Estimation of Cocaine Availability

1996-2000

Executive Office of the President
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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 amount to reducing the supply of and the demand for illicit drugs by 50 percent by year 2007. The nation's ability to meet these goals depends on its efficacy at reducing drug availability through source country programs, transit zone interdiction, and domestic law enforcement.

Having adopted this assessment for monitoring the success of the nation's anti-drug programs, one critical input -- the topic of this paper -- is a reliable estimate of cocaine availability at various points in cocaine's flow from source to the United States. This report updates the Sequential Transition and Reduction (STAR) model through 2000, providing 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 U.S.

The STAR model tracks the flow of cocaine hydrochloride (HCl) from cultivation in source country growing regions, to consumption 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.

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. 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 this research, the model begins at stage 9 and works backward -- *adding in reductions* -- to a U.S. consumption-based estimate of cocaine that departs South America. It also simultaneously begins at stage 1 and works forward -- *subtracting reductions* – to a cultivation -based estimate of.

At most of the transitions, the matrix formulation is an accounting framework incorporating availability estimates. These "accounting transitions" simply apply available data. However, at stages 6, 8, and 9 the model is more than an accounting device. At these 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 (Rhodes, 2002).

The STAR model applies sequential transitions through a serious of matrix operations[1]. 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[2].

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[1] At each of the eight stages, there is 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.

[2] 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.

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 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 ONDCP
Stage 9 - Cocaine availability at domestic retail areas		

Stages in the STAR Model

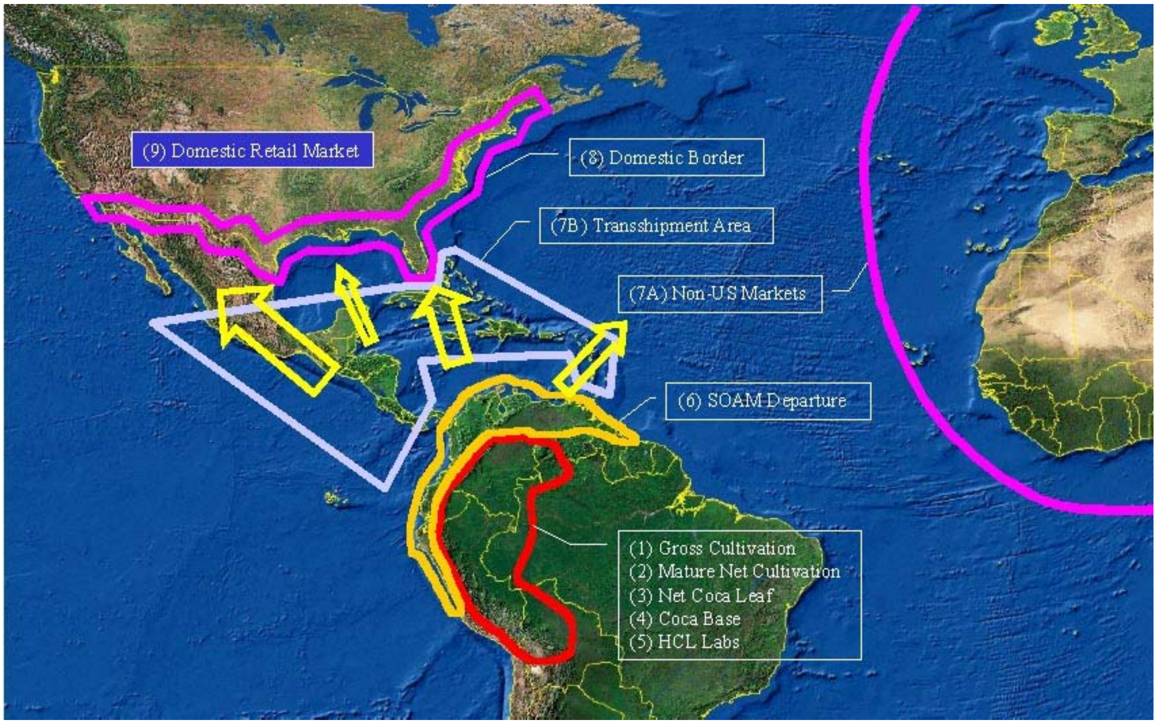
The model is comprised of nine stages and eight transitions. Stages 1 through 4 are production stages within the growing areas, and Stages 5 through 8 track cocaine HCl from Andean labs to the streets of the U.S. and non-U.S. destinations. Figure 1 depicts the geographical areas involved in each stage.

Cocaine availability at each stage was estimated by triangulating between three dynamic existing processes:

1) Estimation of coca cultivation based on overhead imagery
2) Estimation of cocaine departing South America based on tabulation of movement events, and
3) estimation of US consumption based on prevalence estimates and cocaine price/purity trends.

The model transitions availability at one stage to the next through conversions or reductions based on data from multiple sources including, the Federal-wide Drug Seizure System (FDSS), the National Household Survey on Drug Abuse (NHSDA), the Consolidated Counterdrug Data Base (CCDB), the Arrestee Drug Abuse Monitoring (ADAM) Program, the CNC coca cultivation figures, and DEA's System to Retrieve Information on Drug Evidence (STRIDE).

Figure 1 - Geographic Areas of STAR Stages



Stage 1: Net Cultivation From Previous Growing Year
Stage 1 simply represents 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 eighteen growing areas. Transition 1/2 is the computational link between the previous year's net cultivation and the current year's net cultivation. The computation considers new growth, field abandonment, and eradication.

Stage 3: Net Dry Leaf
Stage 3 is the amount of net leaf yielded from coca plants, by growing region. The transition between Stages 2 and 3 applies leaf yield factors (shown in table A1, Appendix A) to transform the amount of net cultivation into available dry leaf amounts, measured in metric tons. The transition from Stage 2 and Stage 3 includes reductions for licit leaf consumption (obtained from the International Narcotics Control Strategy Report (INCSR)), leaf seizures, and for leaf not harvested – which is assumed to be one percent of mature hectares.

Stage 4: Base Availability
Stage 4 is the amount of base created from net dry leaf amounts, by growing region. Transition 3/4 applies leaf-to-cocaine conversion factors (detailed in table A2, Appendix A) for each growing region.

Stage 5: Cocaine Availability at Labs
Stage 5 measures the amount of cocaine produced at labs. Transition 4/5 follows coca base from growing regions to labs through base corridors of movement as defined in the IACM publications (beginning in 1997). 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 base seizures.

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.

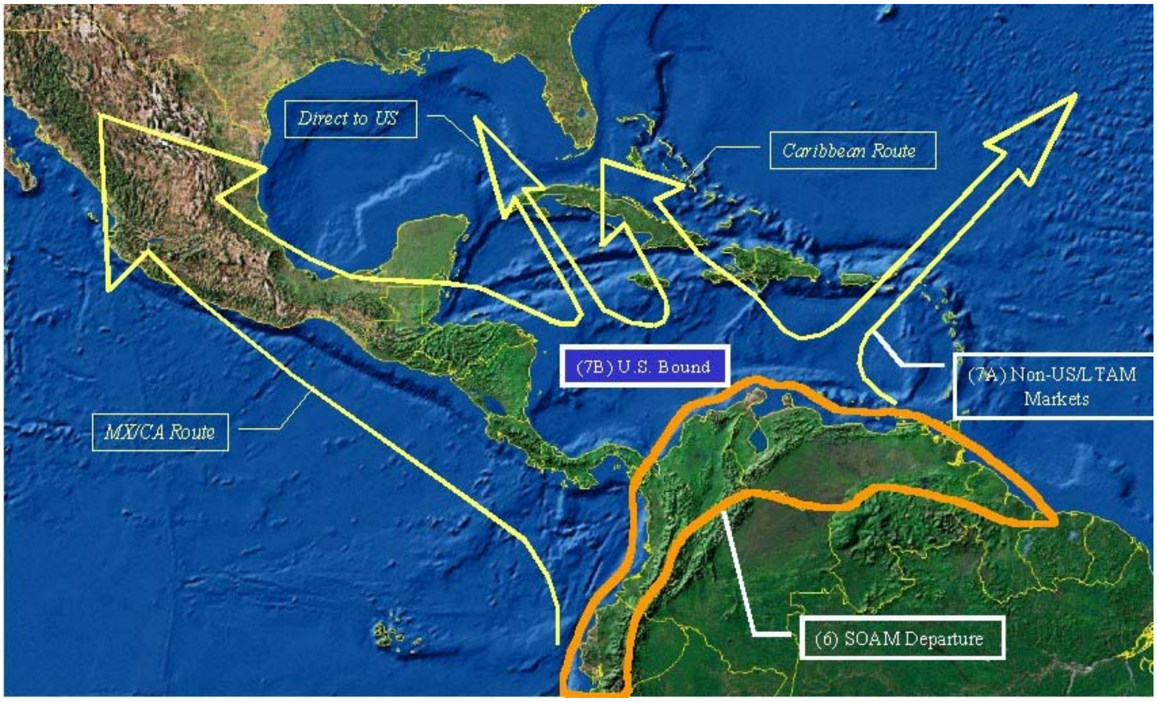
Stage 6: Cocaine Departing South America
Transition 5/6 is the link between cocaine labs and South American departure points, through HCl corridors of movement as defined in the IACM publications. The model apportions the flow of HCl from labs to departure points by the percentages of observed South American cocaine movement described in the IACM.

Reductions taken in this transition include source country seizures and spoilage (assumed to be one percent), and source country consumption (based on a preliminary assessment).

Stage 7A: Non-U.S./South American Markets
Figure 2 shows the split of the flow between that moving toward U.S. markets and that moving toward non-U.S./LTAM markets (primarily Europe). Stage 7A is the amount of cocaine that departs South America and successfully arrives at non-U.S./LTAM markets. Seizures in non-U.S. bound corridors are included in the transition.

Stage 7B: Transshipment Area
This stage is the amount of cocaine that departs South America towards the United States. Transition 6/7B apportions cocaine from South American departure points through corridors of movement, via specific conveyances (noncommercial and commercial air, noncommercial and commercial maritime). Two assumptions are made: cocaine leaving from Colombia transits all three corridors; cocaine leaving from departure points in Peru, Ecuador or Bolivia transits through Mexico/Central America (MX/CA) only. Flows among corridors and conveyances are apportioned in the same proportion as flows in the event-based data.

Figure 2 - Availability at U.S. Bound Transshipment Corridors and Non-U.S./LTAM Markets (Stage 7)



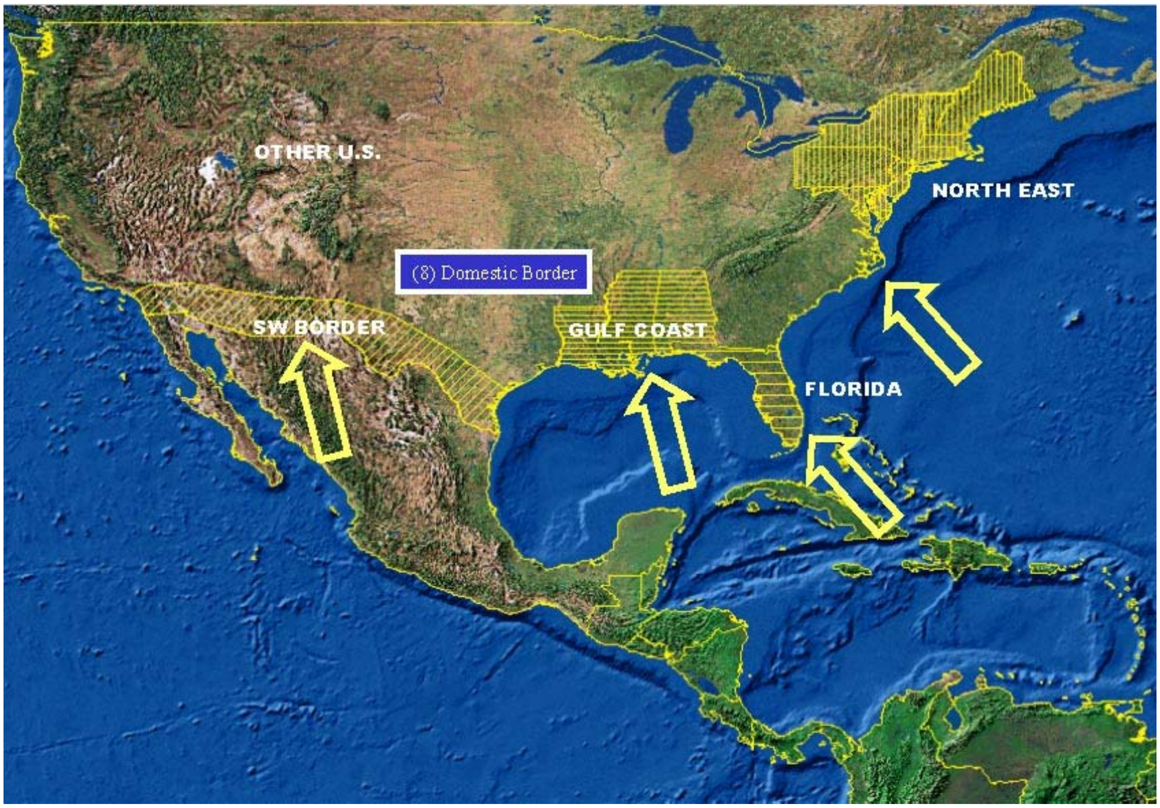
During Transition 6/7B, event-based data is incorporated, which describes cocaine departing South America by corridor and conveyance combinations. Reductions taken in the transition include transit seizures and transit country consumption, which is assumed to be three percent of the flow.

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.

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. Figure 3 illustrates the U.S. border entry regions used in the model. 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. It is assumed that shipments passing through the Mexican/Central American corridor terminate at the southwest border and that shipments in the Caribbean and Direct to U.S. corridors are distributed in proportion to border seizures and conveyance combinations.

Figure 3 - U.S. Border Entry Regions

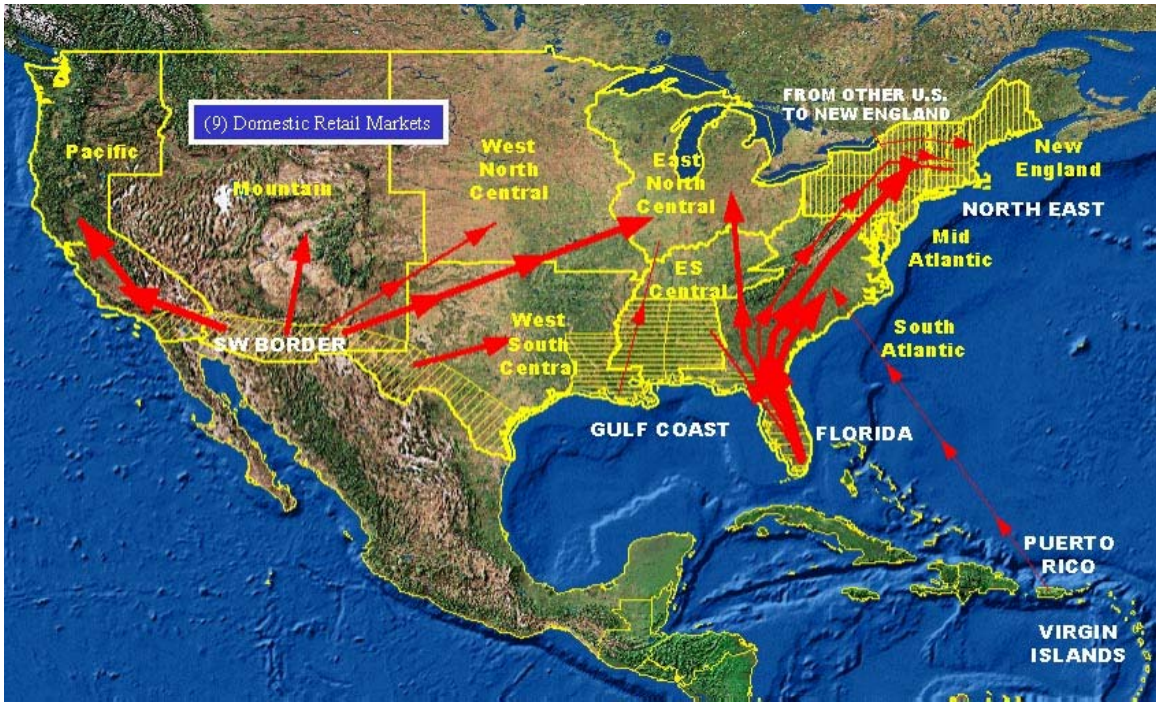


Reductions taken during this transition account for seizures at the border using an Enhanced Seizure Database created for the STAR model. At stage 8 the Border Movement Model provides estimates of cocaine arriving to U.S. regions, by conveyance type. Both the Enhanced Seizure Database and 8 the Border Movement Model are described in the Section 2.

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. Figure 4 depicts domestic retail markets, which have been broken down into ten main regions. Transition 8/9 incorporates domestic (non-border) cocaine seizures. The arrows in the figure depict routes taken from border entry regions, based on the results of the Domestic Allocation Model (described in Section 2).

Figure 4 - Domestric Retail Areas



STAR Model Estimates

The STAR model is used to generate annual stage-by-stage cocaine availability estimates for 1996-2000. First, availability estimates are developed by beginning with the previous year's coca cultivation estimate (Stage 1), then moving forward through the production stages, incorporating losses along the way. These annual availability estimates terminating at the amount available to depart South America. South American cocaine consumption amounts are preliminary.

Parallel cocaine availability estimates for stages (6-9) are determined by beginning with the domestic consumption estimate (Stage 9) and working backward through prior movement stages (by adding in losses between stages). These two approaches, cultivation-based and domestic consumption-based, will then be compared with a third estimate of cocaine availability, the event-based estimate of cocaine departing South America developed by the IACM. No uncertainties will be calculated for these estimates, but there are inherent uncertainties in each component. Reductions in uncertainty will be gained by integration of additional data sets.

Table 2 summarizes cocaine availability estimates developed by the STAR model for the period 1996-2000. Estimates for Stages 1-5 are based on coca cultivation figures and estimates for Stages 6-9 are based on domestic consumption figures. The gray line represents the mean of cultivation estimates and domestic consumption estimates. The STAR model makes all calculations in pure amounts, using two purity figures – one for import purity[3] and retail purity (Rhodes, 2002) for domestic amounts.

The STAR model was used to calculate the cocaine available for export from South America growing areas by integrating all consumption and seizure losses into the production estimation process. Tables B1 through B5 in Appendix B show the detailed data for the stage availability estimates for the period 1996-2000, from cultivation (Stage 1) to the base availability at each growing area (Stage 4). Based on the calculations in tables B1 through B4, the actual base production can be estimated for each year. These estimates are 100 to 150 metric tons less than the potential production estimates. Similar to the potential production estimates, there is a downward trend.

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[3] Obtained from the DEA estimate for Colombia.

Table 2 - Transition and Stages, 1996-2000

TRANSITION	STAGE	1996	1997	1998	1999	2000
1 to 2	**STAGE 1: Previous Year Net Cultivation (ha)**	**214,800**	**209,700**	**194,179**	**190,878**	**183,075**
	New Growth (ha)	29,099	37,170	39,770	36,400	26,000
	STAGE 2: Current Year Net Cultivation (HA)	**209,700**	**194,179**	**190,878**	**183,075**	**184,922**
	Transition Accounts For:					
	Eradication (ha)	14,560	30,554	33,096	42,553	21,245
	Abandonment (ha)	19,640	22,137	9,975	1,650	2,910
2 to3	**STAGE2: Net Cultivation (ha)**	**209,700**	**194,179**	**190,878**	**183,075**	**184,922**
	Dry LeafYield Factors					
	STAGE 3: Net Dry Coca Leaf (MT)	**304,055**	**262,495**	**238,760**	**210,452**	**207,081**
	Transition Accounts For:					
	LeafNot Harvested (ha.): 1%	2,097	1,942	1,909	1,831	1,849
	Licit LeafConsumption (MT)	23,300	23,300	23,300	23,300	23,300
	LeafSeizures (MT)	175	197	227	220	107
3 to 4	**STAGE 3: Net Dry Coca Leaf (MT)**	**304,055**	**262,495**	**238,760**	**210,452**	**207,081**
	Processing Efficiency					
	STAGE 4: Coca Base (MT)	**896**	**805**	**775**	**726**	**736**
4 to 5	**STAGE 5: HCl Labs (Pure MT)**	**851**	**776**	**718**	**703**	**721**
	Transition Accounts For:					
	Base Seizures (MT)	45	29	57	22	15
	Seizures fromLabs (Pure MT)	0	0	0	0	0
5 to 6	**STAGE 6: Departure Areas (Pure MT)**	**602**	**616**	**600**	**554**	**537**
	Transition Accounts For:					
	Spoilage (Pure MT): 1%	9	8	7	7	7
	Seizures (Pure MT)	40	35	36	42	77
	South American consumption (Pure MT)	100	100	100	100	100
	DEPARTURE AREAS (MIDPOINT OF CULTIVATION/CONSUMPTION APPROACHES)	**579**	**592**	**575**	**577**	**519**
6 to7	**STAGE 6: Departure Areas (Pure MT)**	**555.2**	**568.8**	**549.6**	**600.7**	**500.4**
	Colombia	555.2	471.3	444.7	390.3	452.7
	Peru-Ecuador	0.0	46.4	34.9	148.5	37.0
	Bolivia	0.0	51.0	70.0	61.9	10.6
	7A Depart Toward U.S. Markets (Pure MT)	**389.4**	**344.4**	**345.0**	**343.7**	**327.0**
	Transition Accounts For:					
	Transit Seizures (Pure MT)	45.6	74.0	69.7	62.3	71.1
	Transit Country Consumption (Pure MT): 3%	9.6	9.1	9.2	9.1	8.3
	7B Depart for non-US Markets (Pure MT):	**90.9**	**109.7**	**99.8**	**145.2**	**72.7**
	Transition Accounts For:					
	Transit Seizures (Pure MT)	19.7	31.6	25.8	40.4	21.2
7 to 8	**STAGE 7: Transshipment Areas (Pure MT)**	**389.4**	**344.4**	**345.0**	**343.7**	**327.0**
	MX/CENTAM	162.4	136.5	155.7	157.2	156.0
	Caribbean	149.0	157.8	143.4	136.8	112.9
	Direct to U.S.	77.9	50.1	46.0	49.7	58.2
	STAGE 8: Entering U.S.(Pure MT)	**338.7**	**295.0**	**305.2**	**290.5**	**279.4**
	Transition Accounts For:					
	Border Seizures (Pure MT)	50.7	49.4	39.9	53.2	47.7
8 to 9	**STAGE 8: Entering U.S.(Pure MT)**	**338.7**	**295.0**	**305.2**	**290.5**	**279.4**
	Florida	171.7	134.5	150.8	147.3	125.2
	GulfofMexico	4.1	2.0	3.6	3.8	3.9
	NorthEast	9.2	6.0	6.4	7.3	6.0
	Other U.S.	3.0	3.8	4.0	4.7	5.1
	Puerto Rico/Virgin Islands	3.3	27.3	2.4	1.6	1.9
	Southwest Border	147.4	121.4	137.9	125.8	137.1
	STAGE 9: Retail U.S. (Pure MT)	**300.9**	**275.0**	**267.0**	**271.0**	**259.0**
	Transition Accounts For:					0.0
	Domestic Seizures (Pure MT)	37.8	20.0	38.1	19.5	20.4
	Import Purity	86.0%	86.0%	86.0%	84.2%	81.7%
	Retail Purity	69.5%	66.5%	68.3%	62.8%	57.5%

Consumption-Based Availability Estimates

This approach incorporates historical consumption estimates (Stage 9) as the starting point and works *backward* to an estimated amount of cocaine that departs South America. Cocaine availability estimates for stages 6-9 will be based on the U.S. consumption figures America (Appendix C presents step by step details of the calculations). The model estimates transit zone country consumption at three-percent of the flow through the region.

In the STAR model, cocaine availability from the transshipment area (Stage 7B) can be estimated by adding the domestic and border seizures to the domestic consumption. Combining the domestic consumption estimates with the domestic and border seizures results in estimates of cocaine available in the transshipment areas.

Cocaine Departing South America

To estimate cocaine availability at South American departure areas (Stage 6), the STAR model assumes that all of the cocaine entering the Southwest Border originates in the Mexico/Central America corridor, and that cocaine entering other border areas is divided between the Caribbean corridor and the Direct-to-U.S. corridor proportional to the event-based estimate of cocaine departing South America. It is assumed that 3% of the cocaine in the transshipment area is consumed locally. Adding the consumption losses and the seizure losses to the Stage 7B estimate results in the estimate for the component of Stage 6 (bound for the U.S.).

Cocaine departing South America (Stage 6) splits between amounts headed towards non-U.S./LTAM markets (Stage 7A) and towards the U.S.(Stage 7B) market. There are no historical estimates of non-U.S./LTAM consumption. The STAR Model develops its own historical estimates, based on calculating the *equivalent loss-rate*. This 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./LTAM-bound arrival and transit zone seizures to non-U.S./LTAM U.S.-bound flow. Figure 5 details the approach and Table 3 presents the results. A two-year moving average was used to smooth non-U.S./ LTAM seizures, which are highly variable from year to year.

Assumption of an equivalent loss-rate is a simplistic approach. Additional data is needed to further refine the annual magnitude of cocaine smuggled to foreign markets. Event-based estimates also provide under-estimation.

Figure 5 - Equivalent Market Loss Rate

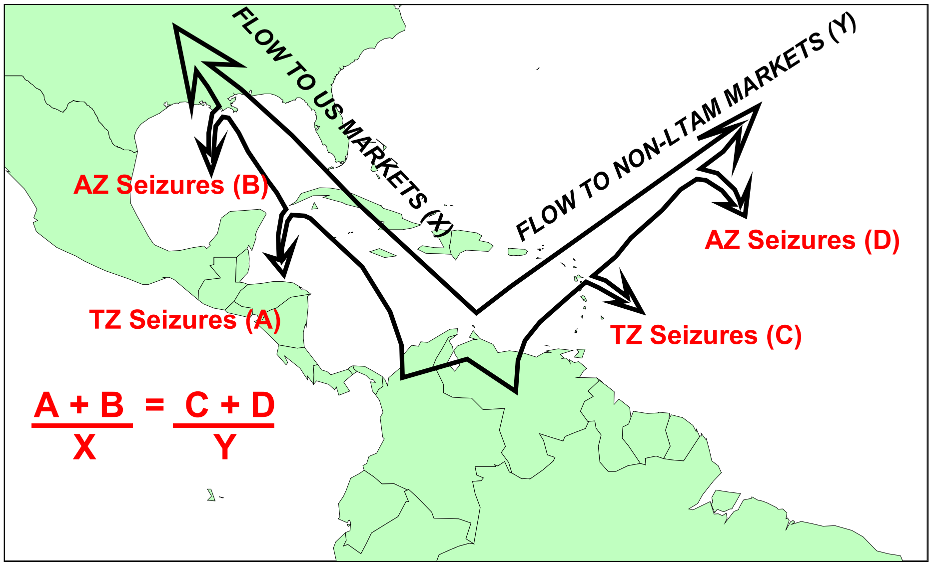


Table 3 - Seizure Rate for Cocaine Bound to U.S., 1996-2000

Variable	Description	1996	1997	1998	1999	2000
A	TZ Seizures	45.6	74.0	69.7	62.3	71.1
B	U.S. Border Seizures	50.7	49.4	39.9	53.2	47.7
X	Flow Toward U.S.	389.4	344.4	345.0	343.7	327.0
(A+B)/X	TZ & AZ Seizure Rate	25%	36%	32%	34%	36%

Using the Equivalent Loss Rate and data shown in Table 3, non-U.S./LTAM consumption is calculated and results shown in Table 4. The trend in equivalent market loss estimates appear reasonable and have been increasing, which agrees with increased South American consumption and constant U.S. demand. This is a preliminary measure and will require further research.

Table 4 – Cocaine for Non-U.S./LTAM Consumption (pure metric tons)

Description	1996	1997	1998	1999	2000
Non-U.S. seizures (2-year average)	19.7	31.6	25.8	40.4	21.2
Flow to non-U.S.	110.6	141.3	125.6	185.7	93.9
Net non-U.S./LTAM consumption	90.9	109.7	99.8	145.2	72.7

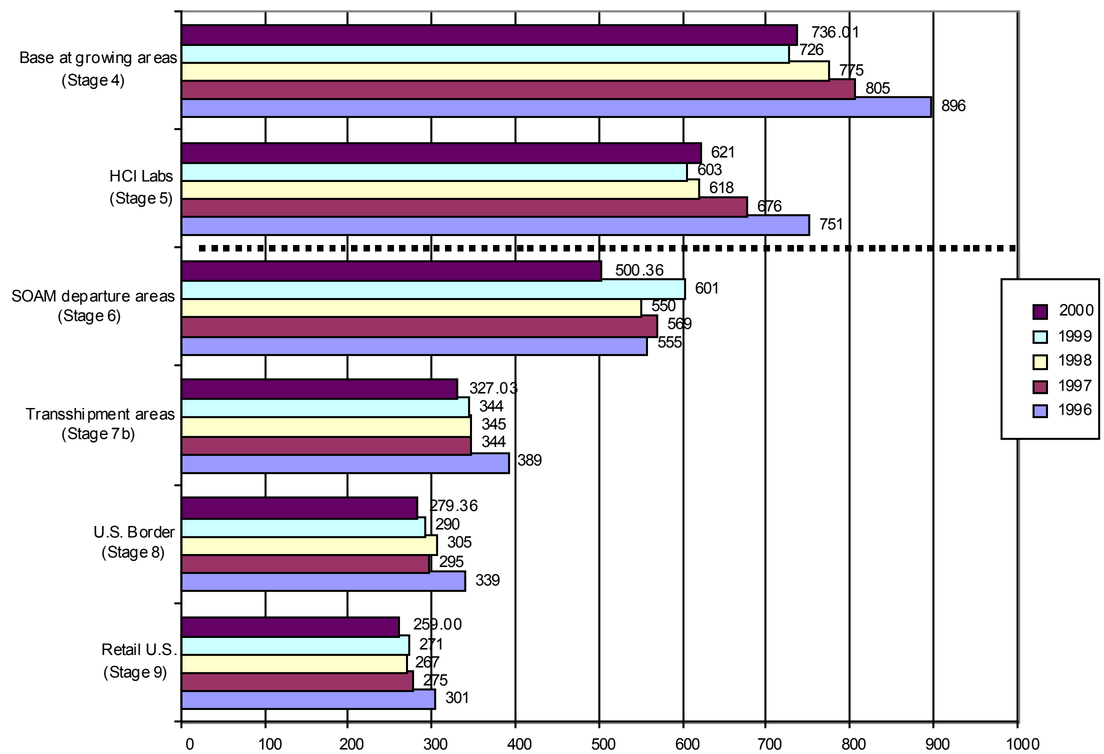
The STAR model develops two estimates of cocaine departing South America; actual production based on cultivation estimates and U.S. consumption based. Figure 8 presents estimates of the two. The consumption-based estimates can only be carried back to Stage 6 because of the lack of historical estimates of South American consumption estimates, although we used recently developed estimates by CNC. Thus there is a disconnect between the actual production estimates and the consumption-based estimates of cocaine departing South America, represented by the dashed line between stages 5 and 6.

Conclusion

The information presented in this paper will be useful to decision-makers interested in the magnitude of cocaine at various locations of its flow from source to street. Other analysts will also benefit from this research because it provides them with a connected and coherent set of availability estimates to frame more detailed assessments of movement between stages[4]. The reader should be aware that various levels of uncertainty are present in each of the component estimates integrated by the STAR Model; thus there is a level of uncertainty within the STAR Model results. But this is to be expected. Drug smuggling is an illegal and covert activity, and therefore not easily subject to controlled research conditions. Improvements in estimates will only come through integration of multiple data sets, such as the STAR Model. Future efforts will focus on this aspect of improving the model through integration of additional data sets.

[4] In addition to the STAR Model, this document also updates the Border Allocation Model and the Domestic Allocation Model. Development of the Border Allocation Model and the Domestic Allocation Model are independent of the STAR Model and describe the distribution of cocaine flow arriving at the U.S border by conveyance and mode, followed by distribution within the U.S.

Figure 6 - Actual Production and Consumption-Bases Estimates (pure metric tons)



Data Used in the STAR Model

Potential Production and Actual Production

This paper makes a distinction between *potential* and *actual* production. Potential cocaine production is calculated, by year, beginning with hectares under coca cultivation and then multiplying by the leaf yield, alkaloid content, and base processing efficiency figures. These figures measure availability for world consumption, assuming all coca hectares are converted to cocaine product. Actual cocaine production is calculated by using the same conversion rates, but subtracts losses that occur during the process, such as leaf spoilage, licit consumption, and base and HCl seizures. Actual production is used in the STAR model.

Table 5 summarizes the stage-by-stage summary of potential production estimates for each year (see Appendix A for details). Over the period 1996-2000, potential production has decreased 50-75 metric tons per year. These figures are worst-case estimates of cocaine availability in the Andean countries because they do not account for known losses such as consumption, or leaf, base, and HCl seizures. The STAR model expands on these estimates in order to calculate the actual availability of cocaine for export from South America.

Table 5 - Cultivation and Potential Production Estimates, 1996-2000

Stage	Description	1996	1997	1998	1999	2000
1	Previous Net Cultivation (ha)	214,800	209,700	194,100	190,800	183,000
2	Net Cultivation (ha)	209,700	194,100	190,800	183,000	231,900
3	Dry Coca Leaf Yield (mt)	333,603	294,242	265,498	230,383	328,325
4	Base Production (mt)	950	875	825	760	777
5	HCl Production (mt)	950	875	825	760	777

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 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, region-specific coca crop estimates are developed. Throughout the 1990's, Colombia was assumed to be cultivating the poorer yielding variety of cocaine, *E. coca var ipadu* and was using processing techniques as efficient as Bolivia and Peru. However, the recent Operation Breakthrough results for Colombia make it clear that Colombia is not only a major cocaine producer, but also a leading coca cultivator.

Figure 7 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. Revision of the Colombian conversion figures caused the total potential production figures to increase by nearly 200 metric tons per year, but a downward trend still remains.

These adjustments highlight the difficulty in maintaining consistent trends during periods of dynamic changes, such as the rapid increases in Colombian cultivation. 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, additional uncertainty is introduced by extrapolating the cultivation figures into potential production estimates. Uncertainties include the detection of new growing areas and eradication estimation (maturity of the eradicated crop, strength of the herbicide, and timing of the harvest). The Breakthrough (DEA 1994, DEA 1997, DEA 2001) estimates provide the crop yield data and processing efficiency data to calculate the potential production from the crop cultivation estimates. These Breakthrough estimates are refined, as updated data becomes available. All of these estimates are snapshots in time, and must therefore be periodically updated. One example of a changing trend is that there have been reports that Peru's coca industry may be recovering[5].

Figure 7 also shows that while production in Bolivia and Peru has dropped, Colombian production has soared. Accounting for only 25% of total coca cultivation in 1995, Colombia's contribution grew to 75% by 2000. Applying time-series techniques to the raw data could reduce what appears to be considerable random variation from year to year.

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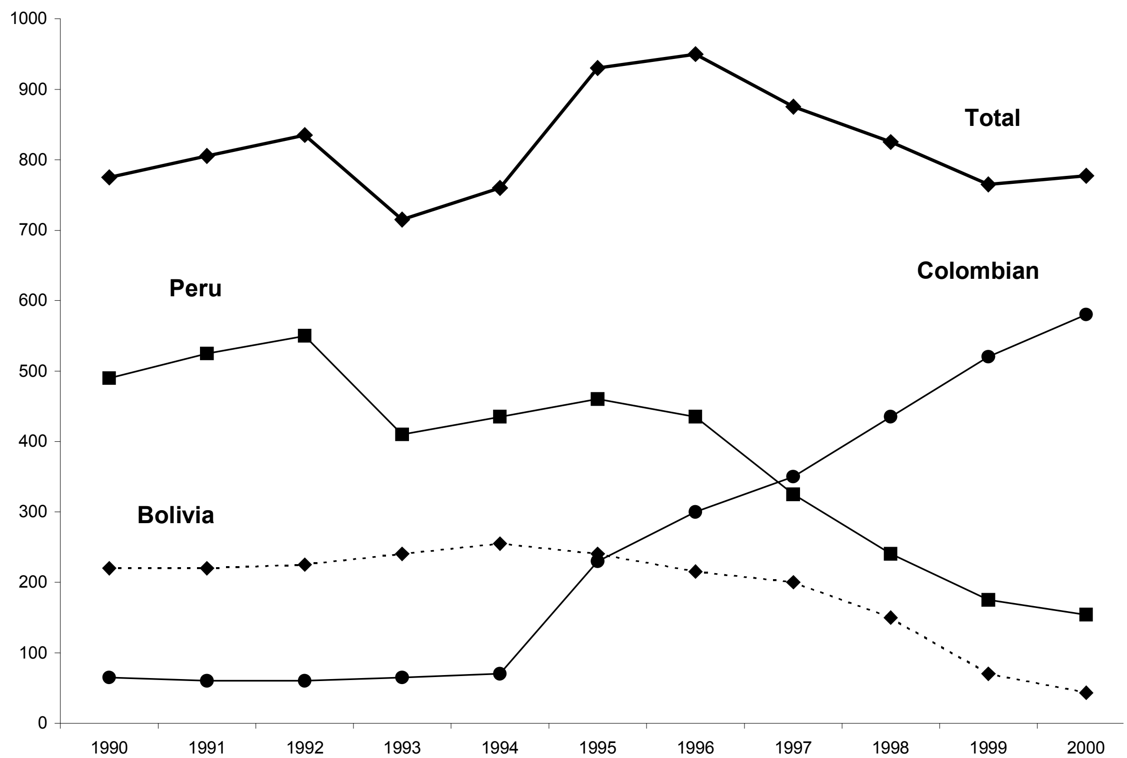
[5] Defense Intelligence Agency, 1999. *Interagency Assessment of Cocaine Movement: August 1999* Eighteenth Edition, Mid-Year Review, p. 2.

Estimates of Cocaine Departing South America Using 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 designated by expert participants of an interagency working group on the basis of the following information: (1) seizure or observation of drugs; (2) observation of activity that could not be reasonably attributed to anything other than drug smuggling; (3) reliable intelligence.

Figure 7 - Potential Cocaine Production, 1990-2000 (mt)



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[6]. 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 to Florida come exclusively from seizures, then one 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 is underestimated.

Table 6 includes event-based estimates of cocaine departing South America for 1996 through 2000[7]. Part of the variability from year to year in these numbers is attributable to evolving methodology. There is considerable uncertainty in the magnitude of the IACM estimates, but the stable trend in the estimate of cocaine departing South America correlates well with other supply indicators.

Table 6 - Event-Based Cocaine Amounts Departing South America By Transit Corridor, 1996-2000 (bulk metric tons)

	1996	1997	1998	1999	2000
Caribbean	174.5	138.4	160.3	220	200
Mexico/Central America	341.7	250.7	318.6	277	424
Direct to U.S.	91.2	43.9	51.4	15	19
Non-U.S. Destinations	42.8	62.6	64.5	75	104
Unknown	2.5	-	1.0	-	-
Total	652.7	495.6	595.8	587.0	747.6

[6] The results are included in the transit zone section of the IACM publications.

[7] Movement events from the CCDB were used for the calculations, and they differ slightly from figures published in the IACM. See Cala, 1999.

Enhanced Seizure Database

To determine reproducible domestic and border seizure amounts, an Enhanced Seizure Database was created, based on a variety of seizure databases. DEA's Federal Drug Seizure System (FDSS) for calendar years 1991-2000 provided the bulk of the data for this effort. 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 and federally-supported cocaine seizures of 500 grams or more. The Enhanced Seizure database only includes those FDSS seizures that were above the threshold set by the FDSS system.
FDSS contains limited details about each seizure, so the FDSS data was augmented with agency-specific seizure data. 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)[8], 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 D details specific variables from each of these data sources. The FDSS data was used as the "master" when conflicting data appeared cross databases. The exception to this is that EPIC data are employed for southwest border seizures. Appendix D details the method used to create the enhanced seizure data.
Figure 8 presents a plot of total border seizures for the years 1991-2000. The figure shows that while there are fluctuations from year to year, they have remained fairly level. The chart also includes a two-year moving average line, to smooth year-to-year variations. Table 8 details border seizures by conveyance types.

In Figure 9, 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 2000. Seizures on the southwest border (the solid line at the top of the figure) remained relatively constant until 1999, when there was an increase. Seizures in Florida (the dotted line at the top of the chart) have declined over most of the period, with an increase in 2000. Seizures in Puerto Rico/Virgin Islands have steadily increased.

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[8] BLISS data were unavailable for 1999 and 2000, instead the southwest border seizure figures from IACM publications (DIA 2000, DIA 2001) were used.

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

Figure 8 - Seizures at the U.S. Border, 1991-2000 (bulk metric tons)

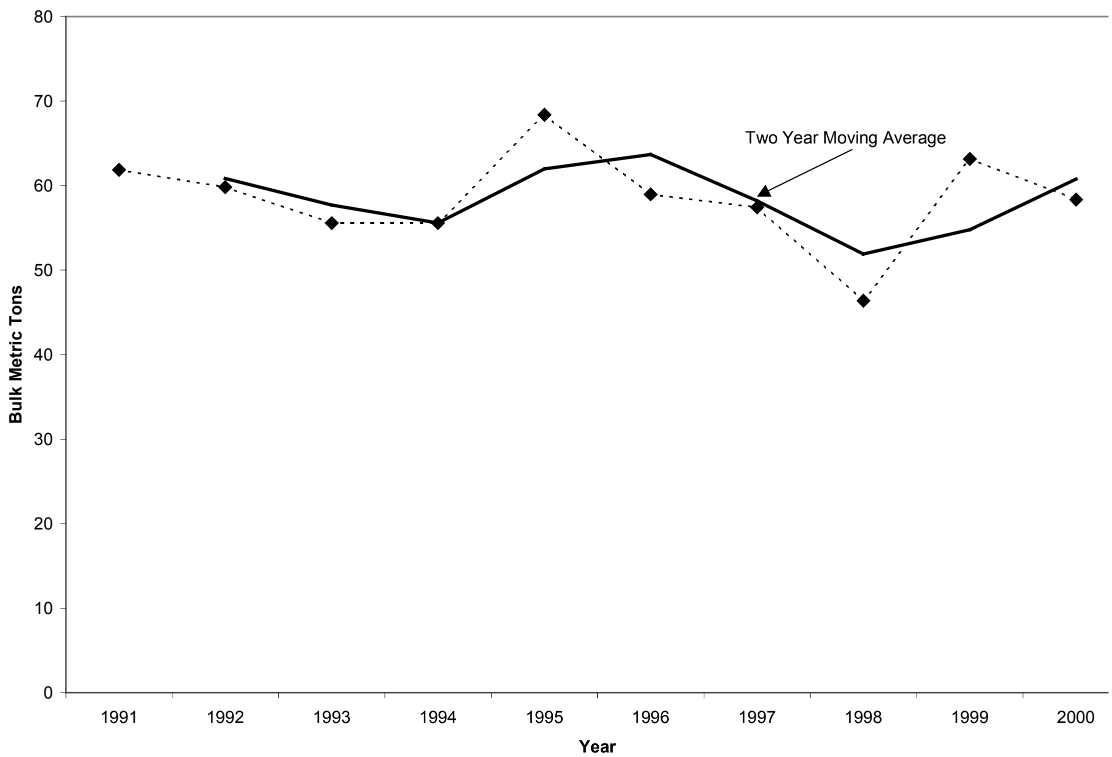


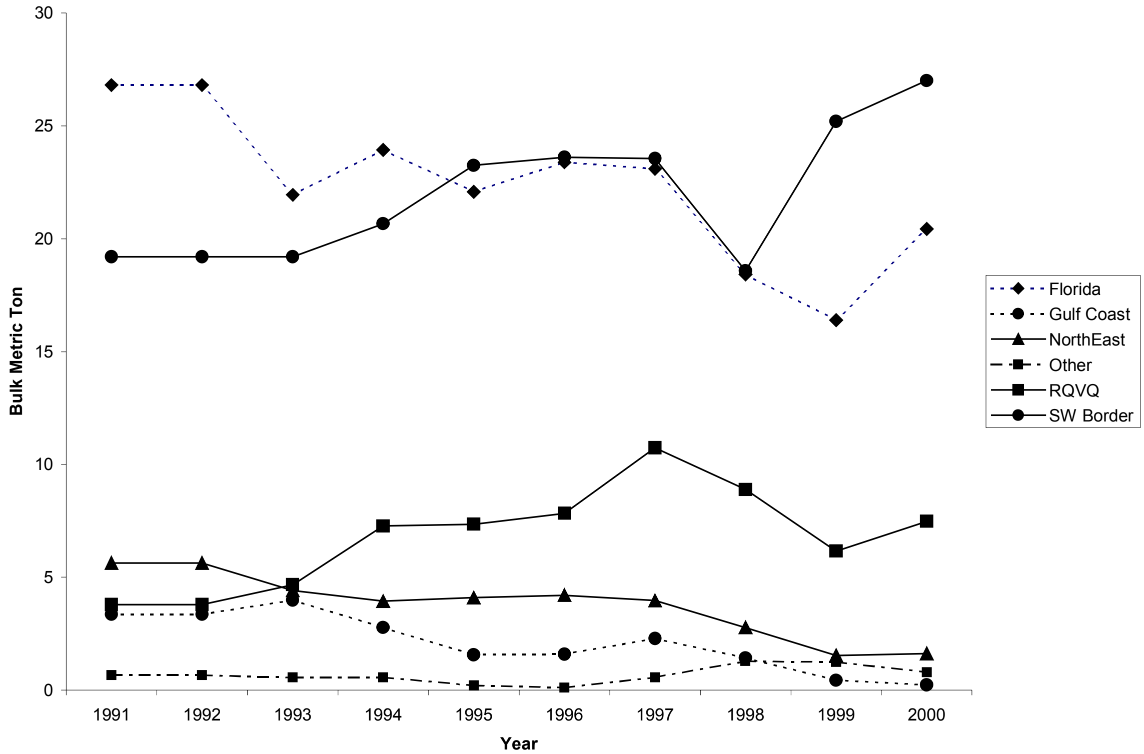
Table 7 - Border Seizures, 1991-2000 (bulk metric tons)

	1991	1992	1993	1994	1995	1996	1997	1998	1999[a]	2000[a]
Commercial Air	5.5	6.2	7.7	7.4	9.6	6.1	6.3	3.0	6.6	4.3
Commercial Maritime	28.5	23.4	21.5	21.5	10.5	22.2	25.0	14.4	13.1	12.0
Commercial Vehicle	3.4	7.3	5.4	2.9	8.1	7.7	5.6	7.4	-	-
Noncommercial Air	6.9	4.1	5.1	2.6	0.6	0.9	0.5	0.0	0.0	0.1
Noncommercial Maritime	9.3	4.2	7.2	10.4	24.4	12.3	11.8	8.7	6.2	19.2
Noncommercial Vehicle	7.0	11.5	8.6	9.5	11.5	8.8	7.3	11.2	-	-
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	-	-
Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	37.3	22.7
Total (export quality mt)	**61.9**	**59.8**	**55.8**	**55.6**	**68.4**	**59.0**	**57.4**	**46.4**	**63.2**	**58.3**

[a] Southwest border figures for 1999 and 2000 were obtained from IACM publications (DIA 2000, DIA 2001) and *land* incorporates commercial vehicle, noncommercial vehicle, pedestrian, and rail.

\- indicates no data available.

Figure 9 - Smoothed Seizures in Border Entry Regions, 1991-1999 (bulk metric tons)



Note: RQ/VQ designates Puerto Rico and U.S. Virgin Islands

Note: RQVQ designate the area of Puerto Rico and U.S. Virgin Islands.

Border Allocation Model

The Border Allocation Model was developed to allocate the cocaine entering the U.S. (Stage 8) among the border entry regions. In particular, the model predicts the percentage of cocaine arriving at 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 E provides details about the methodology.

The Border Allocation Model uses data on U.S. border seizures and on the costs 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 were obtained from Customs Reports of Investigation.

Tables 7 and Table 8 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 region-conveyance combination is feasible, but no occurrences were observed.

Averaging over the ten-year period, 39% of total seizures occurred at the southwest border (SWB) and 39% at the Florida border. In terms of conveyances, 34% of the seizures occurred from land-based-conveyances (commercial/noncommercial vehicle, pedestrian, and rail), while commercial marine ships, noncommercial marine, commercial air, and noncommercial air accounted for 33%, 19%, 11%, 4%, respectively.

Table 9 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 1991-2000 – 48% of cocaine destined for the U.S. arrives at Florida via commercial marine conveyances and 38% arrives at the southwest border via land-based conveyances. Note that the distribution of cocaine amounts (Table 9) differs considerably from the distribution of cocaine seizures (Table 8). 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 22% 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 percentage of the amount shipped to Florida via commercial marine.

Figure 10 plots the amount of cocaine arriving at each border region for the period 1991-2000. The model indicates that most cocaine entering the U.S. does so via Florida and the southwest border. Taking the ten-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 PR/VI, for which the model predicted a jump from 11 metric tons in 1996 to 42 metric tons in 1997.

Table 8 - Border Seizures (bulk metric tons): Average Over Years, 1991-2000

Border Region	Land	Noncom Air	Commercial Air	Noncom Marine	Commercial Marine	**Total**
Florida	-	0.0	4.3	4.4	13.1	**22.6**
Gulf Coast	-	0.0	0.0	0.6	1.3	**1.9**
Northeast	-	0.0	1.2	0.0	2.4	**3.6**
PR/VI	-	0.7	0.3	4.7	1.3	**7.1**
SWB	19.6	0.4	0.2	1.7	0.7	**22.7**
Rest of U.S.	0.0	0.2	0.2	0.0	0.3	**0.7**
Total	**19.6**	**2.1**	**6.3**	**11.4**	**19.2**	**58.5**

- indicates not applicable

Table 9 - Border Seizures (percent): Average Over Years, 1991-2000

Border Region	Land	Noncom Air	Commercial Air	Noncom Marine	Commercial Marine	**Total**
Florida	-	1.4	7.4	7.4	22.4	**38.6**
Gulf Coast	-	0.0	0.0	1.0	2.2	**3.2**
Northeast	-	0.0	2.1	0.0	4.1	**6.2**
PR/VI	-	1.2	0.6	7.9	2.3	**12.0**
SWB	33.5	0.7	0.4	3.0	1.2	**38.8**
Rest of U.S.	0.0	0.3	0.3	0.0	0.6	**1.2**
Total	**33.5**	**3.6**	**10.7**	**19.4**	**32.8**	**100.0**

- indicates not applicable

Table 10 - Percent Allocation of Cocaine By Border Region and Conveyance: Average Over Years, 1991-2000

Border Region	Land	Noncom Air	Commercial Air	Noncom Marine	Commercial Marine	**Total**
Florida	-	0.3	2.0	1.4	47.6	**51.3**
Gulf Coast	-	0.0	0.0	0.2	1.6	**1.8**
Northeast	-	0.0	0.5	0.0	3.1	**3.6**
PR/VI	-	0.2	0.1	1.5	1.0	**2.8**
SWB	38.3	0.1	0.1	0.5	0.7	**39.7**
Rest of U.S.	0.0	0.0	0.0	0.0	0.7	**0.8**
Total	**2.7**	**54.7**	**38.2**	**0.6**	**3.6**	**100.0**

- indicates not applicable

Figure 10 - Border Allocation Model Amounts by Region (pure metric tons), 1991-2000

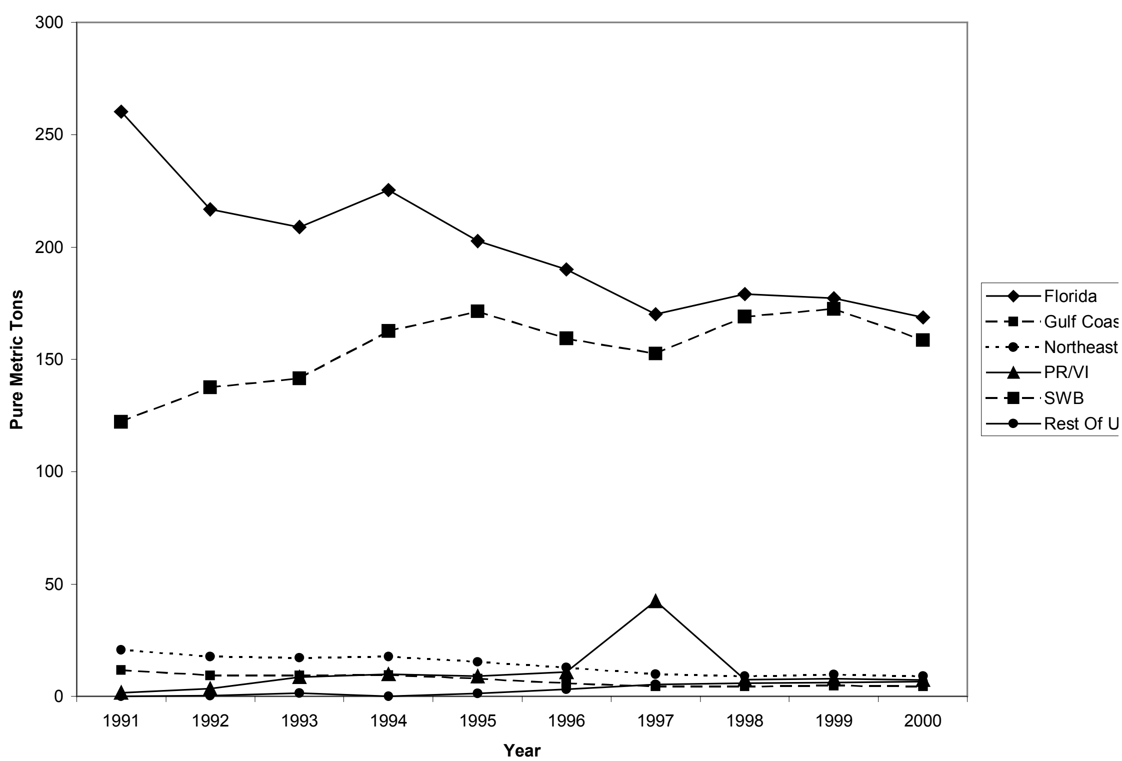
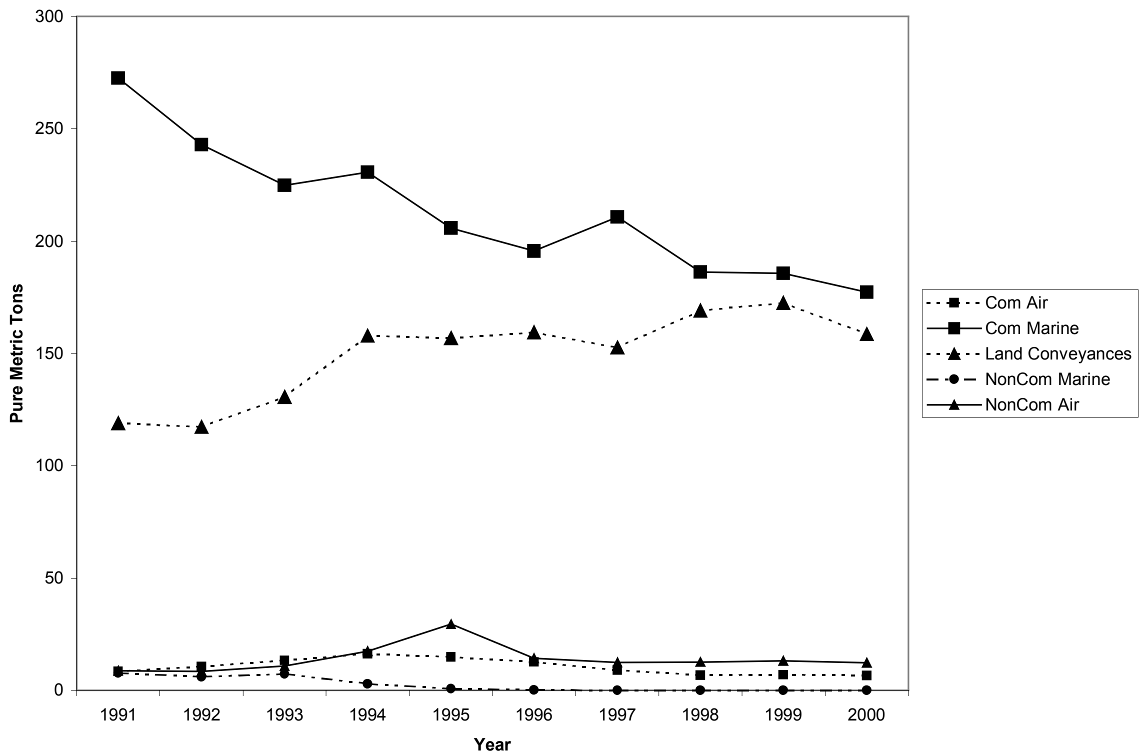


Figure 11 plots model estimates by conveyance type. Conveyance types of choice appear to be land-based conveyances and commercial marine. Although it is likely that noncommercial air actually plays a large role in transporting cocaine, the model does not capture this because the typical flight stops just short of the U.S.- Mexican border. Figure 11 shows that, over the ten year period, conveyance by land has increased at the expense of conveyance by commercial marine: land-based conveyances increased by 25% (from 118 to 158 metric tons) and commercial marine decreased by 53% (from 272 to 177 metric tons). 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 10 and 11 together, it would appear that there has been a shift in smuggling from Florida via commercial marine to the southwest border, via commercial vehicle. Appendix C (Table C6) presents detailed estimates for each year.

Results of the Border Allocation Model indicate a higher proportion of cocaine flow to the Florida destination than current intelligence assessments. The results of the Border Allocation Model should be seen as developmental and not a conclusive result. But the model does provide an interesting perspective. The current intelligence assessment consistently underestimates smuggling via commercial conveyances, which would probably be the primary means of smuggling into the Florida corridor. Further research is needed in the critical border region to determine the more correct estimate.

Figure 11 - Border Allocation Model: Amounts by Conveyance (pure metric tons), 1991-2000



Domestic Seizures

The Enhanced Seizure Database was also used to quantify domestic seizures within the United States. Table 10 shows the annual domestic seizures allocated by census regions.

Domestic Allocation Model

To allocate cocaine entering the U.S. to consumption regions, the Domestic Allocation Model was created. The premise of the model is consistent with the classic operations research transportation problem: given the quantities of cocaine entering the domestic market at the six border regions, and given the quantities demanded in each of the ten U.S. census divisions, 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 E provides details of the model.

Table 11 shows, for each border entry region, the percentage of cocaine moved to each consumption region in 200 (values for other years are shown in Appendix C, Table C6). Taking these estimates at face value, one could 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 areas beyond the southwest border, reflecting the increased role of Mexico-based traffickers[10].

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

Table 10 - Non-Border, Domestic Seizures, By Census Division, 1991-2000 (bulk metric tons)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
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%)	0.2 (1%)	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%)	6.8 (22%)	4.1 (12%)
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%)	4.8 (15%)	1.3 (4%)
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%)	0.5 (2%)	1.2 (3%)
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%)	6.4 (21%)	11.9 (34%)
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%)	1.1 (4%)	0.7 (2%)
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%)	3.4 (11%)	4.2 (12%)
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%)	0.5 (2%)	0.4 (1%)
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%)	1.5 (5%)	7.5 (21%)
PR/VI	3.5 (5%)	2.7 (4%)	4.3 (10%)	3.1 (5%)	2.3 (5%)	5.2 (10%)	2.2 (7%)	4.7 (8%)	5.9 (19%)	3.9 (11%)
Total	**64.1**	**61.4**	**44.7**	**61.3**	**46.6**	**54.3**	**30.4**	**55.7**	**31.0**	**35.5**

[a] Census division breakdowns unavailable at this time.

Table 11 - Percent of Cocaine From Border Entry Regions to Census Divisions, 2000

	Florida	Gulf Coast	Northeast	Rest of U.S.	Puerto Rico Virgin Islands	Southwest Border
New England	5%	0	100%	100%	36%	0
Mid Atlantic	43%	0	0	0	0	0
E. North Central	9%	100%	0	0	0	23%
W. North Central	0	0	0	0	0	8%
S. Atlantic	36%	0	0	0	100%	0
E. South Central	7%	0	0	0	0	0
W. South Central	0	0	0	0	0	15%
Mountain	0	0	0	0	0	11%
Pacific	0	0	0	0	0	42%

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.

3. The enhanced seizure data used in the STAR model may differ from existing agency seizure estimates. The primary reason is differences in definitions and access to data. Interagency cooperation is needed to make existing data available and standardize definitions for categorizing seizures.

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Appendix A: Coca Cultivation and Potential Production Data

Table A1

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

	1996	1997	1998	1999	2000
Colombia (wet leaf)					
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 (dry leaf)					
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 (dry leaf)					
Chapare	1.86	1.78	1.64	1.19	
Yungas/ Apolo	.91	.97	.99	.96	
Other	1.00	1.00	1.00	1.00	

Table A2

Leaf To Base Conversion Factors, By Growing Area

(metric tons of leaf per metric tons of cocaine base)

	All Years
Colombia (wet leaf)	
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
Puerto Leg	959:3
Peru (dry leaf)	
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 (dry leaf)	
Chapare	363:1
Yungas/ Apolo	312:1
Other	312:1

Table A3
Bolivia Cultivation and Potential Production Data

Year	Stage		Chapare	Yungas	Other	Sum
1995		net cult (ha)	33,700	14,200	700	48,600
1996		new growth (ha)	6,800	400	0	7,200
		eradication (ha)	(7,500)	(200)	0	(7,700)
		abandonment (ha)	0	0	0	0
		net change (ha)	(700)	200	0	(500)
	2	net cult (ha)	33,000	14,400	700	48,100
	3	MT leaf(dry)	61,300	13,100	700	75,100
	4 & 5	HCl (mt)	169	42	2	213
1997		new growth (ha)	5,570	0	0	5,570
		eradication (ha)	(7,026)	(400)	(400)	(7,826)
		abandonment (ha)	0	0	0	0
		net change (ha)	(1,456)	(400)	(400)	(2,256)
	2	net cult (ha)	31,544	14,000	300	45,844
	3	MT leaf(dry)				0
	4 & 5	HCl (mt)	155	44	1	199
1998		new growth (ha)	3,620	200	0	3,820
		eradication (ha)	(11,621)	0	0	(11,621)
		abandonment (ha)	0	0	0	0
		net change (ha)	(8,001)	200	0	(7,801)
	2	net cult (ha)	23,543	14,200	300	38,043
	3	MT leaf(dry)				0
	4 & 5	HCl (mt)	106	45	1	152
1999		new growth (ha)	500	300	0	800
		eradication (ha)	(15,353)	0	0	(15,353)
		abandonment (ha)	(1,150)	(500)	0	(1,650)
		net change (ha)	(16,003)	(200)	0	(16,203)
	2	net cult (ha)	7,540	14,000	300	21,840
	3	MT leaf(dry)				0
	4 & 5	HCl (mt)	25	43	1	69

Table A4
Colombia Cultivation and Potential Production Data

YEAR	Stage		Guaviare	WCaqueta	ECaqueta	Caqueta	Putumayo	Norte de Santander	San Lucas	Macarena	Arauca	Sum
1995		net cult (ha)	28,700			15,600	6,600					50,900
1996		new growth (ha)	14,972			6,528	400					21,900
		eradication (ha)	(5,072)			(528)	0					(5,600)
		abandonment (ha)	0			0	0					0
		net change (ha)	9,900			6,000	400					16,300
	2	net cult (ha)	38,600	12,233	9,367	21,600	7,000					67,200
	3	MT leaf(dry)	51,886	13,392	11,754	25,146	6,770					83,803
	4 & 5	HCl (mt)	189	52	43	95	26					310
1997		new growth (ha)	7,900			11,700	12,000					31,600
		eradication (ha)	(17,450)			(1,815)	0					(19,265)
		abandonment (ha)	0			0	0					0
		net change (ha)	(9,550)			9,885	12,000					12,335
	2	net cult (ha)	29,050	18,691	12,794	31,485	19,000					79,535
	3	MT leaf(dry)	39,049	20,461	16,055	36,516	18,377					93,942
	4 & 5	HCl (mt)	142	80	59	138	71					351
1998		new growth (ha)	7,450			11,800	11,100	2,800	2,800			35,950
		eradication (ha)	(9,750)			(3,900)	0	0	0			(13,650)
		abandonment (ha)	0			0	0	0	0			0
		net change (ha)	(2,300)			7,900	11,100	2,800	2,800			22,300
	2	net cult (ha)	26,750	21,708	17,678	39,385	30,100	2,800	2,800			101,835
	3	MT leaf(dry)	35,957	23,763	22,183	45,947	29,113	2,916	3,065			116,998
	4 & 5	HCl (mt)	131	93	81	174	112	11	12			440
1999		new growth (ha)	5,900			3,000	15,800	5,200	1,300	1,800	1,100	34,100
		eradication (ha)	(4,600)			(8,800)						(13,400)
		abandonment (ha)	0			0						0
		net change (ha)	1,300			(5,800)	15,800	5,200	1,300	1,800	1,100	20,700
	2	net cult (ha)	28,050	14,600	19,000	33,585	45,900	8,000	4,100	1,800	1,100	122,535
	3	*MT leaf(dry)*	37,705	15,983	23,843	39,826	44,394	8,330	4,488	2,259	1,380	138,383
	4 & 5	*HCl (mt)*	138	62	87	149	170	33	18	9	5	522

Table A5

Peru Cultivation and Potential Production Data

YEAR	Stage		LHV	CHV	LHV/CHV	UHV	Aguaytia	Pachitea	Apurimac	Cusco	Other	Sum
1995		net cult (ha)	6,500	6,500	13,000	33,700	19,600	7,100	21,000	10,000	10,900	115,300
1996		net change (ha)	(1,500)	(1,500)	(3,000)	(4,300)	(4,600)	(900)	(4,200)	(1,000)	(2,900)	(20,900)
	2	net cult (ha)	5,000	5,000	10,000	29,400	15,000	6,200	16,800	9,000	8,000	94,400
	3	MT leaf(dry)	6,500	8,000	14,500	60,300	25,500	13,000	43,700	8,100	9,600	174,700
	4 & 5	HCl (mt)	16	20	36	151	64	33	109	20	24	437
1997		net change (ha)	(2,200)	(2,500)	(4,700)	(4,400)	(6,600)	(4,000)	(4,200)	(700)	(1,000)	(25,600)
	2	net cult (ha)	2,800	2,500	5,300	25,000	8,400	2,200	12,600	8,300	7,000	68,800
	3	MT leaf(dry)	3,600	4,000	7,600	52,500	14,300	4,600	35,300	7,500	8,400	130,200
	4 & 5	HCl (mt)	9	10	19	131	36	12	88	19	21	326
1998		net change (ha)	(1,800)	(1,400)	(3,200)	(4,000)	(3,600)	(900)	(3,600)	(800)	(1,700)	(17,800)
	2	net cult (ha)	1,000	1,100	2,100	21,000	4,800	1,300	9,000	7,500	5,300	51,000
	3	MT leaf(dry)	1,300	1,800	3,100	44,100	8,200	2,700	24,300	6,800	6,400	95,600
	4 & 5	HCl (mt)	3	5	8	110	21	7	61	17	16	239
1999		net change (ha)			(100)	(5,800)	(3,900)	(300)	(900)	0	(1,300)	(12,300)
	2	net cult (ha)			2,000	15,200	900	1,000	8,100	7,500	4,000	38,700
	3	MT leaf(dry)			2,500	31,100	900	2,100	21,100	6,700	4,800	69,200
	4 & 5	HCl (mt)			6	78	2	5	53	17	12	173

Appendix B: STAR Model for Cultivation and Base Production Stages

Table B1: 1996 STAR Model for Production Stages

Growing Area	COUNTRY	STAGE 1 Net Cultivation (ha)	Net Change (ha)	STAGE 2 Net Cultivation (ha)	Leaf Not Harvested (ha.): 1%	Wet leaf water content	Effective Wet Leaf Yield	Effective Dry Leaf Yield	Licit Leaf Consumption (MT)	Leaf Seizures (MT)	STAGE 3 Net Dry Coca Leaf (MT)	Wet Leaf to Cocaine Conversion Rate	Dry Leaf to Cocaine Conversion Rate	STAGE 4 Coca Base (MT)
Guaviare	*CO*	28,700	9,900	38,600	(386)	71.4%	4.7	1.3	0	0	51,367	959.0	274.3	187
W.Caqueta	*CO*	0	12,233	12,233	(122)	73.3%	4.1	1.1	0	0	13,258	959.0	256.1	52
E.Caqueta	*CO*	15,600	(6,233)	9,367	(94)	73.3%	4.7	1.3	0	0	11,637	1,028.0	274.5	42
Norte de Santander	*CO*	0	0	0	0	73.3%	3.9	1.0	0	0	0	959.0	256.1	0
San Lucas	*CO*	0	0	0	0	73.3%	4.1	1.1	0	0	0	959.0	256.1	0
Arauca	*CO*	0	0	0	0	73.3%	4.7	1.3	0	0	0	959.0	256.1	0
Macarena	*CO*					73.3%	4.7	1.3				959.0	256.1	0
Putamayo	*CO*	6,600	400	7,000	(70)	75.2%	3.9	1.0	0	0	6,703	1,050.0	260.4	26
Upper HV	*PE*	33,700	(4,300)	29,400	(294)			2.1	(3,114)	(34)	56,518		400	141
Aguaytia	*PE*	19,600	(4,600)	15,000	(150)			1.7	(1,589)	(14)	23,642		400	59
Pachitea	*PE*	7,100	(900)	6,200	(62)			2.1	(657)	(7)	12,226		400	31
Central HV	*PE*	6,500	(1,500)	5,000	(50)			1.6	(530)	(5)	7,386		400	18
Lower HV	*PE*	6,500	(1,500)	5,000	(50)			1.3	(530)	(4)	5,902		400	15
Apurimac	*PE*	21,000	(4,200)	16,800	(168)			2.6	(1,780)	(25)	41,438		400	104
Cusco	*PE*	10,000	(1,000)	9,000	(90)			0.9	(953)	(4)	7,061		400	18
Other	*PE*	10,900	(2,900)	8,000	(80)			1.2	(847)	(5)	8,651		400	22
Chapare	*BO*	33,700	(700)	33,000	(330)			1.9	(9,125)	(65)	51,577		363	142
Yungas/ Apolo	*BO*	14,900	200	15,100	(151)			0.9	(4,175)	(12)	9,417		312	30
SUM		214,800	(5,100)	209,700	(2,097)				(23,300)	(176)	306,782			887
Country Summaries														
	BO	48,600	(500)	48,100	(481)				(13,300)	(76)	60,993			172
	CO	50,900	16,300	67,200	(672)				0	0	82,965			307
	PE	115,300	(20,900)	94,400	(944)				(10,000)	(99)	162,824			407
Andean Total		214,800	(5,100)	209,700	(2,097)				(23,300)	(176)	306,782			887

Table B2: 1997 STAR Model for Production Stages

Growing Area	COUNTRY	STAGE 1 Net Cultivation (ha)	Net Change (ha)	STAGE 2 Net Cultivation (ha)	Leaf Not Harvested (ha.): 1%	Effective Wet Leaf Yield	Effective Dry Leaf Yield	Licit Leaf Consumption (MT)	Leaf Seizures (MT)	STAGE 3 Net Dry Coca Leaf (MT)	Dry Leaf to Cocaine Conversion Rate	STAGE 4 Coca Base (MT)
Guaviare	*CO*	38,600	(9,550)	29,050	(291)	4.7	1.3	0	0	38,659	274	141
W.Caqueta	*CO*	12,233	6,458	18,691	(187)	4.1	1.1	0	0	20,256	256	79
E.Caqueta	*CO*	9,367	3,427	12,794	(128)	4.7	1.3	0	0	15,895	274	58
Norte de Santander	*CO*	0	0	0	0	3.9	1.0	0	0	0	256	0
San Lucas	*CO*	0	0	0	0	4.1	1.1	0	0	0	256	0
Arauca	*CO*	0	0	0	0	4.7	1.3	0	0	0	256	0
Macarena	*CO*						0.0				256	0
Putamayo	*CO*	7,000	12,000	19,000	(190)	3.9	1.0	0	0	18,193	260	70
Upper HV	*PE*	29,400	(4,400)	25,000	(250)		2.1	(3,634)	(60)	48,282	400	121
Aguaytia	*PE*	15,000	(6,600)	8,400	(84)		1.7	(1,221)	(16)	12,900	400	32
Pachitea	*PE*	6,200	(4,000)	2,200	(22)		2.09	(320)	(5)	4,227	400	11
Central HV	*PE*	5,000	(2,500)	2,500	(25)		1.6	(363)	(4)	3,592	400	9
Lower HV	*PE*	5,000	(2,200)	2,800	(28)		1.29	(407)	(4)	3,165	400	8
Apurimac	*PE*	16,800	(4,200)	12,600	(126)		2.8	(1,831)	(41)	33,055	400	83
Cusco	*PE*	9,000	(700)	8,300	(83)		0.9	(1,206)	(8)	6,181	400	15
Other	*PE*	8,000	(1,000)	7,000	(70)		1.2	(1,017)	(9)	7,290	400	18
Chapare	*BO*	33,000	(1,456)	31,544	(315)		1.78	(9,151)	(42)	46,394	363	128
Yungas/ Apolo	*BO*	15,100	(800)	14,300	(143)		0.97	(4,149)	(9)	9,575	312	31
SUM		209,700	(15,521)	194,179	(1,942)					267,663		803
Country Summaries												
	BO	48,100	(2,256)	45,844	(458)			(13,300)	(51)	55,969		158
	CO	67,200	12,335	79,535	(795)			0	0	93,003		348
	PE	94,400	(25,600)	68,800	(688)			(10,000)	(147)	118,692		297
Andean Total		209,700	(15,521)	194,179	(1,942)			(23,300)	(197)	267,663		803

Table B3: 1998 STAR Model for Production Stages

		STAGE 1		STAGE 2						STAGE 3		STAGE 4
Growing Area	COUNTRY	Net Cultivation (ha)	Net Change (ha)	Net Cultivation (ha)	Leaf Not Harvested (ha.): 1%	Effective Wet Leaf Yield	Effective Dry Leaf Yield	Licit Leaf Consumption (MT)	Leaf Seizures (MT)	Net Dry Coca Leaf (MT)	Dry Leaf to Cocaine Conversion Rate	Coca Base (MT)
Guaviare	CO	29,050	(2,300)	26,750	(268)	4.7	1.3	0	0	35,598	274	130
W.Caqueta	CO	18,691	3,017	21,708	(217)	4.1	1.1	0	0	23,526	256	92
E.Caqueta	CO	12,794	4,884	17,678	(177)	4.7	1.3	0	0	21,962	274	80
Norte de Santander	CO	0	2,800	2,800	(28)	3.9	1.0	0	0	2,886	256	11
San Lucas	CO	0	2,800	2,800	(28)	4.1	1.1	0	0	3,035	256	12
Arauca	CO	0	0	0	0	4.7	1.3	0	0	0	256	0
Macarena	CO						0.0				256	0
Putamayo	CO	19,000	11,100	30,100	(301)	3.9	1.0	0	0	28,822	260	111
Upper HV	PE	25,000	(4,000)	21,000	(210)		2.1	(4118)	(62)	39,479	400	99
Aguaytia	PE	8,400	(3,600)	4,800	(48)		1.71	(941)	(11)	7,173	400	18
Pachitea	PE	2,200	(900)	1,300	(13)		2.08	(255)	(4)	2,418	400	6
Central HV	PE	2,500	(1,400)	1,100	(11)		1.64	(216)	(2)	1,568	400	4
Lower HV	PE	2,800	(1,800)	1,000	(10)		1.3	(196)	(2)	1,089	400	3
Apurimac	PE	12,600	(3,600)	9,000	(90)		2.7	(1765)	(35)	22,257	400	56
Cusco	PE	8,300	(800)	7,500	(75)		0.91	(1471)	(8)	5,278	400	13
Other	PE	7,000	(1,700)	5,300	(53)		1.21	(1039)	(8)	5,301	400	13
Chapare	BO	31,544	(8,001)	23,543	(235)		1.64	(8231)	(72)	29,922	363	82
Yungas/ Apolo	BO	14,300	200	14,500	(145)		0.99	(5069)	(22)	9,120	312	29
SUM		194,179	(3,300)	190,879	(1,909)			(23,300)	(227)	239,435		759
Country Summaries												
	BO	45,844	(7,801)	38,043	(380)			(13,300)	(94)	39,042		112
	CO	79,535	22,301	101,836	(1,018)			0	0	115,829		435
	PE	68,800	(17,800)	51,000	(510)			(10,000)	(133)	84,565		211
Andean Total		194,179	(3,300)	190,879	(1,909)			(23,300)	(227)	239,435		759

Table B4: 1999 STAR Model for Production Stages

		STAGE 1		STAGE 2						STAGE 3		STAGE 4
Growing Area	COUNTRY	Net Cultivation (ha)	Net Change (ha)	Net Cultivation (ha)	Leaf Not Harvested (ha.): 1%	Effective Wet Leaf Yield	Effective Dry Leaf Yield	Licit Leaf Consumption (MT)	Leaf Seizures (MT)	Net Dry Coca Leaf (MT)	Dry Leaf to Cocaine Conversion Rate	Coca Base (MT)
Guaviare	CO	26,750	1,250	28,000	(280)	4.7	1.3	0	0	37,261	274	136
W.Caqueta	CO	21,708	(7,108)	14,601	(146)	4.1	1.1	0	0	15,823	256	62
E.Caqueta	CO	17,678	1,323	19,001	(190)	4.7	1.3	0	0	23,605	274	86
Norte de Santander	CO	2,800	5,200	8,000	(80)	3.9	1.0	0	0	8,247	256	32
San Lucas	CO	2,800	1,300	4,100	(41)	4.1	1.1	0	0	4,443	256	17
Arauca	CO	0	1,100	1,100	(11)	4.7	1.3	0	0	1,367	256	5
Macarena	CO	0	1,800	1,800	(18)	4.7	1.3			2,236	256	9
Putamayo	CO	30,100	15,800	45,900	(459)	3.9	1.0	0	0	43,951	260	169
Upper HV	PE	21,000	(5,065)	15,935	(159)		2.0	(4,794)	(79)	27,406	400	69
Aguaytia	PE	4,800	(1,158)	3,642	(36)		1.0	(536)	(9)	3,062	400	8
Pachitea	PE	1,300	(314)	986	(10)		2.1	(305)	(5)	1,741	400	4
Central HV	PE	1,100	(265)	835	(8)		1.3	(153)	(3)	877	400	2
Lower HV	PE	1,000	(241)	759	(8)		1.3	(139)	(2)	797	400	2
Apurimac	PE	9,000	(2,171)	6,829	(68)		2.6	(2,616)	(43)	14,954	400	37
Cusco	PE	7,500	(1,809)	5,691	(57)		0.9	(748)	(12)	4,273	400	11
Other	PE	5,300	(1,278)	4,022	(40)		1.2	(710)	(12)	4,057	400	10
Chapare	BO	23,543	(16,003)	7,540	(75)		1.2	(5252)	(22)	3,635	363	10
Yungas/ Apolo	BO	14,500	(200)	14,300	(143)		1.0	(8048)	(34)	5,570	312	18
SUM		190,879	(7,838)	183,041	(1,830)			(23,300)	(220)	203,305		687
Country Summaries												
	BO	38,043	(16,203)	21,840	(218)			(13,300)	(56)	9,205		28
	CO	101,836	20,665	122,501	(1,225)			0	0	136,934		516
	PE	51,000	(12,300)	38,700	(387)			(10,000)	(164)	57,166		143
Andean Total		190,879	(7,838)	183,041	(1,830)			(23,300)	(220)	203,305		687

Appendix C: Application of the Border and Domestic Allocation Models, 1996-2000.

1. Calculate domestic and border seizures from the Enhanced Seizure Database:

Table C1
Border Seizures (pure metric tons)

Region	1996	1997	1998	1999	2000
Florida	(21.2)	(17.1)	(13.3)	(13.5)	(19.9)
Gulf of Mexico	(1.9)	(1.9)	(0.5)	(.3)	(0.1)
North East	(3.8)	(2.8)	(1.8)	(0.8)	(1.9)
Puerto Rico/ Virgin Islands	(7.4)	(0.8)	(1.3)	(5.8)	(6.4)
Rest of U.S.	(0.1)	(10.4)	(4.3)	(.8)	(.5)
Southwest Border	(14.5)	(14.6)	(16.9)	(30.1)	(18.8)
Sum	(48.9)	(47.7)	(38.0)	(51.7)	(47.8)

Table C2
Domestic Seizures (pure metric tons)

Year	New England	Mid Atlantic	E. North Central	W. North Central	S. Atlantic	E. South Central	W. South Central	Mountain	Pacific	Sum
1996	(1.3)	(1.2)	(4.6)	(6.9)	(10.1)	(8.4)	(4.3)	(8.2)	(0.2)	(45.1)
1997	(2.4)	(0.3)	(4.4)	(0.5)	(8.0)	(3.3)	(1.8)	(4.1)	(0.3)	(25.0)
1998	(3.7)	(0.4)	(8.5)	(3.9)	(12.8)	(5.4)	(3.9)	(6.6)	(0.7)	(45.8)
1999	(3.9)	(0.9)	(5.5)	(.5)	(2.9)	(1.3)	(4.8)	(5.2)	(0.4))	(25.4)
2000	(1.1)	(0.6)	(3.4)	(0.3)	(3.5)	(6.2)	(3.2)	(9.8)	(1.0)	(29.0)

2. Calculate the macro availability estimates for Stages 7B-9

Table C3 - Calculation of Cocaine Availability at Transshipment Areas, 1996-2000, (pure metric tons)

Stage or Transition	Description	1996	1997	1998	1999	2000
Stage 9	Retail U.S.	288.0	312.0	291.0	301	278
Transition 8/9	domestic seizures	(45.1)	(25.0)	(45.8)	(25.4)	(29.0)
Stage 8	Entering U.S.	333.1	337.0	336.8	326.4	307
Transition 7/8	Border seizures	(48.9)	(47.7)	(38.0)	(51.7)	(47.8)
Stage 7B	Transshipment areas	382.0	384.8	374.8	378.2	354.8

3. Run the Border Allocation Model for each year and determine the distribution of cocaine arriving from Stage 7B.

Table C4 - Border Allocation Distributions

Year	Region	NCVEH	COMVEH	LAND	NCAIR	COMAIR	NCMAR	COMMAR	Sum
1996	Florida				0.00%	2.50%	1.18%	46.06%	49.75%
	GOMX				0.03%	0.04%	0.13%	1.35%	1.55%
	NorthEast				0.03%	0.52%	0.03%	2.79%	3.37%
	PR/VI				0.00%	0.05%	2.34%	0.43%	2.82%
	Rest of US	0.05%	0.00%		0.00%	0.14%	0.03%	0.57%	0.80%
	SWB	7.89%	33.77%		0.00%	0.03%	0.03%	0.00%	41.71%
1997	Florida				0.00%	1.70%	1.26%	41.25%	44.20%
	GOMX				0.00%	0.00%	0.02%	1.14%	1.16%
	NorthEast				0.00%	0.47%	0.00%	2.11%	2.59%
	PR/VI				0.00%	0.04%	1.95%	9.05%	11.05%
	Rest of US	0.00%	0.00%		0.00%	0.12%	0.00%	1.24%	1.37%
	SWB	6.27%	33.37%		0.00%	0.00%	0.00%	0.00%	39.64%
1998	Florida				0.00%	1.21%	1.73%	44.83%	47.76%
	GOMX				0.00%	0.00%	0.00%	1.18%	1.18%
	NorthEast				0.00%	0.51%	0.00%	1.88%	2.39%
	PR/VI				0.00%	0.04%	1.66%	0.29%	1.99%
	Rest of US	0.00%	0.00%		0.00%	0.03%	0.00%	1.53%	1.56%
	SWB	5.72%	39.39%		0.00%	0.00%	0.00%	0.00%	45.11%
1999	Florida			0.00%	0.00%	1.20%	1.71%	43.94%	48.86%
	GOMX			0.00%	0.00%	0.00%	0.00%	1.26%	1.26%
	NorthEast			0.00%	0.00%	0.55%	0.00%	2.01%	2.56%
	PR/VI			0.00%	0.00%	0.04%	1.75%	0.31%	2.09%
	Rest of US			0.00%	0.00%	0.03%	0.00%	0.00%	1.62%
	SWB			45.61%	0.00%	0.00%	0.00%	0.00%	45.61%
2000	Florida			0.00%	0.00%	1.22%	1.74%	44.6%	47.56%
	GOMX			0.00%	0.00%	0.00%	0.00%	1.25%	1.25%
	NorthEast			0.00%	0.00%	0.55%	1.73%	1.99%	2.54%
	PR/VI			0.00%	0.00%	0.04%	0.00%	0.30%	2.08%
	Rest of US			0.00%	0.00%	0.04%	0.00%	1.82%	1.86%
	SWB			44.71%	0.00%	0.00%	0.00%	0.00%	44.71%

4. Multiply the Stage 7B estimate, for a given year, by the percentages shown in the step #3 table and subtract the border seizures shown in Step #1; the result is the estimate for Stage 8.

Table C5
Distribution of Cocaine in Stages 7B and 8 (pure metric tons)

	1996			1997			1998		
Region	Stage 7B	Border Seizures	Stage 8	Stage 7B	Border Seizures	Stage 8	Stage 7B	Border Seizures	Stage 8
Florida	190.1	(21.2)	168.8	170.1	(17.1)	153.0	179.0	(13.3)	165.7
GOMX	5.9	(1.9)	4.0	4.5	(1.9)	2.6	4.4	(0.5)	3.9
North East	12.9	(3.8)	9.1	10.0	(2.8)	7.1	9.0	(1.8)	7.2
PR/VI	10.8	(7.4)	3.4	42.5	(0.8)	41.7	7.5	(1.3)	6.2
Rest of US	3.0	(0.1)	2.9	5.3	(10.4)	(5.2)	5.8	(4.3)	1.6
SWB	159.4	(14.5)	144.9	152.5	(14.6)	137.9	169.1	(16.9)	152.2
Sum	**382.0**	**(48.9)**	**333.1**	**384.8**	**(47.7)**	**337.0**	**374.8**	**(38.0)**	**336.8**

Table C5 (Cont'd)
Distribution of Cocaine in Stages 7B and 8 (pure metric tons)

	1999			2000		
Region	Stage 7B	Border Seizures	Stage 8	Stage 7B	Border Seizures	Stage 8
Florida	177.2	(13.6)	163.6	168.6	(19.9)	148.8
GOMX	4.8	(.3)	4.6	4.4	(.1)	4.3
North East	9.7	(0.8)	8.9	9.0	(1.0)	7.1
PR/VI	7.9	(5.8)	2.1	7.4	(6.4)	.9
Rest of US	6.1	(0.8)	5.4	6.6	(0.5)	(6.1)
SWB	172.5	(30.6)	141.9	158.6	(18.9)	139.8
Sum	**378.2**	**(51.7)**	**326.4**	**354.8**	**(47.8)**	**307.0**

5. Run the Domestic Allocation Model for each year and determine the distribution of cocaine arriving from Stage 8.

Table C6
Results of the Domestic Allocation Model

Year	Census region	Florida	Gulf of Mexico	North East	Other U.S.	Puerto Rico Virgin Islands	Southwest Border
1996	New England	6%		100%	100%		
	Mid Atlantic	41%					
	E. North Central	13%	100%				20%
	W. North Central						8%
	S. Atlantic	33%				100%	
	E. South Central	7%					
	W. South Central						15%
	Mountain						12%
	Pacific						44%
1997	New England			100%		49%	
	Mid Atlantic	36%			100%	36%	
	E. North Central	21%	100%				15%
	W. North Central						9%
	S. Atlantic	36%				15%	
	E. South Central	8%					
	W. South Central						16%
	Mountain						13%
	Pacific						47%
1998	New England	7%		100%	100%		
	Mid Atlantic	43%					
	E. North Central	10%	100%				23%
	W. North Central						8%
	S. Atlantic	34%				100%	
	E. South Central	7%					
	W. South Central						15%
	Mountain						12%
	Pacific						43%
1999	New England	5%		100%	100%		
	Mid Atlantic	42%					
	E. North Central	13%	100%				20%
	W. North Central						8%
	S. Atlantic	34%				100%	
	E. South Central	7%					
	W. South Central						15%
	Mountain						12%
	Pacific						44%

Table C6 (Cont'd)

Results of the Domestic Allocation Model

Year	Census region	Florida	Gulf of Mexico	North East	Other U.S.	Puerto Rico Virgin Islands	Southwest Border
2000	New England	5%	0	100%	100%	36%	0
	Mid Atlantic	43%	0	0	0	0	0
	E. North Central	9%	100%	0	0	0	23%
	W. North Central	0	0	0	0	0	8%
	S. Atlantic	36%	0	0	0	100%	0
	E. South Central	7%	0	0	0	0	0
	W. South Central	0	0	0	0	0	15%
	Mountain	0	0	0	0	0	11%
	Pacific	0	0	0	0	0	42%

6. Multiply Stage 8 estimate by table percentages shown in Step #5, and sum by census area.

Table C7
Distribution of Cocaine in Stages 8 and 9 (pure metric tons)

	1996			1997			1998		
Census region	Stage 8	Domestic seizures	Stage 9	Stage 8	Domestic seizures	Stage 9	Stage 8	Domestic seizures	Stage 9
New England	8.0	(3.7)	4.3	4.6	(2.4)	2.2	22.6	(1.3)	21.3
Mid Atlantic	65.9	(0.4)	65.5	94.4	(0.3)	94.1	69.9	(1.2)	68.7
E. North Central	61.6	(8.5)	53.1	55.4	(4.4)	51.1	54.8	(4.6)	50.2
W. North Central	13.5	(3.9)	9.6	12.2	(0.5)	11.7	12.1	(6.9)	5.1
S. Atlantic	59.1	(12.8)	46.4	53.6	(8.0)	45.6	58.4	(10.1)	48.2
E. South Central	12.5	(5.4)	7.1	11.5	(3.3)	8.2	11.4	(8.4)	3.0
W. South Central	25.0	(3.9)	21.1	22.6	(1.8)	20.8	22.3	(4.3)	18.0
Mountain	19.5	(6.6)	12.9	17.6	(4.1)	13.5	17.4	(8.2)	9.2
Pacific	71.8	(0.7)	71.1	65.0	(0.3)	64.7	64.3	(0.2)	64.1

Table C7 (Cont'd)
Distribution of Cocaine in Stages 8 and 9 (pure metric tons)

	1999			2000		
Census region	Stage 8	Domestic seizures	Stage 9	Stage 8	Domestic seizures	Stage 9
New England	22.1	(3.9)	18.2	20.8	(1.1)	19.7
Mid Atlantic	68.5	(0.9)	67.6	64.4	(0.6)	63.8
E. North Central	53.7	(5.5)	48.2	50.5	(3.4)	47.2
W. North Central	11.8	(0.5)	11.4	11.1	(0.3)	10.8
S. Atlantic	57.2	(2.9)	54.2	53.8	(3.5)	50.3
E. South Central	11.2	(1.3)	9.9	10.5	(6.2)	4.3
W. South Central	21.9	(4.8)	17.1	20.6	(3.2)	17.4
Mountain	17.1	(5.2)	11.9	16.1	(9.8)	6.3
Pacific	63.0	(0.4)	62.6	59.2	(1.0)	58.3

Appendix D: Enhanced Seizure Data

Border Seizures

Seizures at the border (arriving from foreign countries) were classified 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 Ports of Entry (POE) along the Canadian border)[1].

EPIC has traditionally accounted for border seizures. There is a definitional difference in seizures at the southwest border and at 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.

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, information from EPIC was used. Any car, four-wheel drive, motorcycle, pickup truck, recreational vehicle, towed vehicle, or van was classified as a noncommercial vehicle. Additionally, if the "type" variable indicated "intrusion by vehicle at border (not POE)" or "vehicle at POE" the conveyance was classified 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.

3. To categorize maritime border seizures, Customs information was checked, specifically for 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

[1] Our border seizures figures differ from those reported by EPIC in the IACM. A description of their methodology was unavailable.

fishing or private vessel, then noncommercial maritime was assigned. Coast Guard and CCDB information was used to identify maritime seizures that occurred outside of ports of entry.

4. To categorize border seizures from air conveyances, Customs information was checked 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. CCDB data were consulted for air conveyance seizures.

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

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 E: Technical Details of the Border Allocation Model

In this appendix the Border Allocation model is described 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[1]. Using Customs BRS text search capability, a query was designed to extract those ROIs, intelligence reports, and seizure reports that contained explicit transportation cost information for 1989 through 1999. 14,328 reports were retrieved. The textual extraction programming language, PERL was employed – 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 E1.

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, were excluded. Data prior to 1991 were also excluded, the earliest year for our seizure data, leaving a total of 613 transportation cost observations.

These 613 observations were categorized 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

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[1] 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.

seizure (but not in transportation) data: northeast, Puerto Rico/Virgin Islands, and Rest of U.S. Table E1 summarizes the cost data in terms of the average cost per kilogram, for 1991-1998.

Figure E1

ROI Data Extraction Process

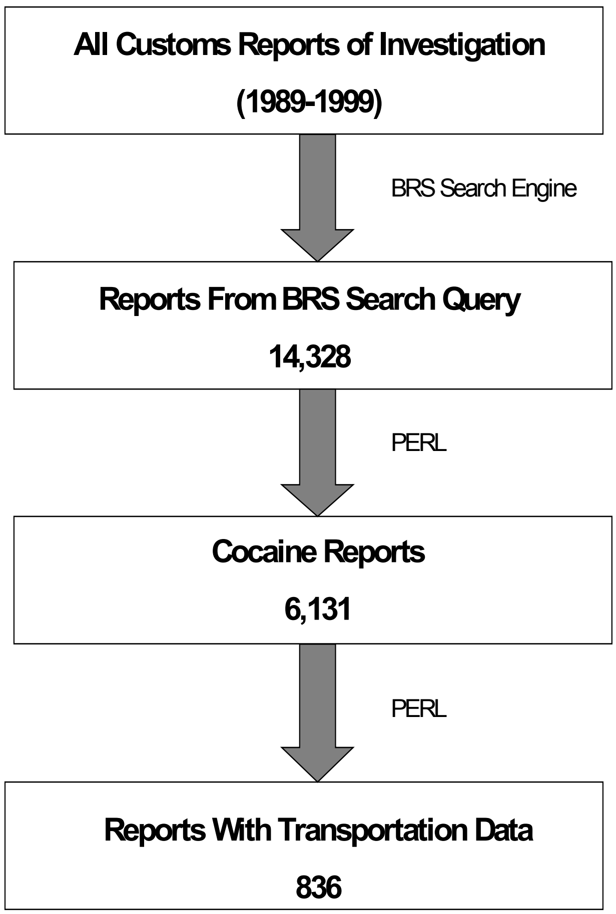

Table E1 - Transportation Costs by Region and Conveyance ($ per kilogram): Average Over Years 1991-1998

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.[2]. Costs for land conveyances were adjusted 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[3].

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[4].
2. The in-kind cost to the Colombians.

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

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

[3] 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.

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

Wholesale price in Colombia ($2,000[5]):	.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), the transportation cost for Colombia to Mexico ($1,400) was used, 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, the cost data were smoothed 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.

$$E(C_{itj}) = \exp(\text{Region}_i + \text{Conveyance}_j)$$
$$CV(C_{itj}) = \phi/\sqrt{n_{itj}}$$

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. It is worth noting, 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.[6]

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

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5 Ibid.

6 Fahrmeir and Tutz, 1994, pp.52-55

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[7].

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. A quantile threshold was chosen such that the probability of excluding genuine data was 0.01. Data were deleted 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 the 1% probability of excluding genuine data, it can be inferred that approximately 12% of the cost data were actually erroneous. Table E2 shows some examples of excluded data.

Table E2
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 E3 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

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

than commercial air, 18% more expensive than noncommercial marine, and 19% more expensive than noncommercial air.

Table E3 - 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?

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, this second possibility was not pursued 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. It is assumed 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[8] over the last decade, V_t is taken 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, $E(S_{itj})/T_{itj}$.

It is further assumed 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, the total transportation cost associated with the *i*th region, *j*th conveyance, and *t*th year can be expressed 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, $T_{itj} = \beta_{itj}T_t$,:

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

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.

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

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 year (the 28th is 1 minus the sum of the first 27 since the 28 probabilities must sum to unity). In passing, it is worth noting 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, this state of affairs is improved 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

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

where the sum is over all ij[9]. (Actually, since only 27 of the 28 β_{itj}'s are estimated, the last β_{6t6}, was dropped, and the denominator changes from $\Sigma\exp(\alpha_{itj})$ to $\{\Sigma\exp(\alpha_{itj}) - \exp(\alpha_{6t6}) + 1\}$).

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

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:

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

$$V(S_{itj}) = \sigma^2$$

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 form $T_{itj} = T_t \times \beta_{itj}$. 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 E4). 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 E4
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. It was assumed that production costs for cocaine, V, and total transportation costs, K, have been constant over the period 1991 through 1998. That is, it was 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 equilibrates. However, it should be noted 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.

Because the typical, noncommercial drug smuggling flight stops short of the U.S. border, the model does not accurately reflect the contribution of noncommercial air. More generally, the model may benefit by incorporating more realistic descriptions of the Colombia-to-U.S. transportation routes.

Appendix F: 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 *i*th source (i=1,2, …., m) has a supply of S_i units to distribute to n destinations and the *j*th 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, it is assumed 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, it is further assumed 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 is 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 *i*th U.S. border region without being seized. This is obtained from the Border Allocation Model described earlier as the estimated total flow into the *i*th region (summed over all conveyances) minus the total amount seized, minus Federal non-border seizures. The demand at the *j*th census division,

D_j, is estimated as the fraction of the number of treatment clients[1] in the census division divided by the total amount of cocaine consumed in the U.S.[2] The costs of distribution, C_{ij}, is the cost of shipping 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, state and local seizures have not been accounted for. Consequently, our working estimates may be significantly flawed.

[1] 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.

[2] 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.