections by geographic regions and conveyance types, while providing *macro* level estimates at various stages. Additionally, new statistical modeling has been introduced into the model.

The current STAR model, which goes well beyond predecessor flow models, provides the best current basis for measuring the flow of cocaine from producer nations, through the transit zones, across the Nation's borders, and throughout the United States.

The STAR model has generated a new approach to modeling cocaine that incorporates ONDCP's long standing research on U.S. consumption as its starting point to work back to the amount of cocaine that departs South America. The Hybrid approach is a break from Global Accounting, which starts with potential cocaine estimates and sequentially reduces them by losses, such as seizures and consumption. The basis of Global Accounting, potential production, is itself doubtful, and consumption in South America, transit zone countries, and non-U.S./Latin American countries is also uncertain. The Hybrid Approach ends by providing estimates of the amount of cocaine that departs South America and obviates the need for uncertain estimates such as potential production and South American consumption. It also provides a new methodology for providing viable estimates of Non-U.S./Latin American flow by calculating equivalent market loss rates.

1. Introduction

Estimation of cocaine supply is an evolving process. Beginning in 1990, ONDCP determined cocaine availability by starting with an estimate of coca cultivation provided by the Crime and Narcotics Center (CNC) and sequentially reducing it by losses due to seizures, spoilage, and non-U.S. consumption. The approach, termed *Global Accounting*, provides a useful "macro" approach to integrating multiple data sets, such as consumption, seizure, and production estimates. A recently published report on Global Accounting[1] organized these data sets into zones (e.g., source, transit, and arrival) to provide a general flow framework for quantifying cocaine at various stages of movement from source to market.

ONDCP has funded research that builds on and expands previous methodologies. The resultant approach is the Sequential Transition and Reduction (STAR) model. The STAR model tracks the flow of cocaine hydrochloride (HCl) from the cultivation of coca in source country growing regions, to the consumption of cocaine in the U.S. – although it could just as easily track *backwards* from U.S. consumption to potential production estimates. It can incorporate various values – or *scenarios* -- and project the impact forward to U.S. consumption, backward to potential production, or to any point in between. It contains a *micro* level component that makes cocaine flow projections by geographic regions and conveyance types, while providing *macro* level estimates at various stages. Additionally, new statistical modeling has been introduced into the model.

This paper presents details of the STAR model. The next section provides an overview, followed by a detailed presentation of aspects of the modeling, including specifics about data utilized. In Section three we discuss limitations of the STAR model and recommendations for its improvement. Section four details several applications of the model.

[1] DCI Crime and Narcotics Center (CNC); Defense Intelligence Agency, April 2000. *Cocaine: A Global Accounting for 1999.*

2. The STAR Model

Overview

The STAR model incorporates various cocaine availability estimates into a cohesive, connected model. The model hinges on the notion of a transition of cocaine from one *stage* – estimate of drug (or drug precursor) availability, distributed within a specific geographic region – to the next stage. The *transition* is a computational link between stages that converts drug (or drug precursor) availability at one stage to availability at another stage, and includes reductions (seizures, losses, etc.). Table 1 details stages and transitions between stages (including reductions), and lists data sources utilized in STAR. Although the table presents stages in numerical order, the model is not necessarily applied sequentially from stage 1 to stage 9. For example, the model could just as easily begin at stage 9 and work back -- *adding in reductions* -- to a potential production number. Alternatively, the model could begin with event-based data and work backward or forward. The important point is that the model is flexible and not bound to any specific ordering of stages.

The model has nine stages and eight transitions. Stages 1 through 4 are production stages, and Stages 5 through 8 track cocaine HCl from Andean growing regions to the streets of the U.S. Figure 1 depicts the geographical areas involved in each stage.

Stage 1 begins with net coca cultivation from the last calendar year. The transition to Stage 2 – net cultivation in the current year – is the net change, calculated as the amounts from Stage 1 plus new growth minus eradication and field abandonment. Stage 3 is net cultivation converted into net leaf amounts, via calculations performed in Transition 2/3. Stage 4 is the amount of coca base available from the net leaf, calculated by using conversion factors utilized in Transition 3/4 .

Stage 5 represents cocaine availability at labs and Transition 4/5 links cocaine from growing regions to base corridors of movement to the HCl labs, as identified in the IACM. Stage 6 and Transition 5/6 detail the flow from labs to South American departure points. These stages and transitions involve multiple geographic regions.

Stage 7 is separated into two parts, A and B. The transition from 6 to 7A is the amount of cocaine that arrives at non-U.S. and non-South American markets; e.g. Europe and Canada. The transition from 6 to 7B allocates cocaine that moves through transit corridors (without being seized) to specific U.S. border entry points.

Stage 8 is cocaine available at U.S. border regions. Stage 8 uses the Border Allocation Model to calculate the amount of cocaine entering each U.S. border entry region. Transition 7/8 subtracts out border seizures.

Stage 9 is the amount of cocaine that successfully passes through the U.S. border and is transported to various consumption regions within the country. Transition 8/9 incorporates a new modeling effort – the Domestic Allocation Model – and accounts for domestic seizures.

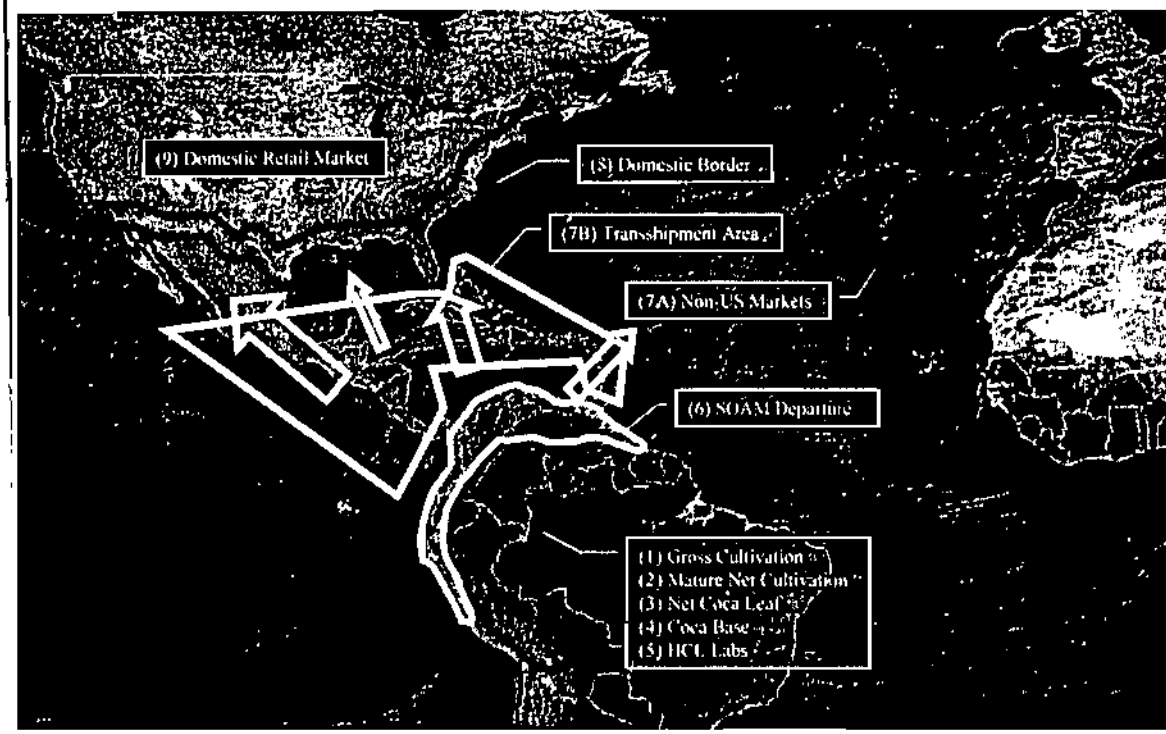
Table 1

STAR Model Stages and Transitions

Stage	Transition and Reductions	Data Sources
Stage 1 - Net cultivation in previous year		CNC
	Transition 1/2 Eradication, abandonment, new growth	CNC
Stage 2 – Net cultivation in current year		
	Transition 2/3 Coca leaf yield, leaf reductions	Operation Breakthrough, CNC
Stage 3 - Net leaf availability at growing areas		
	Transition 3/4 Alkaloid content, base lab processing efficiency, base seizures	Operation Breakthrough
Stage 4 - Base availability at growing areas		
	Transition 4/5 Base movement to cocaine HCl labs, lab seizures	IACM
Stage 5 - Cocaine produced at labs		
	Transition 5/6 Cocaine HCl movement from labs to South American (SOAM) departure areas, SOAM cocaine seizures and consumption	IACM, CNC
Stage 6 - Cocaine availability at SOAM departure areas		
	Transition 6/7A Transit zone seizures, in non-U.S. bound corridors.	IACM, Interpol
Stage 7A - Availability at non U.S./Latin America markets		
	Transition 6/7B Transit zone seizures and consumption in U.S. bound corridors.	IACM, CCDB
Stage 7B- Availability at U.S transshipment corridors.		
	Transition 7B/8 Cocaine subsequent movement to U.S., domestic border seizures	FDSS, EPIC, Customs seizures
Stage 8 - Cocaine availability at domestic border entry regions		Border Allocation Model
	Transition 8/9 Cocaine domestic movement, domestic reductions	FDSS, Domestic Allocation Model
Stage 9 - Cocaine availability at domestic retail areas		ONDCP

Figure 1

Geographic Areas of STAR Stages



The STAR model is comprised of a series of matrix operations.[2] This matrix formulation has several advantages: algebraic conciseness, ability to project assumptions at any stage on predicted flows at subsequent stages, and ability to gauge transition probabilities connecting flows, as well as flow amounts. The model was programmed using the matrix programming language of SAS/IML (SAS Institute, 1990), a program with powerful facilities for simulating alternative flow scenarios.

At most of the transitions, the matrix formulation is an accounting framework, incorporating availability estimates. The information at these "accounting transitions" simply summarizes available data. At stages 6, 8, and 9 the model is more than an accounting device. At these

[2] At each of the eight stages, we have a transition matrix that transforms the input into the predicted output. At stage 1, $v_1 = v_0 * M_1$, where "*" denotes matrix multiplication. At stage 2, $v_2 = v_1 * M_2$. At stage 3, $v_3 = v_2 * M_3$. And so on. The complete model can be written

$$v_8 = v_0 * M = v_0 * M_1 * M_2 * M_3 * M_4 * M_5 * M_6 * M_7 * M_8 ,$$

where v_0 denotes gross hectares by growing area and v_8 denotes cocaine consumed by U.S. geographical subarea.

stages, the model affords a comparison and potential reconciliation of alternate availability estimates. Thus, at stage 6, it estimates the inconsistency in cocaine availability estimates by comparing potential production with event-based estimates of cocaine departing South America. At stage 8, it compares predicted outputs derived from potential production, event-based data, and the Border Allocation Model. At stage 9, it judges the difference in availability estimates by incorporating domestic consumption estimates[3]. Finally, the Domestic Allocation Model was created to allocate cocaine entering the U.S. to consumption regions.

STAR Stage and Transition Details

We now discuss stages and transitions in greater detail, including data specifics. The matrix formulation allows for differing assumptions – or scenarios – to be introduced at any transition and then carried forward (or backward) for comparisons with other scenarios. Although the following discussion presents stages in sequential order, the model does not have to be applied sequentially. In Section three we provide examples of this, while the intent of this section is to provide details about stages, transitions, and data incorporated in each. Appendix A contains summary tables, for stages 1 through 6, by country. Detailed results for each stage and geographic regions can be found in Appendices E through F, for 1996-1998. Future work will update the STAR model for 1999-2000.

Stage 1 Through Stage 5: Cocaine Production Stages

Stages 1 through 4 occur in each of the eighteen Andean growing regions (Guaviare, West Caqueta, East Caqueta, Norte de Santander, San Lucus, Arauca, Putarnayo, Macarena, Upper Huallaga Valley, Central Huallaga Valley, Lower Huallaga Valley, Aguaytia, Pachitea, Apurimac, Cusco, other Peruvian growing areas, Chapare, and Yungas/Apolo/Other). From these regions, coca base moves to cocaine production labs through base movement corridors.

Stage 1: Previous Year's Net Cultivation

For Colombia, Peru and Bolivia, estimates of the quantity of coca under cultivation are developed by CNC, using survey methods similar to those used by agricultural organizations estimating the size of their licit crops. A survey is designed using statistically-based sampling techniques, ensuring that an adequate number of samples are collected over randomly selected areas, as well as sampling of known growing regions. Selected areas are then imaged, using satellites and aerial photography. Using these images, CNC develops region-specific coca crop estimates. Stage 1 is the previous year's net cultivation estimates.

Stage 2: Net Cultivation in Current Year

Stage 2 represents the current year's net cultivation in each of the seventeen growing areas. Transition 1/2 is the computational link between previous year's net cultivation and current year's

[3] W. Rhodes, M. Layne, P. Johnston, L. Hozik, *What America's Users Spend on Illegal Drugs, 1988-1998*, June 2000.

cultivation. The computation considers new growth, field abandonment, and eradication to calculate a net change.

Stage 3: Net Leaf

Stage 3 is the amount of net leaf yielded from net coca plants, by growing region. The transition between Stages 2 and 3 applies leaf yield factors to transform the amount of net cultivation into potential leaf amounts, measured in metric tons (MT). Colombian leaf yields represent amounts of wet leaf, whereas Peruvian and Bolivian leaf yields are for dry leaf. Transition 2/3 includes reductions for licit leaf consumption (obtained from the INCSR), leaf seizures, and leaf not harvested – which we assume is one percent of mature hectares.

Stage 4: Base Availability

Stage 4 is the amount of base created from net leaf amounts, by growing region. Transition 3/4 applies leaf-to-cocaine conversion rates to the Stage 3 amounts, for each growing region. Transition 3/4 incorporates only one reduction, country-wide base seizures, as reported in the INCSR.

Stage 5: Cocaine Availability at Labs

Stage 5 measures the amount of cocaine produced at labs. Transition 4/5 follows base from growing regions to labs through base corridors of movement, as defined in the IACM publications (beginning in 1997). In 1997, three base corridors of movement were identified (Northeast, South, and Northwest) and in 1998 a fourth was added (West). The STAR model apportions base from growing regions to labs by the percentages of observed movement in the IACM. Reductions in the transition include cocaine lost in lab seizures. Figure 1 presents the base corridors of movement from growing areas.

Discussion of Data Incorporated into Stage 1 Through Stage 5

Potential cocaine production is calculated using estimates of leaf yield, leaf cocaine alkaloid content, and base lab processing efficiencies. DEA's Operation Breakthrough has provided these estimates for Peru, Bolivia, and (preliminary ones for) Colombia. Note that CNC does not adhere to the estimates reported in these Breakthrough publications. Rather, CNC uses hybrid estimates and no published documentation or rationale is supplied.

It had been assumed that Colombia was cultivating the poorer yielding variety of cocaine, *E. coca var ipadu* and using less efficient processing techniques. However, recent cultivation and production estimates released by CNC (there have been several revisions over the past year) make clear that Colombia is not only a major cocaine producer, but also a leading coca cultivator. The STAR model incorporates data as of March, 2000.

Figure 2 depicts changes in the distribution of Andean potential production. Note that the figure includes two lines for Colombia, the lower one representing earlier Colombian estimates and the higher one representing data as of March, 2000. For the years that estimates were revised, potential production increased by 188% (1995), 173% (1996), 180% (1997), and 164% (1998).

These staggering adjustments highlight the uncertainty in the potential production estimates. The statistical nature of the imaging process allows standard errors to be calculated, which measures a portion of the uncertainty in the cultivation estimates. However, much uncertainty remains. For example, the detection of new growing areas is elusive, and eradication figures are dubious. Additional error is introduced in the calculation of mature leaf to potential cocaine production amounts because uncertainty is inherent in the Breakthrough estimates. Further, CNC doesn't strictly apply the Breakthrough estimates, but rather creates some sort of hybrid estimates, and this introduces even more potential uncertainty. Finally, there have been reports that Peru's coca industry may be recovering[4].

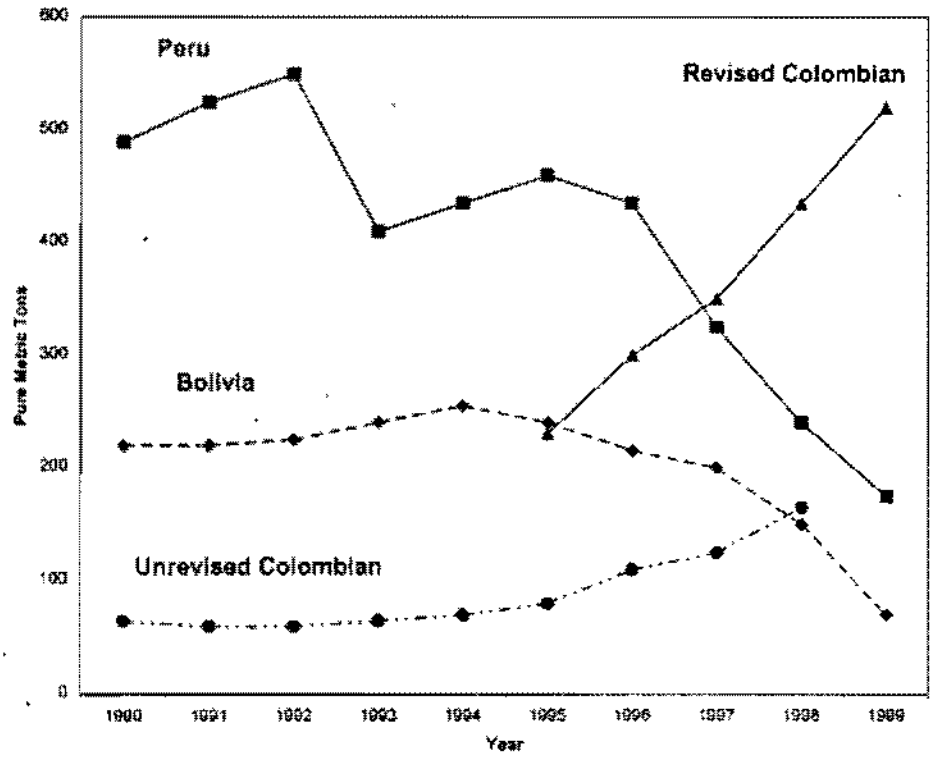
Figure 2 shows that while production in Bolivia and Peru has dropped, Colombian production has soared. Accounting for only 25% in 1995, Colombia's contribution grew to 68% by 1999.

Certainly, additional modeling would aid in understanding any dynamic uncertainty and perhaps in modeling alternative estimates. At a minimum, applying time-series techniques to the raw data could reduce what appears to be considerable random variation from year to year.

[4] Defense Intelligence Agency, 1999. *Interagency Assessment of Cocaine Movement: August 1999* Eighteenth Edition, Mid-Year Review, p. 2.

Figure 2

Andean Potential Cocaine Production Estimates, 1990-1999 (pure metric tons)



Stage 6: Cocaine Departing South America

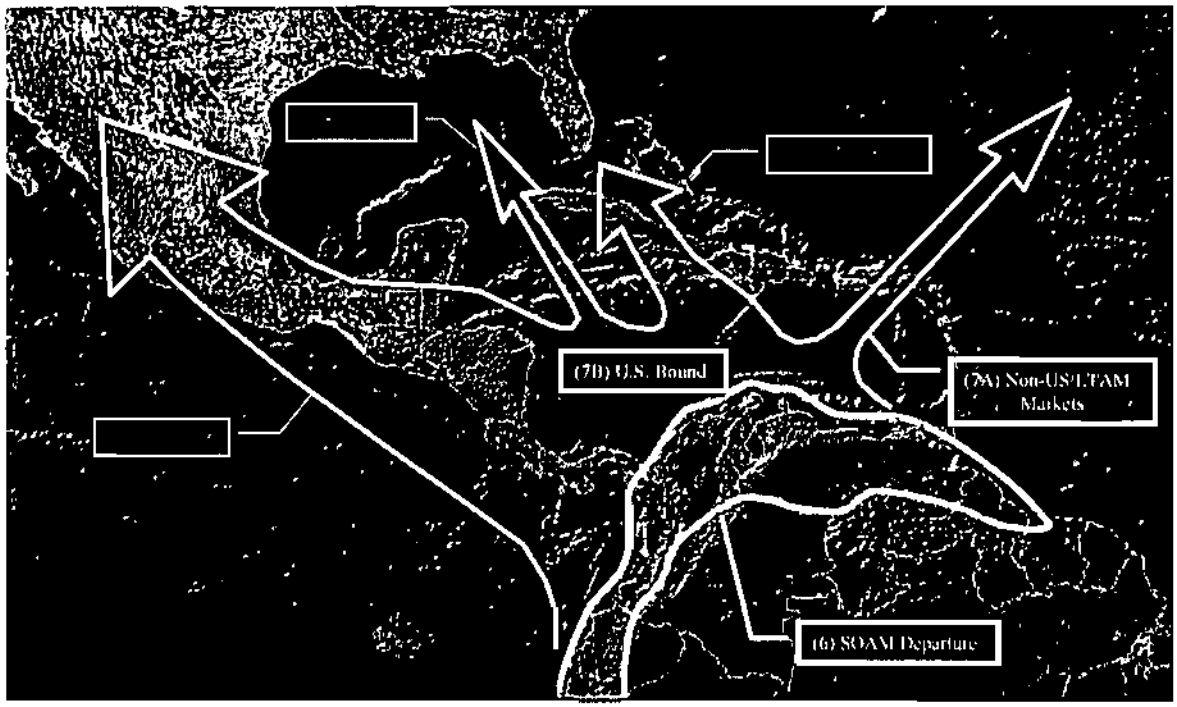
This stage reports the amount of cocaine that departs South America from various departure points. Transition 5/6 is the link between cocaine labs and South American departure points, through HCl corridors of movement as defined in the IACM publications (beginning in 1997). The model apportions the flow of HCl from labs to departure points by the percentages of observed movement in the IACM. Figure 3 depicts the HCl corridors of movement.

Reductions taken in this transition include source country seizures (INCSR) and spoilage, which we assume is one percent. We do not account for source country consumption because there have been no studies that provide convincing estimates.

Transitions 4/5 and 5/6 must be considered tentative for several reasons. First, data on movements of base and cocaine within the source countries are incomplete. Second, data on losses due to base spoilage and source country consumption are fragmentary, imprecise, or

nonexistent. Finally, Transition 4/5 assumes that base movement corridors are independent of growing areas and Transition 5/6 assumes that HCl movement corridors are independent of lab locations. Neither assumption is realistic. Nonetheless, it is useful to begin to model these two transitions, as base and HCl movement may become more detectable in the future. Additionally, the matrix formulation is sufficiently flexible to accommodate varying assumptions about corridor distributions.

Stage 7: Availability at U.S.-Bound Transshipment Corridors and Non-U.S./Latin American Markets



Stage 7A: Non-U.S./South American Markets

Stage 7A is the amount of cocaine that departs South America and successfully arrives at non-U.S./South American markets. Transition 6/7A links cocaine departing South American departure points to non-U.S./South American markets. Seizures in non-U.S. bound corridors are included in the transition.

Stage 7B: Availability at U.S.

This stage is the amount of cocaine that departs South America and successfully transits through U.S.-bound corridors (Caribbean, Mexico/Central America, and Direct to U.S). Transition 6/7B apportions cocaine from South American departure points through corridors of movement that are destined for the U.S. via conveyances (noncommercial and commercial air, noncommercial and commercial maritime). For the cultivation estimates, we make two assumptions: cocaine leaving from Colombia transits all three corridors; cocaine leaving from departure points in Peru, Ecuador or Bolivia transits through Mexico/Central America only. Flows among corridors and conveyances are apportioned in the same proportion as flows in the event-based data.

During Transition 6/7B, we incorporate event-based data on cocaine departing South America by corridor and conveyance combinations. Reductions taken in the transition include transit seizures and transit country consumption, which we assume to be three percent of the flow.

Ideally, Transition 6/7B would include conveyance combinations. In the Mexican/Central American corridor, the most prevalent combination is to use noncommercial maritime to get part

of the way through the transit zone and then to use land conveyance to travel the rest of the way. There are some *secondary movement* events listed in the CCDB, but they were not included in STAR.

Event-Based Data on Cocaine Movements in the Transit Zone

The IACM uses an event-based, interagency consensus methodology to quantify cocaine movement through the transit zone. Event-based data in the Consolidated Cocaine Database (CCDB) combines two efforts: the Interagency Counterdrug Performance Assessment Workgroup (ICPAWG) and the IACM. The ICPAWG -- established in 1992 to measure the performance of international drug interdiction -- maintains a database of *known* drug movements in the transit zone, with a destination of either the U.S. or Canada. *Known events* are distinguished by (1) seizure or observation of drugs; (2) observation of activity that could not be reasonably attributed to anything other than drug smuggling; (3) highly reliable intelligence.

In 1996, the interagency group developed a cocaine flow assessment methodology to determine the amount of cocaine that departs South America along major trafficking routes[5]. A degree of uncertainty for these events was accepted to allow a wide spectrum of cocaine flow information. Three types of uncertainty exist in the data: uncertainty in the amount of cocaine transported, uncertainty in the existence of the event, and uncertainty about how much cocaine remains undetected. For example, if the quantity of cocaine recorded in the database for movements from South America directly to Florida consist exclusively from seizures, then we can assume with a high degree of certainty that more cocaine was moved but not detected. This type of uncertainty is important because it can be used to show that cocaine movement via commercial means directly from South America to the U.S. as well as from South America to Europe is underestimated.

Table 2 includes event-based estimates of cocaine departing South America, for 1996 through 1998[6]. Part of the variability from year to year in these numbers is attributable to evolving methodology associated with any new estimation approach. There are other more subtle reasons as well.

The difference from 1996 to 1997 can be explained by (a combination of) increased operational and intelligence detection capability in the Eastern Pacific in 1996 (especially during the second half of the year), and a very loose definition of the lowest certainty level events in the database, the *possibles*[7]. These two aspects were corrected procedurally in 1997, by tightening up the definition of *possibles*. In 1997, the tightening of the definition of *possible*, as well as the return to lower detection in the Eastern Pacific (due to the cessation of effort), led to a lower count in 1997.

---

[5] The results are included in the transit zone section of the IACM publication.

[6] We used movement events from the CCDB for our calculations, and they differ slightly from figures published in the IACM. See Cala, 1999.

[7] One type of event category -- "Did Not Develop" (DND), used almost exclusively by JIATF East – was eliminated in 1997.

Differences in 1998 can be traced to two phenomena: detection increases and a change in *counting* methodology. Hurricane Mitch destroyed the Pan-American Highway and forced smugglers to take alternate routes. Many switched to the Eastern Pacific where -- in anticipation of these smuggler changes -- detection had been increased. Detection rates also increased along the north coast of Colombia to Panama, a result of interdiction asset allocation re-distributions.

The change in the *counting* methodology refers to the elimination of the "Panama Calculation." This calculation was used before 1998 and allowed for movement departing Panama while at the same time ensuring that movement into Panama did not result in double counting.

Event-based data is introduced to STAR in Transition 6/7 -- departure points in South America to conveyance and transit corridors. It allows us to examine inconsistencies between event-based data and the potential production estimates.

The event-based methodology signaled problems with the older Colombian cultivation estimates, and, in large part, led to the reassessment of these figures.

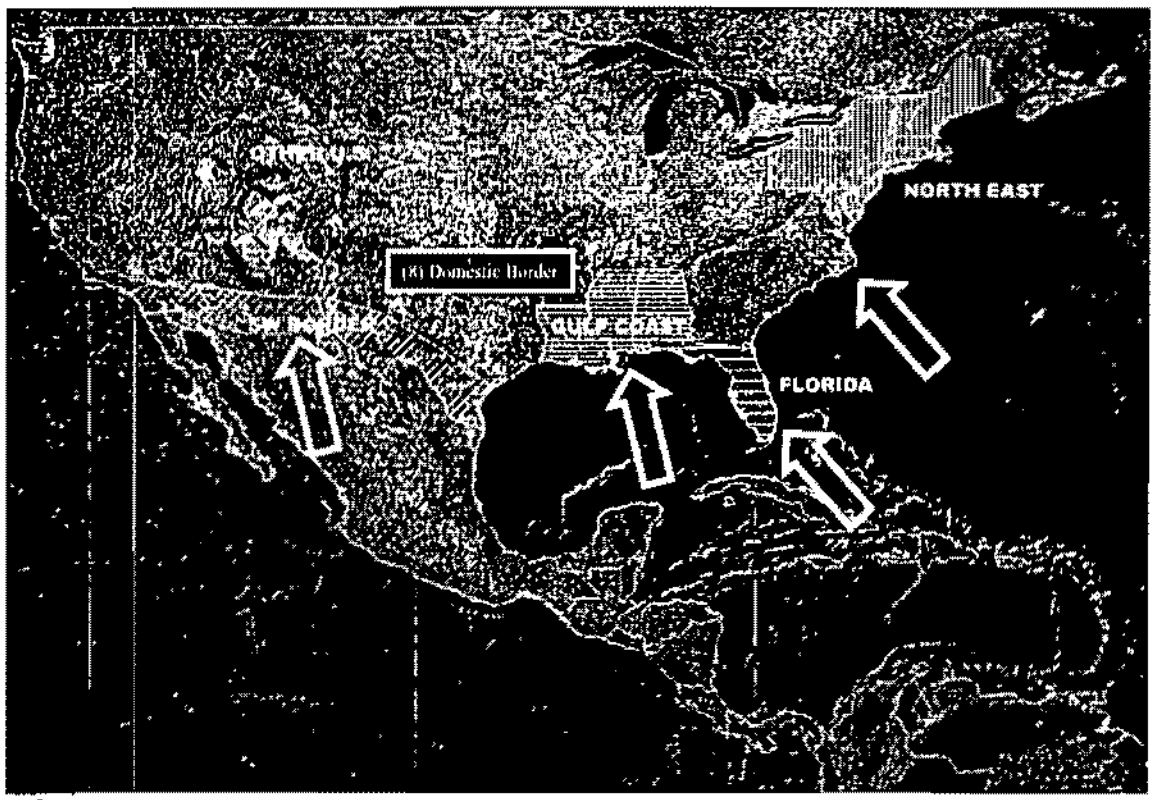
Table 2

Event-Based Cocaine Amounts Departing South America

By Transit Corridor, 1996-1999 (bulk metric tons)

	1996	1997	1998	1999
Caribbean	174.5	138.4	160.3	220
Mexico/Central America	341.7	250.7	318.6	277
Direct to U.S.	91.2	43.9	51.4	15
Non U.S. Destinations	42.8	62.6	64.5	75
Unknown	2.5	-	1.0	-
Total	**652.7**	**495.6**	**595.8**	**587.0**

Stage 8: Cocaine Availability at U.S. Border Entry Regions



Stage 8 is the amount of cocaine that successfully passes into the U.S. by border entry regions. Transition 7B/8 converts the amount of cocaine passing through the transit zone -- by movement corridor and conveyance type -- into amounts entering U.S. borders by geographic region and by conveyance type. The transition table redistributes the input flow estimates across the U.S. border. We assume that shipments passing through the Mexican/Central American corridor terminate at the southwest border (in proportion seizures in each conveyance category) and that shipments in the Caribbean and Direct to U.S. corridors are distributed in proportion to border seizures across six of the border regions and conveyance combinations.

Reductions taken during this transition account for seizures at the border using an enhanced seizure database created for the STAR model. During stage 8 we introduce the estimates from the Border Movement Model (discussed in Section 5) of cocaine arriving to U.S. regions, by conveyance types.

Enhanced U.S. Seizure Data

These data differentiate seizures at the border from other domestic seizures. We created an *enhanced seizure* database that contains rich detail about each seizure. We started with data from DEA's Federal Drug Seizure System (FDSS) for calendar years 1991-1998. FDSS data contain no duplicate records -- each seizure in the FDSS is uniquely identified by a Federal Drug Identifying Number (FDIN), eliminating the risk of double counting. The FDSS includes federal

cocaine seizures of 500 grams or more. Because the FDSS data excludes non-federal seizures, these seizures are not available in the enhanced seizure data.

FDSS contains limited details about each seizure, so we augmented the FDSS data with agency-specific seizure data (linking these data to the FDSS by the FDIN). Customs seizure data includes country of origin and more detailed information about conveyance. Other supplementary data came from the Coast Guard, the El Paso Intelligence Center (EPIC) Border/Land Interdiction Seizure System (BLISS), and the CCDB. The EPIC data covers seizure events occurring at the United States/Mexican border and up to 150 miles inside the United States.

Appendix A details specific variables from each of these data sources. When FDSS data is reported by other sources, we use the FDSS data as the "master". The exception to this is that we use EPIC data for southwest border seizures.

Border Seizures

We classified seizures at the border (arriving from foreign countries), by conveyance types (noncommercial and commercial air, noncommercial and commercial maritime, noncommercial and commercial vehicle, rail and pedestrians) and geographic region (Florida, Gulf Coast, Northeast, Southwest Border, Puerto Rico/Virgin Islands, and Rest of U.S. – including POEs along the Canadian border)[8].

There is a definitional difference in seizures at the southwest border and all other border areas. EPIC's definition of a southwest border extends 150 miles into the U.S., since the drugs likely came from Mexico. In Florida, by contrast, the border does not extend inland, although it would seem just as plausible that the drugs came across the Florida border. This issue points to the need for a consistent definition of a border seizure.

We undertook to identify a border seizure, and to classify it by conveyance type and by geographic region:

1. Seizures on the high seas were excluded from FDSS data because they are included in transit zone seizures.

2. To identify seizures along the southwest border, we used information from EPIC. We classified any car, four wheel drive, motorcycle, pickup truck, recreational vehicle, station wagon, taxi, towed vehicle, or van as a noncommercial vehicle. Additionally, if the "type" variable indicated "intrusion by vehicle at border (not POE)" or "vehicle at POE", we classified the conveyance as a noncommercial vehicle. Conveyance was assigned as commercial vehicle for tanker truck, bus, tractor trailer, trailer, or wrecker. If the type variable indicated "on foot at border" or "pedestrian at POE", then the conveyance was assigned as pedestrian. And finally, if conveyance type was train, the seizure was assigned to the rail conveyance category.

[8] Our border seizures figures differ from those reported by EPIC in the IACM. We were unable to obtain a description of their methodology.

3. To categorize maritime border seizures, we checked Customs information, specifically whether the conveyance arrived from non-U.S. locations. If so, and if the conveyance was listed as a commercial vessel, then commercial maritime was assigned. If conveyance was listed as a fishing or private vessel, then noncommercial maritime was assigned. We used Coast Guard and CCDB information to identify maritime seizures that occurred outside of ports of entry.

4. To categorize border seizures from air conveyances, we again checked Customs information to determine if the conveyance arrived from non-U.S. locations. If so, and if the conveyance was listed as commercial air, mail, or express consignment, then commercial air was designated as the conveyance type. If conveyance was listed as private aircraft, then noncommercial air was designated. We also consulted CCDB data on air conveyance seizures.

5. Finally, we examined 113 border seizures classified by Customs as "other" or "no transport involved", individually to determine if they were border seizures.

Figure 3 presents a plot of total border seizures for the years 1991-1999. Overall, border seizures have decreased 31.5%, from 61.9 MT in 1991 to 42.4 MT in 1999. The chart also includes a two-year moving average line to smooth year to year variations. Table 3 details border seizures, by conveyance types.

In Figure 4, smoothed seizure (three-year moving average for southwest border and two-year moving average for all other areas[9]) figures are plotted by region, for the period 1992 through 1999. Seizures on the southwest border (the solid line at the top of the figure) have remained relatively constant over the period. Seizures in Florida (the dotted line at the top of the chart) have declined over the period, while seizures in Puerto Rico/Virgin Islands steadily increased.

[9] A two-year moving average for the southwest border still yielded considerable variation from year to year.

Figure 3

Seizures at The U.S. Border, 1991-1999 (bulk metric tons)

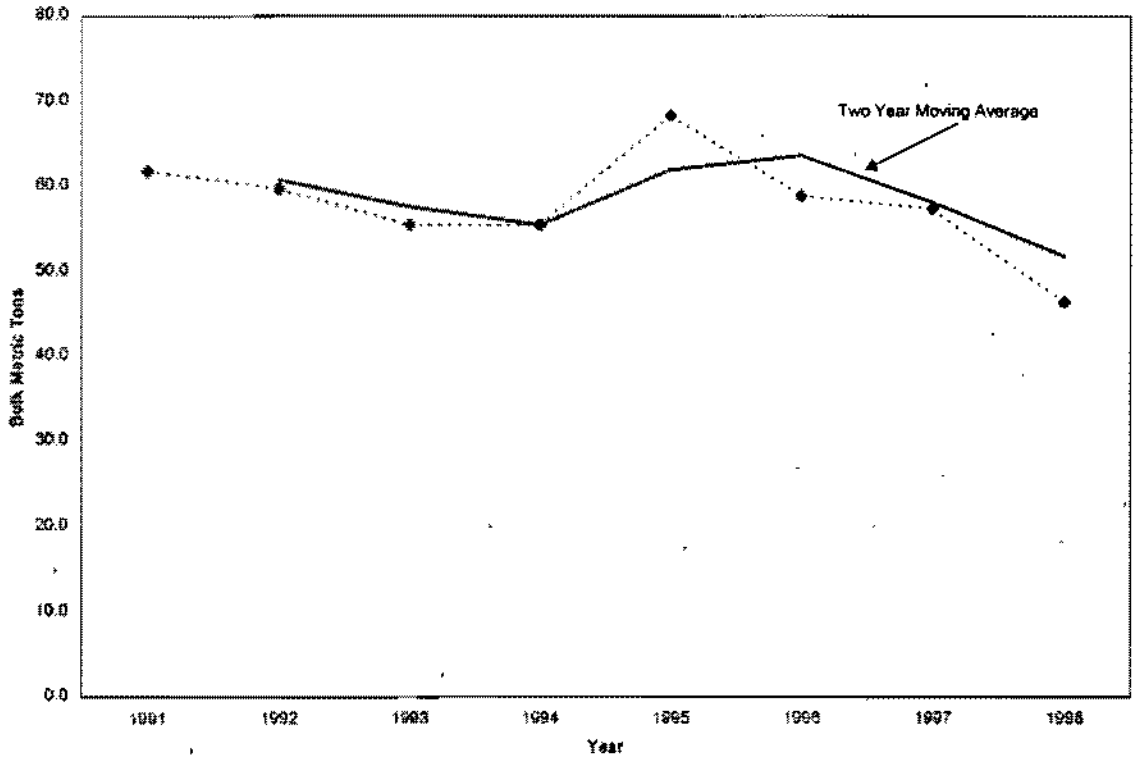


Table 3

Border Seizures, 1991-1999 (bulk metric tons)

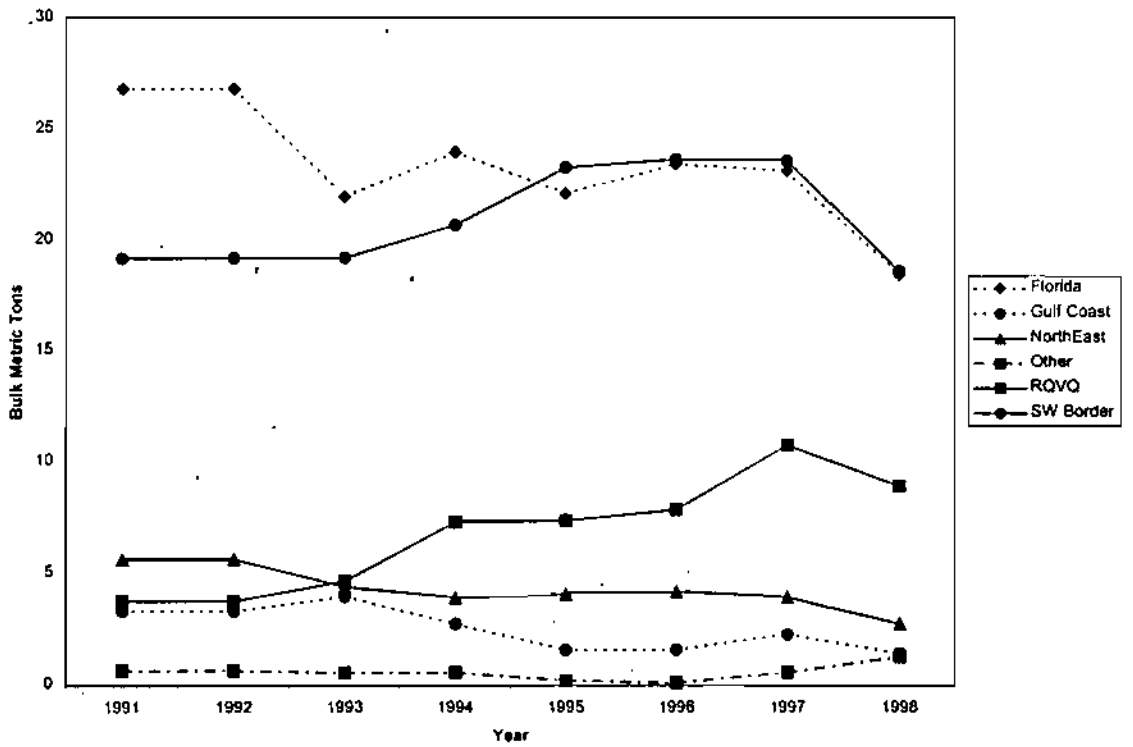
	1991	1992	1993	1994	1995	1996	1997	1998	1999[a]
Commercial Air	5.5	6.2	7.7	7.4	9.6	6.1	6.3	3.0	7.0
Commercial Maritime	28.5	23.4	21.5	21.5	10.5	22.2	25.0	14.4	5.1
Commercial Vehicle	3.4	7.3	5.4	2.9	8.1	7.7	5.6	7.4	9.4
Noncommercial Air	6.9	4.1	5.1	2.6	0.6	0.9	0.5	0.0	0.0
Noncommercial Maritime	9.3	4.2	7.2	10.4	24.4	12.3	11.8	8.7	7.2
Noncommercial Vehicle	7.0	11.5	8.6	9.5	11.5	8.8	7.3	11.2	13.7
Pedestrian	1.4	3.2	0.2	1.4	3.6	0.9	0.9	1.7	-
Rail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Total (bulk MT)	**61.9**	**59.8**	**55.8**	**55.6**	**68.4**	**59.0**	**57.4**	**46.4**	**42.4**

[a] Figures for 1999 obtained from El Paso Intelligence Center. 1999 Southwest border seizures were into seizures at ports of entry (9.4 MT), between ports of entry (3.6 MT), and at traffic stops/checkpoints (10.1 MT). We have put the port of entry seizures into the commercial vehicle category and the other two types of seizures into noncommercial vehicles.

- indicates no data available.

Figure 4

Smoothed Seizures in Border Entry Regions, 1991-1999 (bulk metric tons)



Border Allocation Model

Stage 8 introduces a new modeling effort, the Border Allocation Model. This nonlinear, economic model allocates cocaine arriving at the U.S. border to border regions and to conveyance types. In particular, the model predicts the percentage of cocaine arriving to specific regions, by specific conveyance types. Cocaine amounts are then obtained by multiplying the percentages by the estimated total. The proportions can be employed in the allocation of amounts based on any estimate of the amount of cocaine arriving to the U.S. For example, using percentages generated by the Border Allocation model, cocaine amounts estimated via event-based data can be allocated to specific U.S. border regions and conveyances (after subtracting transit zone seizures and consumption). Any amount that the STAR model incorporates (including potential production estimates) can be distributed into conveyance/border region combinations. Appendix C provides details about the methodology used in the Border Allocation Model.

The Border Allocation Model uses data on U.S. border seizures and the cost smugglers pay to transport cocaine from Colombia to the U.S. Data on U.S. border seizures were obtained from the Enhanced Seizure Database, and data pertaining to smuggler transportation costs from Customs Reports of Investigation.

Table 4 and Table 5 show the average number of metric tons seized, and the percentage of the total amount seized, for each conveyance and border region combination. Note that seizures from land conveyances in Florida, Gulf Coast, Northeast, and Puerto Rico/Virgin Islands (PR/VI) are impossible and these region-conveyance combinations therefore contain *structural zeros*. This contrasts with *observed zeros* (such as that obtained for Gulf Coast, commercial air) where the this region-conveyance combination is feasible, but no occurrences were observed.

Averaging over the eight year period, 45% of total seizures occurred at the southwest border (SWB) and 34% at the Florida border. In terms of conveyances, 31% of the seizures occurred upon commercial marine ships, while noncommercial vehicle, noncommercial marine, commercial vehicle, commercial air, and noncommercial air accounted for 28%, 16%, 12%, 10%, and 4%, respectively.

Table 6 shows how the Border Allocation Model allocates the total cocaine quantity arriving at U.S. borders to specific border regions and conveyance types. The model predicts that – averaged over the years 1991-1998 – 48% of cocaine destined for the U.S. arrives at Florida via commercial marine conveyances and 37% arrives at the southwest border via commercial and noncommercial vehicles. Note that the distribution of cocaine amounts (Table 6) differs considerably from the distribution of cocaine seizures (Table 5). This is because estimates of cocaine amounts are not simply proportional to seizures. For example, even though cocaine seizures for Florida via commercial marine are only 21% of total seizures, the proportion of the total amount transported through this region-conveyance combination is 48%. This occurs because transportation costs were relatively high in this case ($3,568 compared to the mean of $3,111), which, assuming constant total transportation costs, implies that the probability of seizure, and therefore seizure costs, were relatively low. Thus the amount seized was a relatively low percent of the amount shipped to Florida via commercial marine.

Figure 5 plots the amount of cocaine arriving at each border region for the period 1991-1998. The model indicates that most cocaine entering the U.S. does so via Florida and the southwest border. Taking the eight-year period as a whole, quantities arriving at the southwest border have increased at the expense of quantities arriving at Florida. All other regions have remained fairly constant, with the exception of Puerto Rico/Virgin Islands, for which the model predicted a jump from 11 MT in 1996 to 42 MT in 1997.

Table 4
Border Seizures (bulk metric tons): Average Over Years 1991-1998

Border Region	Noncom. Vehicle	Commercial Vehicle	Noncom. Air	Commercial Air	Noncom. Marine	Commercial Marine	Total
Florida	-	-	1.0	4.6	3.5	14.1	23.1
Gulf Coast	-	-	0.0	0.0	0.8	1.5	2.3
Northeast	-	-	0.0	1.3	0.0	2.9	4.1
PR/VI	-	-	0.9	0.2	4.6	1.3	7.0
SWB	18.8	8.3	0.5	0.3	2.2	0.8	30.8
Rest of U.S.	0.0	0.0	0.2	0.1	0.0	0.3	0.7
Total	**18.8**	**8.3**	**2.6**	**6.5**	**11.0**	**20.9**	**70.0**

- indicates not applicable

Table 5
Border Seizures (percent): Average Over Years 1991-1998

Border Region	Noncom. Vehicle	Commercial Vehicle	Noncom. Air	Commercial Air	Noncom. Marine	Commercial Marine	Total
Florida	-	-	1.5	6.8	5.1	20.7	34.0
Gulf Coast	-	-	0.0	0.0	1.1	2.2	3.4
Northeast	-	-	0.0	1.9	0.0	4.2	6.1
PR/VI	-	-	1.3	0.2	6.8	1.9	10.2
SWB	27.6	12.2	0.7	0.4	3.2	1.2	45.3
Rest of U.S.	0.0	0.0	0.3	0.2	0.0	0.5	1.0
Total	**27.6**	**12.2**	**3.8**	**9.5**	**16.2**	**30.7**	**100.0**

- indicates not applicable

Table 6
Percent Allocation of Cocaine By Border Region and Conveyance: Average Over Years 1991-1998

Border Region	Noncom. Vehicle	Commercial Vehicle	Noncom. Air	Commercial Air	Noncom. Marine	Commercial Marine
Florida	-	-	0.3	2.2	1.3	47.9
Gulf Coast	-	-	0.0	0.0	0.2	1.7
Northeast	-	-	0.0	0.5	0.0	3.3
PR/VI	-	-	0.2	0.1	1.5	1.2
SWB	7.8	28.8	0.2	0.1	0.5	0.9
Rest of U.S.	0.0	0.8	0.1	0.0	0.0	0.4

- indicates not applicable

Figure 5
Border Allocation Model: Amounts by Region (pure metric tons)

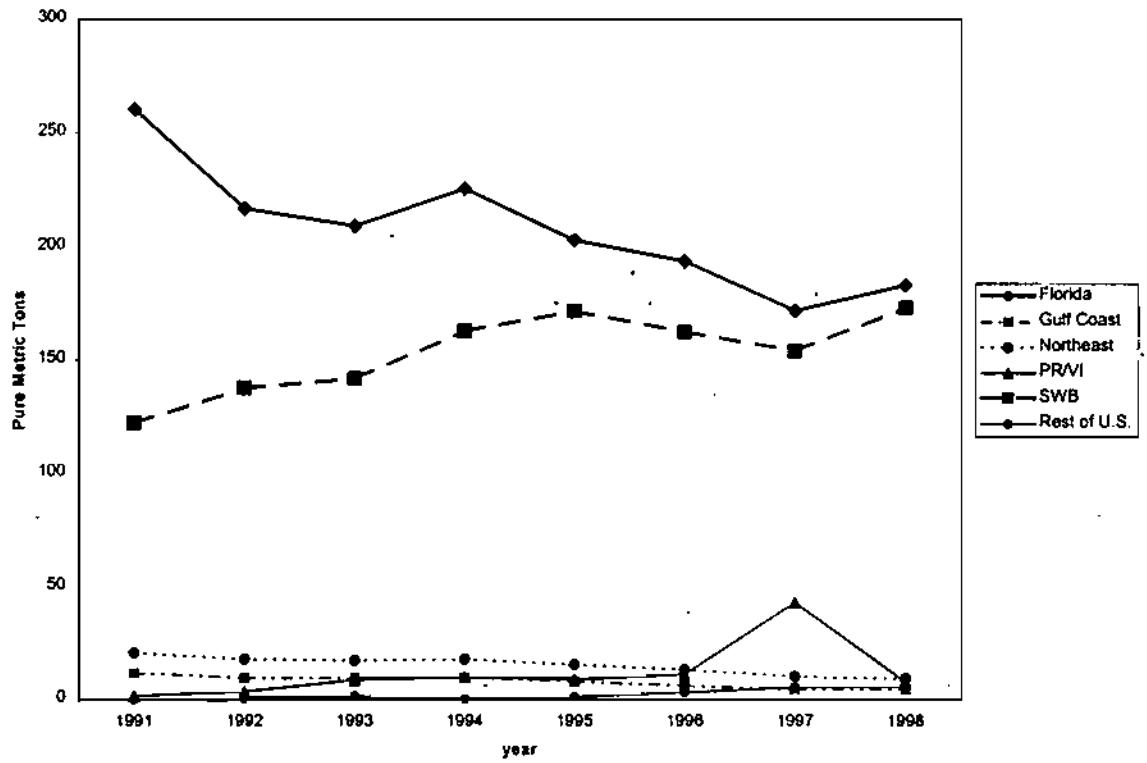
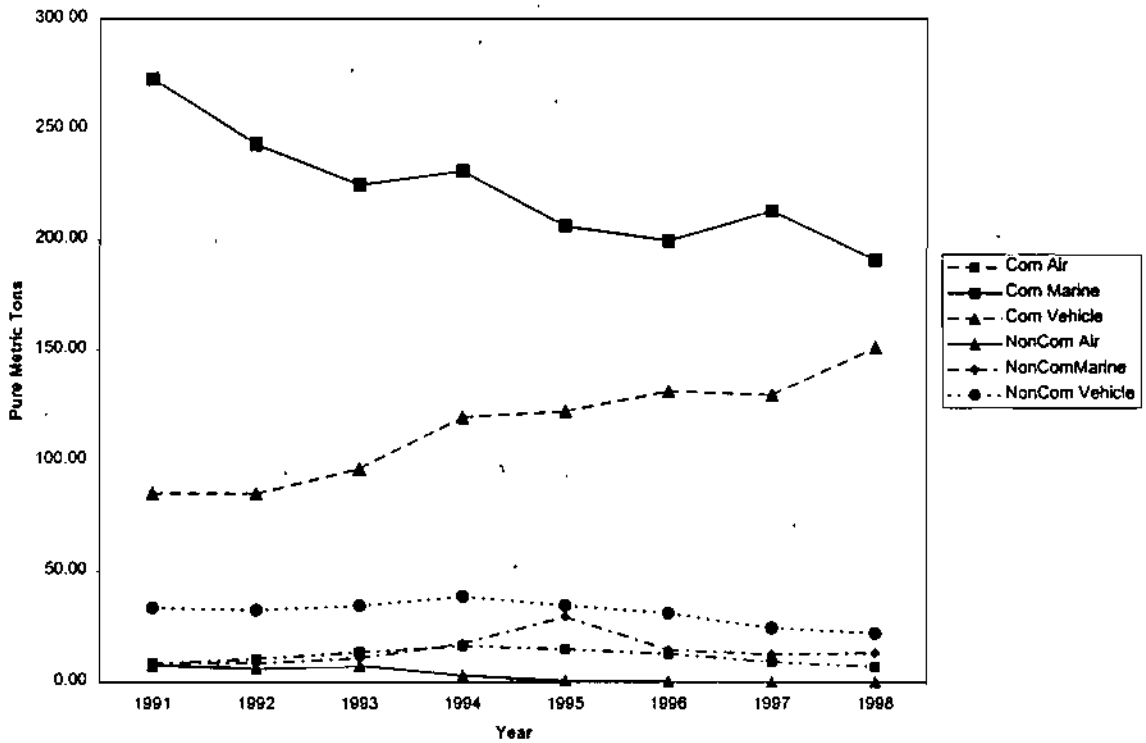


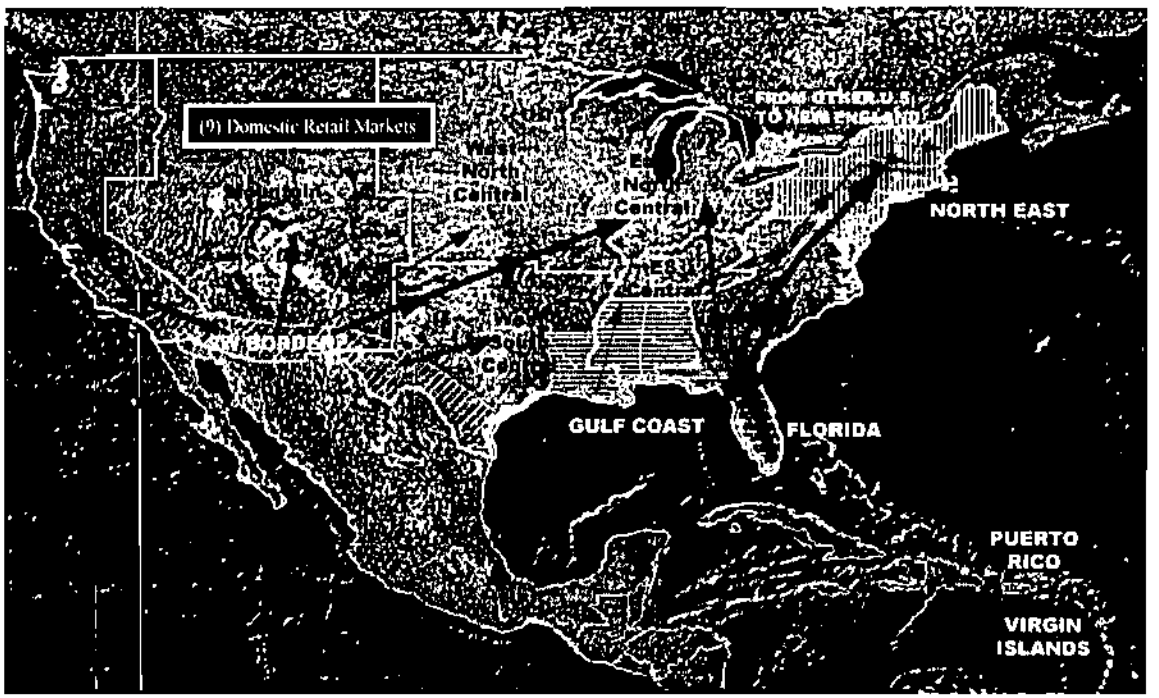
Figure 6 plots model estimates by conveyance type. The model indicates that the conveyance types of choice for cocaine smugglers are commercial vehicle and commercial marine. Although it is likely that noncommercial air actually plays a large role in transporting cocaine, the model does not capture this because the typical flight stops just short of the U.S.- Mexican border.

Figure 6 shows that, over the eight year period, conveyance by commercial vehicle has increased at the expense of conveyance by commercial marine: commercial vehicle increased by 78% (from 91 to 162 MT) and commercial marine decreased by 29% (from 286 to 203 MT). These estimates are consistent with Colombian drug lords allowing Mexico-based trafficking organizations to play an increasing role in shipping cocaine to the U.S. Indeed, taking Figures 8 and 9 together, it would appear that there has been a shift in smuggling from Florida via commercial marine to the southwest border, via commercial vehicle.

Figure 6
Border Allocation Model: Amounts by Conveyance (pure metric tons)



Stage 9: Cocaine Availability at Domestic Retail Areas



Cocaine at this stage represents the amount of cocaine arriving to U.S. consumption regions from U.S. border entry regions. Transition 8/9 incorporates domestic (non-border) cocaine seizures. Table 7 details non-border, domestic seizures in each of the ten Census Divisions, for 1991-1999. There has been a 38% decline in seizures between the beginning and end of this period.

The Pacific, West South Central, and South Atlantic census divisions have the highest number of seizures averaged over the period 1991-1998, with 13.5, 12.8, and 7.9 metric tons, respectively. The Pacific region has experienced the steepest decline in seizures.

Table 7

Non-Border, Domestic Seizures, By Census Divisions, 1991-1998 (bulk metric tons)

	1991	1992	1993	1994	1995	1996	1997	1998	1999[a]
New England	4.5 (7%)	0.1 (0%)	0.1 (0%)	0.1 (0%)	0.0 (0%)	0.0 (0%)	0.1 (0%)	0.1 (0%)	
Mid Atlantic	10.9 (17%)	4.0 (7%)	3.7 (8%)	6.0 (10%)	3.0 (6%)	5.5 (10%)	5.3 (18%)	10.4 (19%)	
East North Central	1.0 (2%)	1.5 (2%)	.8 (2%)	4.1 (7%)	1.4 (3%)	1.5 (3%)	2.9 (9%)	4.5 (8%)	
West North Central	0.3 (0%)	0.5 (1%)	1.0 (2%)	1.3 (2%)	0.6 (1%)	0.2 (0%)	0.4 (1%)	.0.8 (1%)	
South Atlantic	9.6 (15%)	14.0 (23%)	5.3 (12%)	5.4 (9%)	6.4 (14%)	9.9 (18%)	4.9 (16%)	8.0 (14%)	
East South Central	1.2 (2%)	1.6 (3%)	1.2 (3%)	2.7 (4%)	0.5 (1%)	1.4 (3%)	0.4 (1%)	0.4 (1%)	
West South Central	12.3 (19%)	10.2 (17%)	14.3 (32%)	14.0 (23%)	14.0 (30%)	12.2 (22%)	9.6 (32%)	15.5 (28%)	
Mountain	2.6 (4%)	3.7 (6%)	1.6 (4%)	4.4 (7%)	4.7 (10%)	8.3 (15%)	0.6 (2%)	4.7 (8%)	
Pacific	18.2 (28%)	23.1 (38%)	12.4 (28%)	20.2 (33%)	13.7 (29%)	10.1 (19%)	4.0 (13%)	6.6 (12%)	
Puerto Rico/Virgin Islands	3.5 (5%)	2.7 (4%)	4.3 (10%)	3.1 (5%)	2.3 (5%)	5.2 (10%)	2.2 (7%)	4.7 (8%)	
Total (bulk MT)	**64.1**	**61.4**	**44.7**	**61.3**	**46.6**	**54.3**	**30.4**	**55.7**	**40.0**

[a] Census division breakdowns unavailable at this time.

Domestic Allocation Model

The Domestic Allocation Model was created to allocate cocaine entering the U.S. to consumption regions. The premise of the model is consistent with a classic operations research transportation problem: given the quantities of cocaine entering the domestic market at the six border regions (southwest border, Florida, Puerto Rico/Virgin Islands, southeast, Gulf Coast, and other U.S. destinations), and given the quantities demanded in each of the ten U.S. census divisions (New England, Mid Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, Pacific, and Puerto Rico), it is assumed traffickers determine the allocation that satisfies demand in all divisions while minimizing total transportation costs. Standard linear programming techniques were used to solve this problem. Appendix D provides details of the model.

The Domestic Allocation Model and the Border Allocation Model can be used in parallel. For instance; if the Domestic Allocation Model estimates that 65% of cocaine coming in at the

Florida border ends up in the South Atlantic region, and the Border Allocation Model estimates that 170 MT of cocaine arrives at the Florida border, we can conclude that 65% of 170 MT, or 110.5 MT of cocaine, is transported through Florida to the South Atlantic region.

Table 8 shows, for each border entry region, the percentage of cocaine moved to each consumption region. Taking these estimates at face value, we would conclude that cocaine smuggled in at the Gulf Coast, Northeast, and Rest of U.S. stays in that general area, while shipments through Florida, Puerto Rico and the southwest border go to other regions. In particular, 90% of the southwest border's imported cocaine is distributed to other areas, reflecting the increased role of Mexico-based traffickers[10].

Table 8
Percent of Cocaine From Border Entry Regions to Census Divisions, 1998

	Florida	Gulf Coast	Northeast	Puerto Rico/Virgin Islands	Southwest Border	Rest of U.S.
New England	0	0	100	50	0	0
Mid Atlantic	35	0	0	29	13	100
E. North Central	0	0	0	0	27	0
W. North Central	0	0	0	0	6	0
S. Atlantic	65	0	0	0	0	0
E. South Central	0	100	0	0	4	0
W. South Central	0	0	0	0	10	0
Mountain	0	0	0	0	9	0
Pacific	0	0	0	0	31	0
Puerto Rico/Virgin Islands	0	0	0	21	0	0

[10] Drug Enforcement Administration, August 1997, *Changing Dynamics of the U.S. Cocaine Trade.*

Consumption Estimates

Every two years, Abt Associates estimates and reports the amount of cocaine consumed in the U.S. in a report to ONDCP, *What America's Users Spend on Illegal Drugs*[11]. Table 9 captures estimated U.S. cocaine consumption amounts and purity, by year. Consumption and purity levels have remained fairly constant over time.

Table 9

U.S. Cocaine Consumption Estimates (pure metric tons)

1991-1999

Year	Purity (%)	Amount
1991	84.7	299.0
1992	85.6	273.0
1993	83.3	296.0
1994	85.8	305.0
1995	84.8	304.0
1996	83.0	288.0
1997	83.1	312.0
1998	81.9	291.0
1999	81.9[a]	276.0[b]

[a] Data are unavailable, so the 1998 figure is repeated.

[b] Estimated.

[11] Rhodes, W., Layne, M., Johnston, P., Hozik, L.1995. *What America's Users Spend on Illegal Drugs, 1988-1998.* May 2000.

3. Limitations of the STAR Model and Directions for Improvement

While these results give insights into detailed patterns of flow, the STAR model has important limitations. Some, but not all, of these deficiencies can be ameliorated by refining the stages and classifications of the model, by incorporating additional data, and by undertaking data improvement and alternative estimation procedures, such as modeling the dynamics of cultivation data. Two more difficult problems remain:

1. The model includes no time dimension. It takes time to grow crops, process them into cocaine, transport the product to destination countries, and distribute that product within destination countries. This temporal dimension is highly relevant to understanding the flow of cocaine, but it is difficult to know whether cocaine detected in transit this year was grown and processed earlier in the year or grown and processed last year, and stored in a stockpile.

2. The model is static rather than dynamic and thus lacks economic perspective. For example, decisions by farmers in South America to cultivate or not to cultivate cocaine are influenced by trends in the demand for cocaine in the United States, but the model incorporates no feedback mechanisms by which market conditions in the U.S. can affect supply, or vice-versa. The model includes no calculus for predicting future cocaine flows based on current trends in either demand or supply. Flicker and Nilsson (1996) developed a dynamic economic model based on the assumption that the cocaine market is "demand-driven," i.e., that opportunities to produce and transport cocaine are so plentiful, and profit margins so favorable, that substitute cartels of producers quickly arise to replace cartels that are put out of business or that can no longer enforce monopolistic controls over production and distribution. Flicker and Nilsson provide very useful inferences about the dynamics of the cocaine trade; similar approaches would increase the STAR's utility.

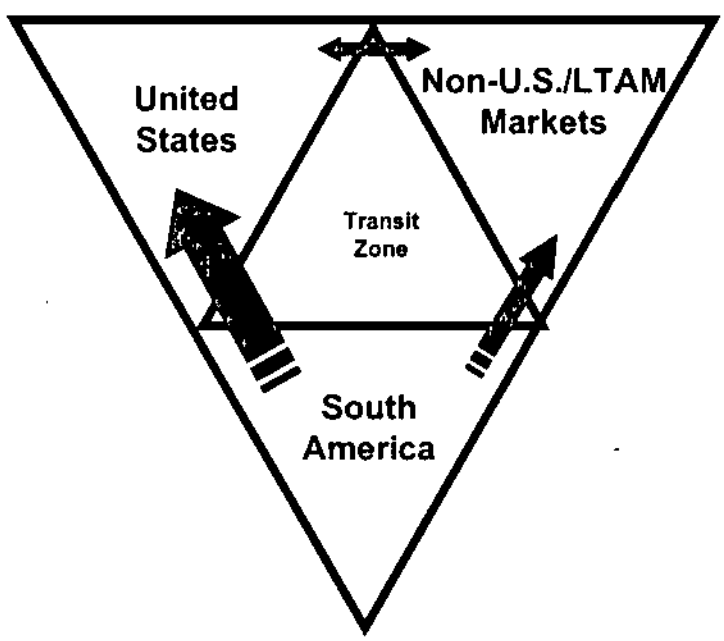
4. Applications of the STAR Model

Figure 7 diagrams the regions in the cocaine flow system: South America, transit zone countries, the U.S., and non-U.S./Latin America markets (e.g., Europe and Canada). Additionally, there may be cocaine shipped from non-U.S./Latin America to the U.S. or vice-versa.

Three quantities are consistently measured: cocaine production, seizures, and U.S. consumption. The problematic pieces of the system are estimates of potential production and consumption in South America, transit zone countries, and non-U.S./Latin American countries. CNC has attempted to provide estimates for these areas, however they are extremely preliminary and exist for only one year. Additionally, there is uncertainty in the cocaine production estimates, as discussed in Section 2.

Figure 7

Component Regions of the Cocaine System



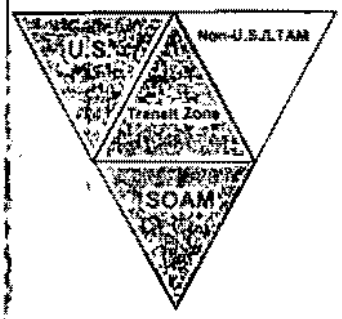
Because transit zone country consumption is considered to be minor, we concern ourselves with three cocaine markets: South America, the U.S., and non-U.S./Latin America. There is a great deal of uncertainty in the amount of cocaine consumed in South America and non-U.S./Latin America markets. ONCP has been estimating U.S. consumption for some time and these estimates have been accepted by the drug community. Table 10 presents various approaches we explore for measuring unknown consumption amounts.

Table 10

Estimation Approaches

Approach	Quantities and Data Sources		
	South American Supply	U.S. Consumption	Non U.S./LTAM Consumption
Global Accounting	CNC production and consumption estimates	ONDCP consumption estimates	***Estimated***
Modified Global Accounting	CNC production and consumption estimates	ONDCP consumption estimates	***Estimated***
Consumption	***Estimated***	ONDCP consumption estimates	CNC consumption estimates
U.S. Residual	CNC production and consumption estimates	***Estimated***	CNC consumption estimates
Hybrid	***Estimated***	ONDCP consumption estimates	Equivalent market loss rate estimates

Global Accounting Approach



This is the method incorporated in the recently published report on Global Accounting by the intelligence community. The unknown components estimated are Non-U.S./Latin America consumption and South American consumption, both of which are thought to be on the rise to compensate for the gap between growing cocaine production (due to increasing Colombian cultivation) and stable U.S. consumption.

Table 11 reports the results of this methodology, which begins with an estimated range of potential cocaine and sequentially reduces it by seizures. While it does acknowledge and attempt to deal with various uncertainties, it includes vague notions such as "coefficient of corruption" -- "an undetermined, but possibly significant, amount of cocaine that reenters the system due to theft or corrupt practices". While such an occurrence seems plausible, until the numbers are shown to have validity, we are skeptical about the current estimates.

As the table shows, the estimate of Non-U.S./Latin America consumption includes a large range of uncertainty, as does potential production. The approach seems tentative at best.

Table 11

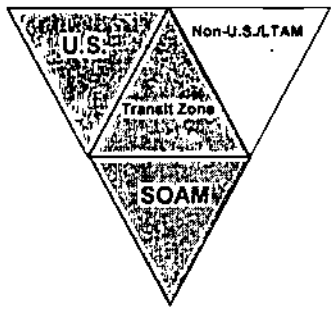
Global Accounting Approach, 1998-1999 (pure metric tons)

Stage	Description	Transition Operations	Low	High	Source
5	HCl Labs		655	915	CNC
		Source Zone Seizures[1]	(65)	(50)	IACM
		Source Zone Consumption	(175)	(120)	CNC
6	Departure areas		415	745	Calculated
		Non-LTAM Seizures[1]	(40)	(30)	IACM
7A	Non-U.S./LTAM markets		(110)	(300)	***Estimated***
		Transit Zone Seizures[1]	(60)	(50)	IACM
		Transit Zone Consumption	(25)	(15)	CNC
7B	U.S. Transshipment Corridors		400	350	
		Arrival Zone Seizures	(50)	(45)	EPIC
8	Entering the U.S.		400	305	
		Domestic Seizures	(30)	(25)	FDSS
9	Retail U.S.		320	280	ONCDP

[1]Includes 10-20% corruption factor

Source: DCI Crime and Narcotics Center (CNC), Defense Intelligence Agency, April 2000. *Cocaine: A Global Accounting for 1999*

Modified Global Accounting Approach



This is the method is similar to Global Accounting, but uses the STAR model (and its assumptions) to calculate amounts. It begins with CNC cocaine production estimates and sequentially reduces it (with reductions described in Section 2), including an estimate of the flow to non-U.S./Latin American markets. This is estimated in the model by using event-based data. These data are used to calculate the proportion of non-U.S. bound events to all events in event-based data to apportion flow leaving South America to non-U.S./Latin America markets.

The model includes licit leaf consumption in South America, but does not attempt to include illicit consumption. An assumption is made that transit zone consumption is three-percent of the flow through the region. We don't include any compensation for the so-called "corruption factor" because there are no precise data.

Table 12 presents the results and shows that there are several problems with this approach. First, the one-percent spoilage rate is based on conjecture and while it seems reasonable, it is a still a guess.. Second, the three-percent transit country consumption rate is also a guess, but the estimates it provides falls within the range suggested by CNC (15-25 MT). Third, since non-U.S./Latin America flow is calculated based on event-based data, it is dependent on the ability to detect cocaine movements and is much lower than estimates provided by the Global Accounting Approach.

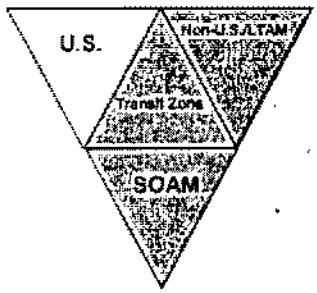
The estimate for U.S. availability is unrealistically high because there is no estimate for South American consumption. Clearly, this approach is unsatisfying.

Table 12

Modified Global Accounting Approach, 1996-1998 (pure metric tons)

Stage	Description	Transition Operations	1996	1997	1998	Source
5	HCl Labs		841.4	773.8	702.1	Calculated
		Source Zone HCl Seizures	(38.4)	(50.7)	(67.0)	INCSR
		Source Zone HCl Spoilage	(8.4)	(7.7)	(7.0)	1%
		Source Zone Consumption	Unknown	Unknown	Unknown	
6	Departure Areas		794.6	715.4	628.1	Calculated
		Non-LTAM Seizures	(19.0)	(30.6)	(24.6)	IACM
7A	Non-U.S./LTAM Markets		33.3	74.8	55.0	***Estimated***
	Toward U.S.		742.3	610.0	548.5	Calculated
		U.S.- Bound Transit Zone Seizures	(44.0)	(71.5)	(66.3)	IACM
		U.S.- Bound Transit Zone Consumption	(18.9)	(17.6)	(15.9)	3% of U.S. flow, excluding direct to U.S. flow
7B	U.S.-Bound Transshipment Corridors		679.4	520.9	466.3	Calculated
		Arrival Zone Seizures	(48.9)	(47.7)	(38.0)	Enhanced seizure database
8	Entering the U.S.		630.5	473.2	428.3	Calculated
		Domestic Seizures	(45.1)	(25.0)	(45.8)	FDSS
9	Retail U.S.		585.4	448.2	382.5	Calculated

U.S.-Residual Approach



This method is similar to the Modified Global Accounting approach and begins with CNC cocaine production estimates and sequentially reducing it with losses to estimate U.S. consumption. This procedure differs form Modified Global Accounting in that we include CNC estimates for South American and transit country consumption, as well as amounts flowing to non-U.S./Latin America markets (we use the mean of the range reported by CNC, without compensating for the corruption factor).

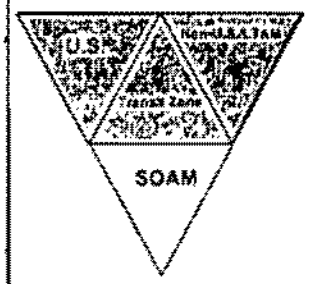
Table 13 reports the results. The calculated residual cocaine available for U.S. consumption is extremely low.

Table 13

U.S.-Residual Approach, 1998-1999 (pure metric tons)

Stage	Description	Transition Operations	1998	Source
5	HCl Labs		702.1	Calculated
		Source Zone HCl Seizures	(67.0)	INCSR
		Source Zone HCl Spoilage	(7.0)	1%
		Source Zone Consumption	(147.5)	CNC
6	Departure Areas		480.6	Calculated
		Non-LTAM Seizures	(24.6)	IACM
7A	Non-U.S./LTAM Markets		(185.0)	CNC
	Toward U.S.		271.0	Calculated
		U.S.- Bound Transit Zone Seizures	(66.3)	IACM
		U.S.- Bound Transit Zone Consumption	(20.0)	CNC
7B	U.S.-Bound Transshipment Corridors		184.7	Calculated
		Arrival Zone Seizures	(38.0)	Enhanced seizure database
8	Entering the U.S.		146.7	Calculated
		Domestic Seizures	(45.8)	FDSS
9	Retail U.S.		100.9	***Estimated***

Consumption Approach



In this method, we begin with U.S. consumption and work back to cocaine availability at South American labs. We include CNC's estimates for South American and transit country consumption, as well as amounts flowing to non-U.S./Latin America markets (we use the mean of the range reported by CNC, without compensating for the corruption factor).

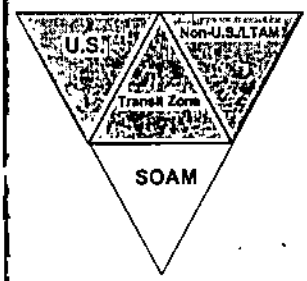
The results are displayed in Table 14. The estimated amount, availability at HCl labs, falls toward the high end of the range CNC reports for potential production

Table 14

Consumption Approach, 1998 (pure metric tons)

Stage	Description	Transition Operations	1998	Source
5	HCl Labs		885.2	*Estimated*
		Source Zone HCl Seizures	(67.0)	INCSR
		Source Zone Consumption	(147.5)	CNC
6	Departure Areas		670.7	Calculated
		Non-LTAM Seizures	(24.6)	IACM
7A	Non-U.S./LTAM Markets		185.0	CNC
	Toward U.S.		461.1	Calculated
		U.S.- Bound Transit Zone Seizures	(66.3)	IACM
		U.S.- Bound Transit Zone Consumption	(20.0)	CNC
7B	U.S.-Bound Transshipment Corridors		374.8	Calculated
		Arrival Zone Seizures	(38.0)	Enhanced seizure database
8	Entering the U.S.		336.8	Calculated
		Domestic Seizures	(45.8)	FDSS
9	Retail U.S.		291.0	ONDCP

Hybrid Approach



The Hybrid approach incorporates historical price and purity series data as the starting point and works *backwards* to an estimated amount of cocaine that departs South America. This approach has the benefit of avoiding the problematic estimation of South American consumption and potential production, both of which have considerable uncertainty. The model estimates transit zone country consumption at three-percent of the flow through the region.

The Hybrid approach incorporates a new methodology to estimate cocaine flow to non-U.S./Latin America markets. Figure 11 presents the estimation technique, referred to as the *equivalent market loss rate.* It assumes that the ratio of U.S.-bound arrival and transit zone seizures to U.S.-bound flow is equal to the ratio of non- U.S./Latin America-bound arrival and transit zone seizures to non- U.S./Latin America U.S.-bound flow. We use a two-year moving average to smooth non-U.S./ Latin America seizures, which are highly variable from year to year.

Figure 11

Equivalent Market Loss Rate

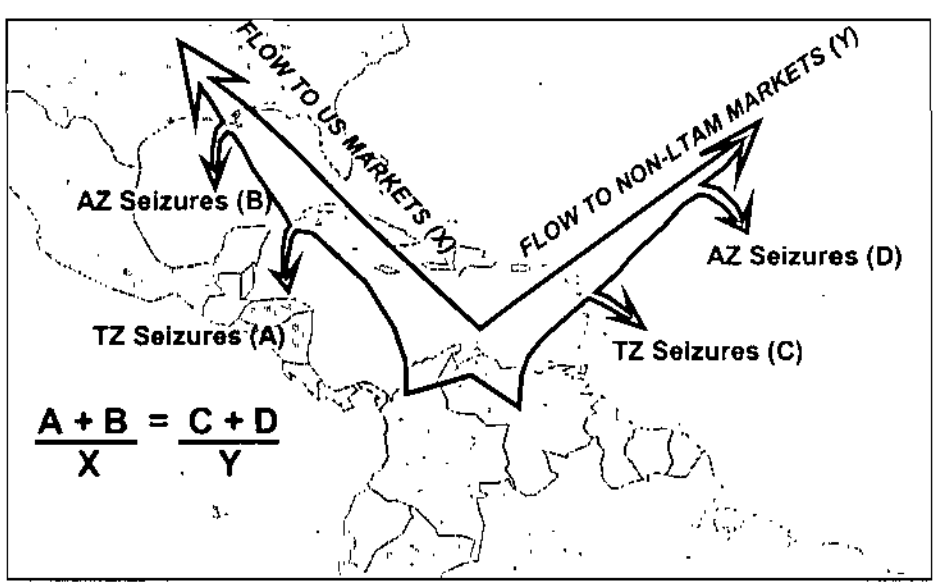


Figure 15 details the estimates from the approach. The advantage of the approach is that it terminates at South American departure areas, so there is no need for the uncertainty inherent in the potential production estimates and South American consumption.

The greatest uncertainty with this method is in non-U.S./Latin American consumption. The equivalent market loss estimates appear reasonable and have been increasing, which agrees with increased South American consumption and constant U.S. demand.

Table 15

Hybrid Approach, 1996-1999 (pure metric tons)

Stage	Description	Transition Operations	1996	1997	1998	1999[1]	Source
6	Departure Areas		532.4	595.9	563.9	574.0	***Estimated***
		Non-U.S./LTAM Seizures	(19)	(30.6)	(24.6)	(39.4)	IACM
7A	Non-U.S./LTAM Markets		(78.1)	(98.7)	(88.3)	(105.2)	Equivalent Market Loss
	Toward U.S.		435.3	466.6	451.0	429.4	Calculated
		U.S.- Bound Transit Zone Seizures	(44)	(71.5)	(66.3)	(60.7)	IACM
		U.S.- Bound Transit Zone Consumption	(9.3)	(10.4)	(10.0)	(21.3)[2]	3% of U.S. flow, excluding direct to U.S. flow
7B	U.S.-Bound Transshipment Corridors		382.0	384.7	374.7	347.4	Calculated
		Arrival Zone Seizures	(48.9)	(47.7)	(38.0)	(34.3)[3]	Enhanced seizure database
8	Entering the U.S.		330.0	337.0	336.7	313.1	Calculated
		Domestic Seizures	(45.1)	(25.0)	(45.8)	(37.1)	FDSS
9	Retail U.S.		287.9	311.9	291.0	276.0	ONCDP

[1]The STAR model was not used to generate results for this year, future work will estimate 1999-2000 data.

[2]CNC estimates

[3]Amounts are derived from EPIC data.

5. Conclusion

Available data are an imperfect reflection of true cocaine flows, but the STAR model provides a means of incorporating differing data within a cohesive structure. Analysts are able to examine detailed flow results as each estimate is carried forward or backward, inspect inconsistencies, and evaluate the impact of each estimate. It provides a setting for more detailed analysis of specific transition points. The Border Allocation model is an illustration of this, but the STAR model can accommodate and would benefit from additional modeling efforts. The model is a power platform for expressing specific research findings within the context of other analysis and estimates.

We have used the STAR model to examine various approaches to estimating cocaine availability and demonstrated that the Hybrid approach is the most useful. It obviates the need for uncertain estimates such as potential production and South American consumption. It provides a new methodology for providing viable estimates of Non-U.S./Latin American flow by calculating equivalent market loss rates.

References

Cala, M., Comparison of IACM Published Figures With Those Extracted From a Historical Data Base, October 1999. Office of National Drug Control Policy.

Crime and Narcotics Center, February, 1999. *Colombian Coca Yields: An Update.*

Defense Intelligence Agency, *Interagency Assessment of Cocaine Movement*, February 1997, Thirteenth Edition.

Defense Intelligence Agency, *Interagency Assessment of Cocaine Movement: March 1999 Year End Review.*

Defense Intelligence Agency, 1998. *Interagency Assessment of Cocaine Movement: February 1998 Year End Review.*

Drug Enforcement Administration, 1994, *Operation Breakthrough: Coca Cultivation and Cocaine Production in Bolivia.*

Drug Enforcement Administration, 1997, *Operation Breakthrough: Coca Cultivation and Cocaine Production in Peru.*

Drug Enforcement Administration, August 1997, *Changing Dynamics of the U.S. Cocaine Trade.*

Fahrmeir L. and Tutz G. *Multivariate Statistical Modeling Based on Generalized Linear Models*, Springer, New York, 1994.

Flicker, M. and K. Nilsson, 1996. *A Dynamic Targeting Model of the Cocaine Trade for Policy Makers and Intelligence Analysts.* Unpublished MA thesis. Naval Postgraduate School.

Hillier, F. and G. Lieberman, *Introduction to Operations Research*, New York: Holden-Day, 1980, Chap. 4.

Judge G.G., Griffiths W.E., Hill R.C., Lutkepohl H, Lee T-C. *The Theory and Practice of Econometrics*, Second Edition. Wiley, New York, 1985.

Layne, M., Rhodes, W., Chester, C., *The Cost of Doing Business for Cocaine Smugglers*, March 2000, Abt Associates Inc. Report prepared for U.S. Customs Service.

McCullagh P. and Nelder J.A. *Generalized Linear Models*, Second Edition. Chapman and Hall, London, 1989.

Rhodes, W., Layne, M., Johnston, P., Hozik, L. *What America's Users Spend on Illegal Drugs, 1988-1998.* May 2000, Abt Associates Inc. Report prepared for ONDCP.

Rhodes, W., D. Hunt, and L. Truitt, Simeone, R., 1997, *A Plan for Estimating the Number of "Hardcore" Drug Users in the United States*, Abt Associates Inc.

SAS Institute Inc., 1990. *SAS/IML Software: Usage and Reference.* Version 6, 1st edition. Cary, NC: SAS Institute.

SAS Institute Inc., 1990, *SAS/STAT User's Guide*. Version 6, Fourth Edition. Cary, NC: SAS Institute.

Substance Abuse and Mental Health Services Administration, 1997. *Uniform Facility Data Set (UFDS): Data for 1995 and 1980-1995*. Rockville, MD: Office of Applied Statistics.

Appendix A: Summary Tables for STAR Production Stages

Stage 1: Net Cultivation for Previous Year (hectares)

	1996	1997	1998	1999
Colombia	50,900	67,200	79,535	101,836
Peru	96,400	94,400	68,800	51,000
Bolivia	48,600	48,100	45,844	38,043
Andean Total	**195,900**	**209,700**	**194,179**	**190,879**

Stage 2: Net Cultivation for Current Year (hectares)

	1996	1997	1998	1999
Colombia	67,200	79,535	101,836	122,535
Peru	94,400	68,800	51,000	38,700
Bolivia.	48,100	45,844	38,043	21,840
Andean Total	**209,700**	**194,179**	**190,879**	**183,075**

Stage 3: Net Coca Leaf (metric tons)

Includes Reductions Taken

	1996	1997	1998	1999
Colombia				
Leaf Not Harvested (1%)	672	795	1,018	-
Licit Leaf Consumption	0	0	0	-
Leaf Seizures	0	0		-
Net Coca Leaf	299,872	343,926	433,228	521,645
Peru				
Leaf Not Harvested (1%)	944	688	510	-
Licit Leaf Consumption	10,000	10,000	10,000	-
Leaf Seizures	99	147	133	-
Net Coca Leaf	162,824	118,692	84,565	69,200
Bolivia				
Leaf Not Harvested (1%)	481	458	380	-
Licit Leaf Consumption	13,300	13,300	13,300	-
Leaf Seizures	76	51	94	-
Net Coca Leaf	48,100	55,969	39,042	22,800
Net Andean Total	**510,796**	**518,586**	**556,835**	**613,645**

Leaf Yield Factors, By Growing Area (metric tons of leaf per hectare)

	1996	1997	1998	1999
Colombia				
Guaviare	4.7	4.7	4.7	4.7
W. Caqueta	4.1	4.1	4.1	4.1
E. Caqueta	4.7	4.7	4.7	4.7
Norte de Santander	3.9	3.9	3.9	3.9
San Lucas	4.1	4.1	4.1	4.1
Arauca	4.7	4.7	4.7	4.7
Putamayo	3.9	3.9	3.9	3.9
Macarena	4.7	4.7	4.7	4.7
Peru				
Upper Hallaga Valley	2.1	2.1	2.1	2.1
Aguaytia	1.7	1.7	1.7	1.7
Pachitea	2.1	2.1	2.1	2.1
Central Hallaga Valley	1.6	1.6	1.6	1.6
Lower Hallaga Valley	1.3	1.3	1.3	1.3
Apurimac	2.6	2.6	2.6	2.6
Cusco	.9	.9	.9	.9
Other	1.2	1.2	1.2	1.2
Bolivia				
Chapare	1.86	1.78	1.64	1.19
Yungas/ Apolo	.91	.97	.99	.96
Other	1.00	1.00	1.00	1.00

Leaf To Base Conversion Factors, By Growing Area

		All Years
Colombia		
	Guaviare	959:1
	W. Caqueta	959:1
	E. Caqueta	1028:1
	Norte de Santander	959:1
	San Lucas	959:1
	Arauca	959:1
	Putamayo	1050:1
	Macarena	959:1
Peru		
	Upper Hallaga Valley	400:1
	Aguaytia	400:1
	Pachitea	400:1
	Central Hallaga Valley	400:1
	Lower Hallaga Valley	400:1
	Apurimac	400:1
	Cusco	400:1
	Other	400:1
Bolivia		
	Chapare	363:1
	Yungas/ Apolo	312:1
	Other	312:1

Stage 4: Net Coca Base (metric tons)

Includes Reductions Taken

		1996	1997	1998	1999
Colombia					
	Base Seizures	20	14	31	-
	Net Coca Base	288	334	405	522
Peru					
	Base Seizures	19	9	20	-
	Net Coca Base	388	288	192	173
Bolivia					
	Base Seizures	7	7	6	-
	Net Coca Base	165	152	105	69
Net Andean Total		**841**	**774**	**702**	**764**

Stage 5: Net Cocaine Produced at Labs (metric tons)

Includes Reductions Taken

Base Corridor of Movement	1996	1997	1998	1999
North				
Seizures From Labs	NA	NA	0	-
Net Cocaine Produced	NA	NA	35	-
Northeast				
Seizures From Labs	0	0	0	-
Net Cocaine Produced	841	681	590	-
Northwest				
Seizures From Labs	0	0	0	-
Net Cocaine Produced	NA	31	35	-
Southern				
Seizures From Labs	NA	0	0	-
Net Cocaine Produced	NA	62	42	-
Net Andean Total	**841**	**774**	**667**	**-**

Stage 6: Net Cocaine Available in South America (metric tons)

Includes Reductions Taken

HCl Corridor of Movement	1996	1997	1998	1999
Colombia				
1% Spoilage	8	6	6	-
Cocaine Seizures	38	43	62	-
Net Cocaine Available	795	593	508	-
Peru-Ecuador				
1% Spoilage	NA	1	0	-
Cocaine Seizures	NA	3	2	-
Net Cocaine Available	NA	58	40	-
Bolivia				
1% Spoilage	NA	1	1	-
Cocaine Seizures	NA	5	4	-
Net Cocaine Available	NA	64	80	-
Net Andean Total	**795**	**715**	**628**	-

Appendix B: Sources For Enhanced Seizure Data

Information in FDSS Data

FDIN
Drug Name
Weight in Grams
Date of Seizure
State
Southwest Border Flag - value is "Y" if seizure was made on southwest border
Conveyance Type:

- Aircraft
- Business
- Cargo
- Internal (body)
- Mail
- Other
- Person
- Residence
- Unknown
- Vehicle
- Vessel

Location –varies by conveyance type:

- Aircraft – airport or city
- Business – street address
- Cargo – airport or city
- Internal (body) – airport or city
- Mail –courier or city
- Other – latitude/longitude or city
- Person – city, street address, terminal name, or name of port of entry
- Residence – street address, city
- Unknown – lat/long or city
- Vehicle – street address, city, name of port of entry, or Border Patrol checkpoint
- Vessel – lat/long, city or name of port of entry

Conveyance ID –varies by conveyance type:

- Aircraft – flight number or location of drugs in aircraft
- Business – name of business
- Cargo – bill of lading number, type of courier
- Internal (body) – number of pellets or flight number
- Mail – city or bill of lading number
- Other – container number, street address, or business name
- Person – flight number, license plate number, carry location in/on body
- Residence – street address or location in house (room)
- Unknown – various things that can't be categorized
- Vehicle – type of car, license plate number (with state)

Vessel – vessel name

Enforcement Activity:

- Abandoned
- Buy/Bust
- Buy/Walk
- Controlled delivery
- Consent search
- Eradication
- Free sample
- Interdiction
- Clandestine laboratory
- Other/unknown
- Reverse undercover operation
- Search warrant
- Traffic stop
- Undercover operation

Information in EPIC BLISS Data

DATE	Date of Incident
TIME	Time of Incident
DAY	Day of Incident
ZONE	EPIC defined Seizure Zones within the SWB States
	AZ01 – Arizona state line to 113 degrees west
	AZ02 – 113 degrees west to 111 degrees west
	AZ03 – 111 DEGREES west to New Mexico state line
	CA01 – Pacific Coast to 116 degrees west
	CA02 – 116 degrees to Arizona state line
	NM01 – New Mexico west of Texas
	NM02 – New Mexico north of Texas
	TX01 – Anthony, TX to 105 degrees west
	TX02 – 105 degrees west to 102 degrees west
	TX03 – 102 degrees west to 100 degrees west
	TX04 - 100 degrees west to 99 degrees west
	TX05 – 99 degrees west to 98 degrees west
	TX06 – 98 degrees west to Texas Gulf coast
LOCATION	City, State, Country
HWY	Highway Seizure Location (if applicable)
T	Type
	A – Abandoned
	I – Intrusion by vehicle at border (not POE)
	N – Investigation
	F – On foot at border (not POE)
	O – Other
	P – Pedestrian at POE
	T – Traffic stop seizure
	L – Train
	U – Unknown
	V – Vehicle at POE
K	Kind
	B – Between port-of-entry
	P – Through port-of-entry
	U - Unknown
ENTRY	Entry zone (if known) CA01, etc.
TOT	Number of Suspects Detained
S	Sex (M-male or F-female)
R	Race
BC	Birth Country
CZ	Citizenship
ST	Vehicle Registration State
YEAR	Year Vehicle Built
MAKE	Vehicle Make
MODEL	Vehicle Model

TYPE	Vehicle Type
	BUS. – Bus
	CAR – Car
	4WD – 4-Wheel Drive
	MOR – Motorcycle
	FOT – On foot
	OTR – Other
	PUC – Pickup truck with camper
	PUT – Pickup truck without camper
	REC – Recreational vehicle
	STW – Station wagon
	TNK – Tanker Truck
	TXI – Taxi
	TOW - Towed vehicle
	TRC – Tractor/Trailer rig
	TLR – Trailer
	TRN – Train
	TRK – Truck
	VAN – Van
	WRK - Wrecker
LOC	Concealment Location
DRG	Type of drug
AMOUNT	Amount seized
MARKING	Drug marking/packaging

Information in Customs Seizure Data

Port

Conveyance Type

- Auto
- Bus
- Commercial air
- Fishing vessel
- Bicycle
- Commercial truck
- Train
- Motorcycle
- Other
- Van
- Private aircraft
- Mail
- Truck
- Commercial vessel
- Pedestrian
- Private vessel
- Express consignment
- No transport involved

Discovery Date

Agency Participation:

- Discovering
- Seizing
- Participated in seizure
- Air Operations Branch

Itinerary Info:

- In/Out Bound
- Date
- From

Conveyance Info:

- Type
- Searched?
- Seized?

Vessel Name

Flight #

Search Type

Results

Abandoned

Blitz

Dog Alert

X-Ray

Enforcement Aid Used

- Long-range night vision system
- Non-airborne infrared sensor devices
- Airborne radar system
- Mobile 3-d radar
- Airborne flir system
- Airborne radio d/f equipment
- Unattended ground/sea intrusion detection system
- UHF scanner
- Remote CCTV
- Hand held night vision devices
- Intel
- Air intel
- Marine units
- C^3I
- Other
- Plane
- Enforcement profile
- Helicopter
- Beeper
- Transponder
- U.S.CS fixed radar side
- Buster (density detector)

Containerized

Place of Discovery

Place of Seizure

Qty

FDIN

Weight Determination code

Nbr of Packages

Pkg Type

Country of Origin

Export

Destination

Concealment Location

- Body cavity (including swallowed)
- On body
- Clothing
- Other body (including dead body)
- Suitcase
- Trunk (as in luggage)
- Box
- Other bag
- Mail parcel
- Cargo
- Auto/truck
- Vessel
- Aircraft
- Other (bus, train, motorcycle, etc.)
- Camper
- Within cargo container
- Express consignment package
- Not concealed

Concealed in Secret Compartment

Information in Coast Guard Seizure Data

Amount (lbs)

Date of seizure

Coast Guard District

Drug seized

Flag country

Location

State

Seizing unit

Vessel name

Vessel type

Information sources

Appendix C: Technical Details of the Border Allocation Model

In this appendix we describe the Border Allocation model in considerable detail. The model utilizes data from the Enhanced Seizure database and data about fees smugglers receive to deliver cocaine to the U.S.

Transportation Costs

As used in this report, *transportation cost* is the amount it costs to ship cocaine from the source country to a particular U.S. border destination via a particular mode of transportation. This cost does not include the cost of lost cargo due to seizure, which is addressed subsequently.

Transportation costs were obtained from Customs Reports of Investigations (ROIs) and from seizure and intelligence reports[12]. Using Customs BRS text search capability, we designed a query to extract those ROIs, intelligence reports, and seizure reports that contained explicit transportation cost information for 1989 through 1999. 14,328 reports were retrieved. We then used the textual extraction programming language, PERL – first to screen for references to cocaine, and – next, to screen for data pertaining to transportation costs. The first and second stages reduced the 14,328 reports to 6,131 and 836 reports respectively. The ROI data extraction process is summarized in Figure C1.

In some cases, payments consist of a portion of the load (in-kind payment), with or without a cash payment. Because these transactions are difficult to identify through the ROI extraction process, and, therefore, would likely be under-represented, we excluded them. We also excluded data prior to 1991, the earliest year for our seizure data, leaving a total of 613 transportation cost observations.

We categorized these 613 observations by geographical region (Florida, the southwest border, and Rest of the U.S.) and by conveyance types (noncommercial and commercial air, noncommercial and commercial marine, and noncommercial and commercial vehicle). Transportation costs for "Rest of U.S." were applied to the three regions that are identified in seizure (but not in transportation) data: northeast, Puerto Rico/Virgin Islands, and Rest of U.S. Table C1 summarizes the cost data in terms of the average cost per kilogram, for 1991-1998.

[12] Layne, M., Rhodes, W., Chester, C., *The Cost of Doing Business for Cocaine Smugglers*, March 2000, Abt Associates Inc. Report prepared for U.S. Customs Service.

Figure C1

ROI Data Extraction Process

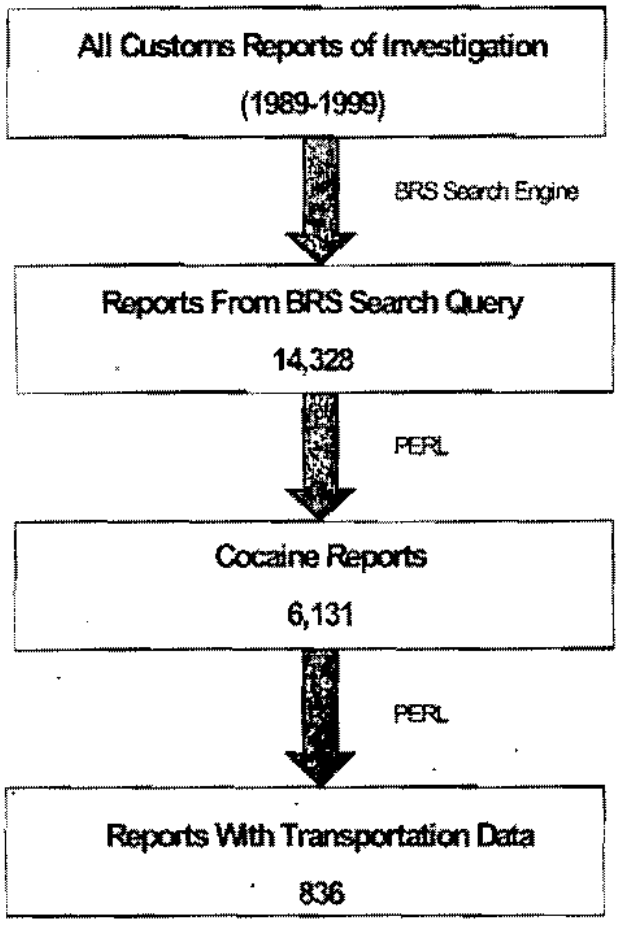


Table C1
Transportation Costs by Region and Conveyance ($ per kilogram): Average Over Years 1991-1998

Border Region	Noncom. Vehicle	Commercial Vehicle	Noncom. Air	Commercial Air	Noncom. Marine	Commercial Marine
Florida	-	-	$2,796	$3,236	$2,852	$2,902
SWB	$452	$870	$2,141	$3,647	$3,530	$3,716
Rest of U.S.	$1,371	$2,875	$2,788	$2,892	$2,932	$3,304

- indicates not applicable

Transportation costs for land conveyances (commercial/non commercial vehicles) crossing the southwest border are much lower than elsewhere, because they do not include the costs associated with the air or sea journey from Colombia, only with the cost of driving the cocaine from Mexico into the U.S.[13]. We adjusted costs for land conveyances such that they represent the full cost of shipping from Colombia to the U.S. The Mexican transportation cost adjustment problem is complicated by the fact that Colombians pay Mexican traffickers in kind (generally 35 to 50 percent of the shipment) rather than in cash[14].

Colombians pay Mexican traffickers up to one half a kilogram of cocaine for each kilogram successfully delivered. Thus, the adjusted transportation cost of shipping 1 kilogram consists of two components:

1. Cost of shipment from Colombia to Mexico: $1,400[15].
2. The in-kind cost to the Colombians.

From the Colombian perspective, the in-kind cost of shipping one kilogram is:

Wholesale price in Colombia ($2,000[16]):	.5 x $2,000
Transportation cost from Colombia to Mexico:	.5 x $1,400
Total Colombian In-Kind Cost:	**$1,700**

The two costs, when added together, created the adjusted the transportation cost of $3,100.

For land conveyance costs to the rest of the U.S. (i.e. from Canada), we simply used the transportation cost for Colombia to Mexico, or $1,400, as no other estimate was available.

Transportation Cost Smoothing Model

The transportation cost data contained several figures that were inordinately high or low. Because the Border Allocation Model is sensitive to very high or low cost values, we smoothed the cost data by modeling and removing outliers. A suitable model for the cost data appeared to be a multiplicative model (with no interaction) with coefficient of variation (standard deviation divided by the mean) proportional to sample size.

---

[13] Costs for moving cocaine from Canada into the U.S. are higher, suggesting that poverty in Mexico leads to lower prices for smuggling services.

[14] During the late eighties Colombians were paying the Mexicans cash fees for transportation services. One Mexican group shipped large quantities of Colombian-owned cocaine across the border to warehouses. They refused to release the load to Colombian wholesale distributors until they were paid their transportation fees. Over a three-month period in 1989, 40 metric tons were seized from various warehouses in the U.S. (including 21 metric tons from a single warehouse in Sylmar, California – the largest cocaine seizure in U.S. history). Since then, Mexicans have adopted an in-kind arrangement.

[15] Senior Special Agent Frederick J. Stacey, U.S. Customs Service, 1999.

[16] Ibid.

$$E(C_{itj}) = \exp(\text{Region}_i + \text{Conveyance}_j)$$

$$CV(C_{itj}) = \phi/\sqrt{n_{itj}}$$

In these expressions, a cost observation from the *i*th region and *j*th conveyance at the *t*th time period is represented by C_{itj}. The mean and coefficient of variation of C_{itj} are $E(C_{itj})$ and $CV(C_{itj})$, and the number of data points in *itj*th combination is n_{itj}. The constant ϕ is to be estimated. This model represents a considerable simplification of the original cost data, and one which residual analysis appears to support. We note, in passing, that the specification of the coefficient of variation is not critical, in the sense that consistency and asymptotic normality are known to hold, even under mis-specification.[17]

Outliers

The transportation cost data contained several costs that were inordinately high or low. These outlying costs were detected, and subsequently removed, in the context of the multiplicative model above. A cost observation was deleted if its residual was sufficiently large – the residual being the difference between the observed cost and predicted cost given the region and conveyance. Of course, in order to gauge the degree of discrepancy, it was necessary to know the probability distribution of residual prices. For normal linear models, the standardized residuals (residuals divided by their standard errors) follow a standard normal distribution and the probability of a large residual is readily calculated. In the case of the above multiplicative model, deviance residuals (which are approximately normally distributed under an assumed gamma response) were used in an analogous way[18].

By rejecting cost observations with large residuals, one hopes to exclude a high proportion of the erroneous data and a low proportion of the genuine data. We chose a quantile threshold such that the probability of excluding genuine data was 0.01. We deleted data in an iterated fashion because our experiments with simulated data indicate that iteration increases the probability of detecting outliers. This occurs because the distribution of deviance residuals in early iterations is artificially dispersed because of the presence of inordinately extreme residuals which will be absent from subsequent iterations. In this case, no further outliers could be detected after the ninth iteration. Of the 613 cost observations, 82, or about 13%, were deleted. Given our 1% probability of excluding genuine data, we infer that approximately 12% of the cost data were actually erroneous. Table C2 shows some examples of excluded data.

[17] Fahrmeir and Tutz, 1994, pp.52-55

[18] McCullagh and Nelder, 1989, pp. 37-40

Table C2
Examples of Cost Outliers ($ per kilogram): Florida by Commercial Air

Iteration	Year	Region	Conveyance	Reported	Predicted	Dev. Resid
1	1998	Florida	ComAir	50	3,144	-3.8
1	1998	Florida	ComAir	23,000	3,144	4.5
2	1998	Florida	ComAir	417	2,963	-3.0
3	1998	Florida	ComAir	640	3,076	-2.8
4	1998	Florida	ComAir	7,900	3,104	2.7
7	1998	Florida	ComAir	926	3,098	-2.6

Table C3 shows the smoothed conveyance costs (i.e., outliers removed) actually used in the Border Allocation Model. The model implies, among other things, that Florida's costs are consistently 4% higher than other regions, and that commercial marine is 14% more expensive than commercial air, 18% more expensive than noncommercial marine, and 19% more expensive than noncommercial air.

Table C3
Smoothed Transportation Costs by Region and Conveyance ($ per kg): Average Over Years 1991-1998

Border Region	Noncom. Vehicle	Commercial Vehicle	Noncom. Air	Commercial Air	Noncom. Marine	Commercial Marine
Florida	-	-	$2,998	$3,136	$3,017	$3,568
Gulf Coast	-	-	$2,882	$3,015	$2,900	$3,431
Northeast	-	-	$2,882	$3,015	$2,900	$3,431
PR/VI	-	-	$2,882	$3,015	$2,900	$3,431
SWB	$3,067	$3,569	$2,875	$3,007	$2,893	$3,422
Rest of U.S.	$3,075	$3,578	$2,882	$3,015	$2,900	$3,431

- indicates not applicable

Based on conveyance costs alone, the least expensive route into the U.S. is by noncommercial air through the southwest border. What then prevents the entire cocaine flow destined for the U.S. from entering via this route?

We consider two, possibly equilibrating forces. One is that, for a given region and conveyance, the probability of detection – and therefore the cost of seizure – increases with the total quantity shipped. Highly traveled routes probably attract larger quantities of U.S. enforcement assets, and low-risk methods (e.g. flying at night) tend to be crowded out as more smugglers use them. Another possible equilibrating force is the preference to choose a border close to the ultimate U.S. market. However, we did not pursue this second possibility because transportation costs within the U.S. are negligible compared to external transportation costs.

Technical Details of Border Allocation Model

The model used here is essentially an economic one that assumes that smugglers choose to minimize total transportation costs and thus, as a group, unwittingly equalize total transportation costs across all routes (region-conveyance combinations) and times. We assume that the *total transportation cost* for the *ij*th route at the *t*th time, K_{itj}, is the *transportation cost*, C_{itj}, (the sum required to ship cocaine from its source to the *i*th region in the U.S. via the *j*th conveyance type) plus the *seizure cost*, Z_{itj} (the cost associated with the cargo being seized). From the viewpoint of a Colombian shipper, it is assumed that the cost of seizure is simply the replacement cost of the lost cargo. This is just the probability of seizure, P_{itj}, times the cost of producing a metric ton, V_t. Since costs of production have been reasonably stable[19] over the last decade, we take V_t to equal V. The probability of being seized for the *ij*th route at the *t*th time is simply the expected amount seized as a fraction of the amount shipped, $E(S_{itj})/T_{itj}$.

We further assume that Colombian shippers choose routes such that transportation costs are equal across all region-conveyance combinations and times, that is, $K_{itj} = K$ for all *itj*. This behavioral assumption is based on the grounds that if one route were cheaper than others, smugglers would increase activity through that route, thus increasing the likelihood of seizure and increasing total transportation costs, until equality prevailed. Similarly, if smugglers expected next year's total transportation costs to be lower than this year's, they would choose to store some cocaine this year and ship it next year.

Summarizing the above assumptions algebraically, we can express the total transportation cost associated with the *i*th region, *j*th conveyance, and *t*th year as:

$$\begin{aligned} K &= C_{itj} + Z_{itj} \\ &= C_{itj} + P_{itj}V \\ &= C_{itj} + \{E(S_{itj})/T_{itj}\}V \end{aligned}$$

Solving for $E(S_{itj})$ and writing the amount through the *ij*th route in a given year as a proportion of the total amount during that year, $T_{itj} = \beta_{itj}T_t$, we obtain:

$$\begin{aligned} E(S_{itj}) &= T_{itj}(K - C_{itj})/V \\ &= \beta_{itj}T_t(K - C_{itj})/V \qquad (1) \end{aligned}$$

In these expressions, S_{itj} and C_{itj} are observed variables, while β_{itj} and K are parameters to be estimated. Incidentally, the quantities T_t and V do not affect the estimates of β_{itj} the key parameters of interest.

As it stands, with 217 parameters and 224 observations, model (1) is almost saturated. The 224 seizure observations result from the 28 routes (six regions times six conveyances minus eight structural zeros) over eight years, and the 217 parameters result from estimating K plus 27 β_{ij}s in each

[19] Senior Special Agent Frederick J. Stacey, U.S. Customs Service.

year (the 28th is 1 minus the sum of the first 27 since the 28 probabilities must sum to unity). In passing, we note that even a fully saturated model (model (1) with eight distinct K_ts) is not entirely trivial inasmuch as it provides information that is far from obvious by an inspection of the data. Nevertheless, high parameter models tend to over-fit the data at hand, and we improve on this state of affairs by letting β_{itj} be a parsimonious function of time, $\beta_{itj} = f_{ij}(t)$.

Three simple polynomial functions were considered, ones that allowed β_{itj} to vary over time in a constant, linear, or quadratic fashion:

$$\beta_{itj} = u_{ij}$$
$$\beta_{itj} = u_{ij} + v_{ij}t$$
$$\beta_{itj} = u_{ij} + v_{ij}t + w_{ij}t^2$$

In these expressions, u, v, and w are parameters to be estimated. When these expressions are incorporated into model (1), the resulting models contain 28, 55, and 82 parameters respectively (e.g. the quadratic model estimates 27 u_{ij}s, 27 v_{ij}s, 27 w_{ij}s, and K), all of which are considerable simplifications over model (1) itself. A likelihood ratio test indicated that the quadratic function was much preferred to the linear function ($p<0.0001$), while the linear function was similar to the constant function ($p=0.156$). Thus the model (1) becomes:

$$E(S_{itj}) = (u_{ij} + v_{ij}t + w_{ij}t^2)T_t(K - C_{itj})/V \qquad (2)$$

In fact, it was necessary to modify model (2) in two ways. Firstly, since the β_{itj}s are probabilities, it was desirable to constrain them to lie between zero and one. This was achieved by expressing β_{itj} as a multivariate logistic function of an unconstrained parameter $\alpha_{itj} = (u_{ij} + v_{ij}t + w_{ij}t^2)$, which means β_{itj} took the form

$$\beta_{itj} = \exp(\alpha_{itj})/\{\sum\exp(\alpha_{itj})\}$$

where the sum is over all ij[20]. (Actually, since only 27 of the 28 β_{itj}'s are estimated, the last β_{666}, was dropped, and the denominator changes from $\sum\exp(\alpha_{itj})$ to $\{\sum\exp(\alpha_{itj}) - \exp(\alpha_{666}) + 1\}$).

The second modification was entirely technical. Since K is at least as large as the largest C_{itj}, K was estimated via the parameter γ, where $K = \max(C_{itj}) + \exp(\gamma)$. In light of these modifications, the final model was:

$$E(S_{itj}) = (\exp(u_{ij} + v_{ij}t + w_{ij}t^2)/\{\sum(\exp[u_{ij} + v_{ij}t + w_{ij}t^2])\})T_t\{\max(C_{itj}) + \exp(\gamma) - C_{itj}\}/V \qquad (3)$$
$$V(S_{itj}) = \sigma^2$$

In these expressions, S_{itj} represents the kilograms seized from the *i*th region, *j*th conveyance and *t*th year, with mean $E(S_{itj})$ and variance $V(S_{itj})$. Note that parameters such as u_{ij} actually represent the sum of 27 parameter-dummy variable terms of the form $u_{ij}I_{ij}$, where $I_{ij} = 1$ for the *ij*th region-conveyance and $I_{ij} = 0$ otherwise. As previously noted, estimates of β_{itj} are unaffected by the inclusion of T_t, but for each year an estimate of T_t was obtained to produce estimates of T_{itj} of the

[20] Judge et al., 1985, pp 770-77

form $T_{ij} = T_t \times \beta_{ij}$. In this study, the estimate of T_t was obtained as the sum of (1) estimates of pure cocaine consumed in the U.S., (2) pure cocaine seized inside the U.S., and (3) pure cocaine seized at the U.S. border.

Model (3) was successfully fit via the method of least squares with the Gauss-Newton algorithm using SAS's NLIN procedure. The analysis of residual (the difference between observed and predicted seizures) supported the adequacy of the model specification in various ways (Table C4). First, the variance of the residuals was unrelated to the mean level of seizures, which vindicates the assumption of constant variance. Second, residuals were small relative to seizure amounts, which implies the model closely fit the observed seizure data. Third, there was no obvious region-conveyance pattern in the residuals, which suggests that the model fit the data uniformly well.

Table C4
Residuals By Region and Conveyance (metric tons): Average Over Years 1991-1998

Border Region	Noncom. Vehicle	Commercial Vehicle	Noncom. Air	Commercial Air	Noncom. Marine	Commercial Marine
Florida	-	-	0.11	0.02	0.02	0.02
Gulf Coast	-	-	-0.03	-0.04	0.02	0.04
Northeast	-	-	-0.03	0.02	-0.03	0.00
PR/VI	-	-	0.15	0.00	0.12	0.30
SWB	-0.10	-0.02	0.01	0.01	0.45	0.02
Rest of U.S.	-0.04	-0.19	0.03	0.02	-0.03	-0.01

- indicates not applicable

Limitations of the Model

As a nonlinear economic model, the Border Allocation Model represents a new approach to estimating cocaine availability at the U.S. border, and its estimates are strikingly different from those that might be obtained from simpler models, such as those assuming proportionality between seizures and flows. Nevertheless, the Border Allocation Model has important limitations, both as a model and in terms of the data on which it is based. The following are some of these limitations:

1. We have assumed that production costs for cocaine, V, and total transportation costs, K, have been constant over the period 1991 through 1998. That is, we have assumed $V_t = V$ and $K_t = K$ for all t. More accurate data is needed.
2. The method used to reconcile southwest border and Canadian transportation costs with transportation costs in other regions is tenuous. In particular, the estimate used for the Colombia-to-Mexico leg needs improvement, and an invariant 50% payment-in-kind is undoubtedly an over-simplification.
3. It was noted that definitions of seizure are inconsistent, particularly at the southwest and Florida borders. This inconsistency should be addressed.

4. The economic component of the model could be made more realistic. For example, the cost of a seizure may be more involved than simply the replacement cost of lost cargo. Also, the model may be insufficiently dynamic in that it implicitly assumes a market that instantly equilibriates. However, we should note that the model is already complicated from a statistical viewpoint (e.g. difficulties in convergence occurred with certain optimization methods), and economic enhancements are likely to cause further complications.
5. We have noted that because the typical, noncommercial drug smuggling flight stops short of the U.S. border, our model does not accurately reflect the contribution of noncommercial air. More generally, our model may benefit by incorporating more realistic descriptions of the Colombia-to-U.S. transportation routes.

Appendix D: Technical Details of U.S. Domestic Allocation Model

The premise of the Domestic Allocation Model is consistent with a classic, operations research transportation problem: given quantities of cocaine entering the domestic market at six border regions, and given quantities demanded in each of ten U.S. divisions, it is assumed traffickers determine the allocation that satisfies demand in all divisions while minimizing total transportation costs. Standard linear programming techniques are used.

The general transportation problem is concerned with distributing a commodity from a group of supply centers (sources), to a group of receiving centers (destinations), in such a way as to minimize total distribution cost. In general, suppose that the ith source (i=1,2, ..., m) has a supply of S_i units to distribute to n destinations and the jth destination (j=1, 2, ... , n) has a demand of D_j units to be received from the m sources. If X_{ij} is the number of units to be distributed from source i to destination j, then $S_i = \sum X_{ij}$, and $D_j = \sum X_{ij}$.

Subject to these demand and supply constraints, we assume suppliers choose X_{ij} in order to minimize the total distribution cost, $Z = \sum\sum f(C_{ij}, X_{ij})$, where C_{ij} is the distribution cost per unit. For simplicity, we further assume that the distribution cost are proportional to the number of units distributed, so that $f(C_{ij}, X_{ij}) = C_{ij}X_{ij}$. The Domestic Allocation Model now becomes a standard linear programming problem, which we solved using the LP call in SAS IML:

Minimize $$Z = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij}X_{ij}$$

Subject to $$\sum_{j=1}^{n} X_{ij} = S_i, \text{ for } i=1, 2,..., m$$

$$\sum_{i=1}^{m} X_{ij} = D_j \text{ for } j=1, 2,..., n$$

$$X_{ij} \geq 0, \text{ for all } i \text{ and } j$$

In generic terms, the observed variables S, D, and C represent supply, demand and costs of distribution. In our particular setting, S_i is the amount of cocaine that passes through the ith U.S. border region without being seized. This is obtained from the Border Allocation Model described earlier as the estimated total flow into the ith region (summed over all conveyances) minus the total amount seized, minus Federal non-border seizures. The demand at the jth census division, D_j, is estimated as the fraction of the number of treatment clients[21] in the census division divided by the total amount of cocaine consumed in the U.S.[22] The costs of distribution, C_{ij}, is the cost of shipping

[21] Substance Abuse and Mental Health Services Administration, 1997, Uniform Facility Data Set (UFDS): Data for 1995 and 1980-1995. Rockville, MD: Office of Applied Statistics.

[22] Rhodes, W., Layne, M., Johnston, P., Hozik, L.1995. What America's Users Spend on Illegal Drugs, 1988-1998. November 1999, Abt Associates Inc. Report prepared for ONDCP.

via U.S. interstate highways, including costs associated with risks of seizure en route. This is assumed to be roughly proportional to the distance between origin and destination.

Limitations of the Model

While the model provides a plausible first-order method for allocating cocaine from border regions to consumption areas, a fundamental flaw is its assumption that there are no barriers to trade. As cocaine is illegal, transporting it involves considerable risk, and paying for taking on this risk must surely dwarf the costs of gasoline. Further, cocaine transporters cannot simply carry their goods to the nearest/cheapest city, but must go to a place where they have a buyer. Finally, we have not accounted for state and local seizures. Consequently, our working estimates may be significantly flawed.

Appendix E: Transition Tables For 1996

Appendix F: Transition Tables For 1997

Appendix G: Transition Tables For 1998

Assessment of Two Cost-Effectiveness Studies on Cocaine Control Policy

NATIONAL RESEARCH COUNCIL

Clinton Presidential Records
Digital Records Marker

This is not a presidential record. This is used as an administrative marker by the William J. Clinton Presidential Library Staff.

This marker identifies the place of a publication.

Publications have not been scanned in their entirety for the purpose of digitization. To see the full publication please search online or visit the Clinton Presidential Library's Research Room.