A Hybrid Approach to Develop Freight Model from Commercial Vehicle Travel Surveys and Commodity Flow Data

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presented by

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Background/Objectives

- First Urban Truck Model in USA
  - » Developed by CS in 1992 for MAG
  - » Key reference and case study in FHWA Quick Response Freight Manual

- Resources available
  - » 2007 MAG Internal Truck Travel Survey
  - » 2007 TRANSEARCH Database

- Objectives: To update Internal and External Truck Travel Model

Unique and Innovative Features

- Collected O-D travel information from trucks that travel within the MAG region using different surveying techniques for different sectors;

- Instead of using a single gravity model by truck size distributed trucks by purpose in a series of gravity models using land use-to-land use interchanges;

- Developed equations to forecast external freight flows based socio-economic activity at the zonal level;

- Integrated land use-based internal truck model and commodity flow-based external truck model into a "hybrid" truck model.

Data Collection

Survey Process

Truck Surveys

- **Establishment Surveys**
- **Truck Trip Diaries**
- **Research/ National Databases**

Geographic Distribution of MAG Employment Database Sampling Frame

- Warehouse/ Distribution Centers/ Terminals
- Manufacturing

- Local, Pickup, and Delivery
- Construction
- Mail/Parcel
- For-hire
- Retail

Service Industry
- Safety
- Utility
- Public Service
- Personal Business

EMPLOYMENT SUBSET
TAZ
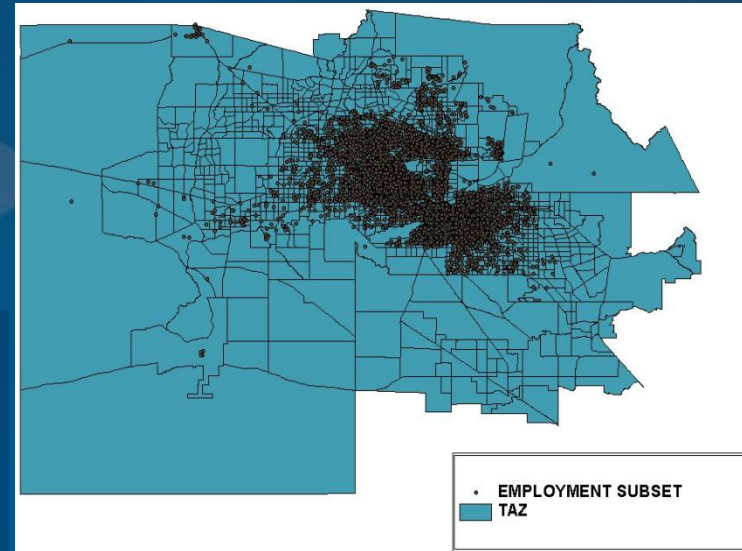
Sources of Sample

- MAG Employment Database
- Fleet Seek
- ATA Fleet Directory
- U.S. Data Corporation

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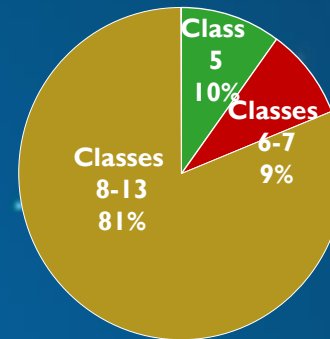
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Survey Results (establishment surveys)

- Phone surveys using CATI System
- Pre-Tests – 10 surveys
- Full Survey – 552 completes

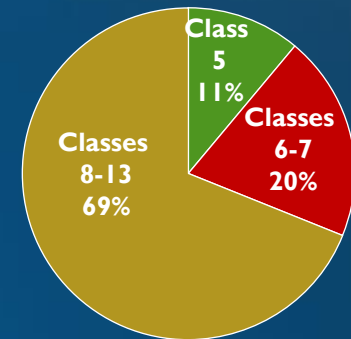| Sector	Frequency	Percent
Manufacturing	3,030	49%
Wholesale Trade	2,730	44%
Warehousing / Transportation	383	6%
Total	6,143	100%

Sector	Number of Surveys
Manufacturing	275
Wholesale Trade	198
Warehousing / Transportation	89

Warehousing/ Transportation

Class 5 10%
Classes 6-7 9%
Classes 8-13 81%

Manufacturing

Class 5 11%
Classes 6-7 20%
Classes 8-13 69%

Wholesale Trade

Class 5 10%
Classes 6-7 22%
Classes 8-13 68%
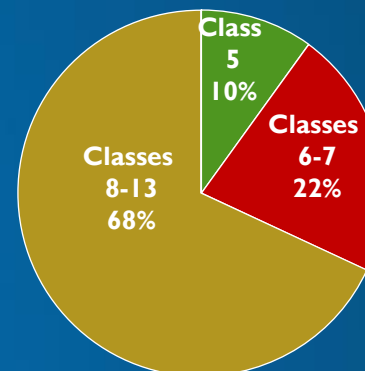
FHWA Truck Class	
Class 5 Trucks	2 axle 6 Tire Single Unit
Class 6-7 Trucks	3+ axle Single Units
Class 8-13	Combination Trucks

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Survey Results (trip diary surveys)

Survey Question	Survey Response	Frequency
Truck Size	33,001 lbs and above	134
	14,001 – 33,00 lbs	60
Number of Axles	Combo Unit, 4+ axle (8-13)	91
	Single Unit, 2-4 axle (5-7)	84
Fuel Type	Diesel	223

- Mail-in/Mail-back surveys
- Pre-Tests – 24 diaries, 132 stops
- Full Survey – 236 Diaries, 1304 stops

Aggregate Business Sector	NAICS Codes in Sector	Number of Firms	Percent of Firms
Construction / Agriculture / Mining	11, 21, 23	3,860	33%
Retail Trade	44, 45	2,791	24%
Accommodation & Food Services	72	2,754	23%
Delivery / Publishing	48	689	6%
Equipment / Rental / Leasing	49, 51, 53		
Other Services with Product Delivery	32, 54, 56, 81	1,603	14%
Total		11,697	100%

Bar chart:
- All other location: 10%
- Industrial: 7%
- Retail store/restaurant/mall: 8%
- House/other residential: 11%
- Warehouse/wholesale store: 17%
- Construction site: 24%
- My company employer: 23%

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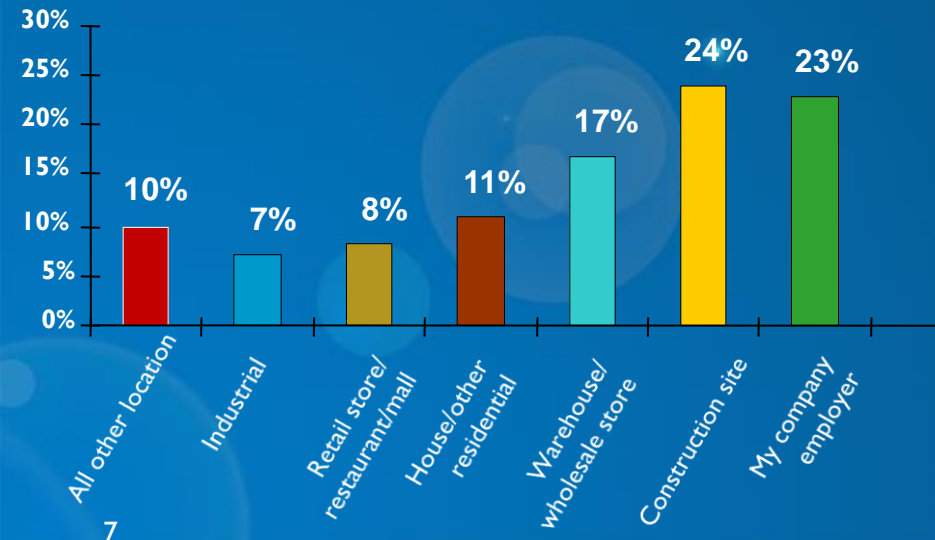
Internal Truck Model

Internal Truck Trip Generation

- 2-digit NAICS employment data (13 categories)

- Land-use based trip rates (P & A) from expanded surveys

- Internal truck trip ends by land use and truck type

•**My Employer**
•**Retail**
•**Construction**
•**Farming**
•**Mining**
•**Household**
•**Warehousing**
•**Transportation**
•**Industrial**
•**Service**   **(Office, Government, Other)**

Internal Truck Trip Distribution

- Gravity models based on friction factors by truck type
- LU-to-LU trip exchange proportions
  - » Production percents shown sum across to 100%
  - » Attraction percents, not shown, restated to sum down to 100%

	1 MY EPLOYER	2 HOUSE HOLD	3 OFFICE	4 GOVT	5 RETAIL	6 CONST.	7 WARE HOUSE	8 INDUST.	9 TRANSP.	10 FARM	11 MINE	12 OTHER
1 MY COMPANY/EMPLOYER LOCATION	10%	6%	0%	1%	2%	33%	36%	5%	2%	1%	3%	2%
2 HOUSE/OTHER RESIDENTIAL	18%	42%	14%	0%	2%	13%	10%	0%	0%	0%	0%	0%
3 OFFICE/BANK/MEDICAL/REPAIR	12%	0%	12%	63%	0%	12%	0%	0%	0%	0%	0%	0%
4 GOVERNMENT*	30%	0%	0%	0%	70%	0%	0%	0%	0%	0%	0%	0%
5 RETAIL/STORE/RESTAURANT/MAIL	13%	4%	0%	4%	40%	16%	9%	0%	13%	0%	0%	0%
6 CONSTRUCTION SITE	35%	2%	1%	0%	1%	44%	4%	3%	2%	0%	6%	3%
7 WAREHOUSE/WHOLESALE STORE	45%	6%	0%	0%	4%	5%	35%	2%	2%	0%	0%	2%
8 INDUSTRIAL	29%	0%	0%	0%	0%	20%	4%	31%	16%	0%	0%	0%
9 TRANSPORTATION HUB	7%	0%	0%	0%	14%	24%	14%	14%	14%	0%	0%	14%
10 FARM	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
11 MINE	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
12 OTHER	7%	5%	0%	0%	0%	14%	9%	9%	5%	0%	0%	51%

* Including GOVERNMENTBUILDING/SCHOOL/MILITARY BASE/HOSPITAL

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# Internal Truck Trip Distribution (contd)

- Conventional gravity model calculates all truck trips between zones i and j

  » Based on Productions in i, Attractions in j and Friction Factor (FF) between zones i and j

- Interchange gravity model calculates truck trips from the lane use in i to the land use in j

  » Based on Productions in i, Attractions in j and Friction Factor (FF) between zones i and j;   and

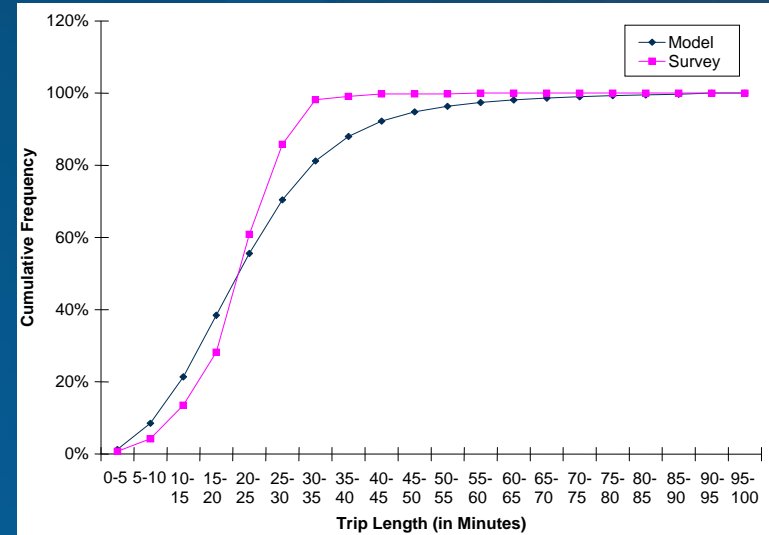 » Based on the percentage those land uses have of total productions or attractions for that exchange

$$T_{ilu_m lu_n} = PctP_{lu_m lu_n} * P_{ilu_n} * \frac{PctA_{lu_n lu_m} * A_{jlu_n} * FF_{ij}}{\sum_j PctA_{lu_n lu_m} * A_{jlu_n} * FF_{ij}}$$

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Trip Distribution Results

Medium-Truck Trip Length Frequency Distribution
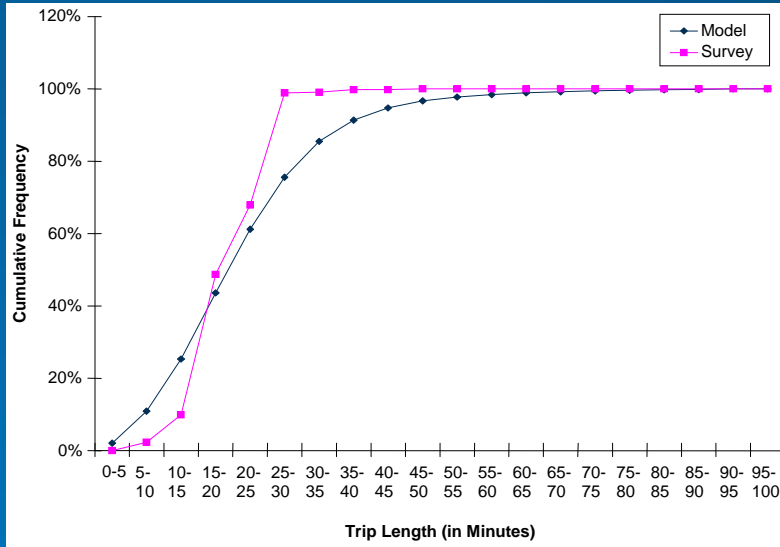
Heavy-Truck Trip Length Frequency Distribution

Average Trip Length by Truck Type

Truck Type	Survey (In Minutes)	Model (In Minutes)	Difference (In Minutes)	Trips
Light	N/A	15.89	N/A	1,732,178
Medium	20.13	23.52	3.39	646,311
Heavy	23.11	25.53	2.42	145,855

External Truck Model

External Truck Model

- External model based on TRANSEARCH commodity flows

  » TRANSEARCH is annual commodity flow database developed by IHS Global Insight

  » Represents flows at Statewide, Countywide and Zip Code Tabulation Area (ZCTA) level

  » Includes Payload Factors for each commodity

  » TRANSEARCH has 32 commodities (STCC2) which were grouped into 10 major commodity groups

External Trip Generation

CG Number	Commodity Group (CG) Name	STCC2 Names
1	Farm	Agriculture, Forest Products, Fish
2	Mining	Metallic Ores, Crude Petroleum, Nonmetallic Minerals, Ordnance
3	All Consumer Manufacturing	Food, Tobacco, Textiles, Apparel, Leather
4	Lumber	Lumber
5	(Non-Consumer) Nondurable Manufacturing	Paper, Chemicals, Petroleum, Rubber/Plastics
6	(Non-Consumer) Durable Manufacturing	Furniture, Metal, Metal Products, Machinery, Electrical Equipment, Transportation Equipment, Instruments, Misc Mfg Products
7	Printing	Printed Goods
8	Miscellaneous Freight	Waste, Misc Freight Shipments, Waste
9	Empty trucks	Shipping Containers
10	Warehousing	Secondary and Drayage

- 10 CGs serve as 10 trip purposes for external model

  » Commodity Flow = f (Employment)

  » STCC2 (TRANSEARCH) and SIC2 (employment) production relationships by same code

  » Using SIC2 and NAICS2 crosswalk, STCC2 = f (NAICS2)

  » STCC2 (TRANSEARCH) and SIC2 (employment) attraction relationships by regression

External Truck Production Model

| CG #	Name	Variable	Coefficient	t-stat	R^2
1	Farm	Natural Log of Agriculture	125.2	9.226	0.810
2	Mining	*	*	*	*
3	All Consumer Manufacturing	Consumer Manf	8.281	11.931	0.785
4&5	(Non-consumer) Nondurable Manufacturing Including Lumber	Non Durable Manf	12.989	10.356	0.691
6	(Non-consumer) Durable Manufacturing	Non Durable Manf	2.715	7.154	0.795
		Durable Manf	0.451	4.555	
7	Printing	Durable Manf	0.434	12.973	0.816
8	Miscellaneous Freight	Natural log of Warehousing	0.036	8.073	0.739
9	Empty trucks	Sum of total truck attraction	0.287	68.083	0.994
10	Warehousing	Wholesale Trade	0.532	8.719	0.613

- Mining identified as a special generator

- Combined CG 4&5 due to limitation in detail in NAICS2

- CG6 function of two employment variables

- Empty trucks produced as a function of attraction

External Truck Attraction Model

CG #	Name	Variable	coefficient	t-stat	R^2
1	Farm	Consumer Manf	0.266	1.616	0.783
		Wholesale	0.272	6.599	
2	Mining	Durable Manf	8.492	10.619	0.831
3	All Consumer Manufacturing	Consumer Manf	1.626	1.613	0.782
		Wholesale	1.659	6.591	
4&5	(Non-consumer) Nondurable Manufacturing incl. Lumber	Wholesale	3.662	8.461	0.757
6	(Non-consumer) Durable Manufacturing	Wholesale	3.059	8.448	0.756
7	Printing	Wholesale	0.13	8.441	0.756
8	Miscellaneous Freight	Non Durable Manf.	0.001	10.618	0.831
9	Empty trucks	Sum of total truck production	0.39	29.111	0.91
10	Warehousing	Wholesale	2.701	8.866	0.759

- Different variables than production for each CG attraction

- Combined CGs 4 & 5 due to limitation in detail in NAICS2

- CG1 and CG3 attractions driven by two employment variables

- Empty trucks attracted based on total production

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Special Generators
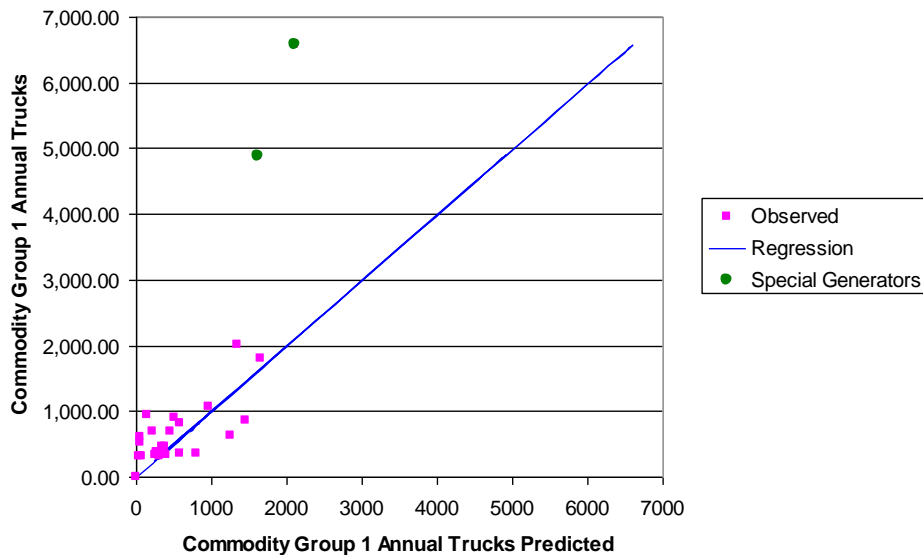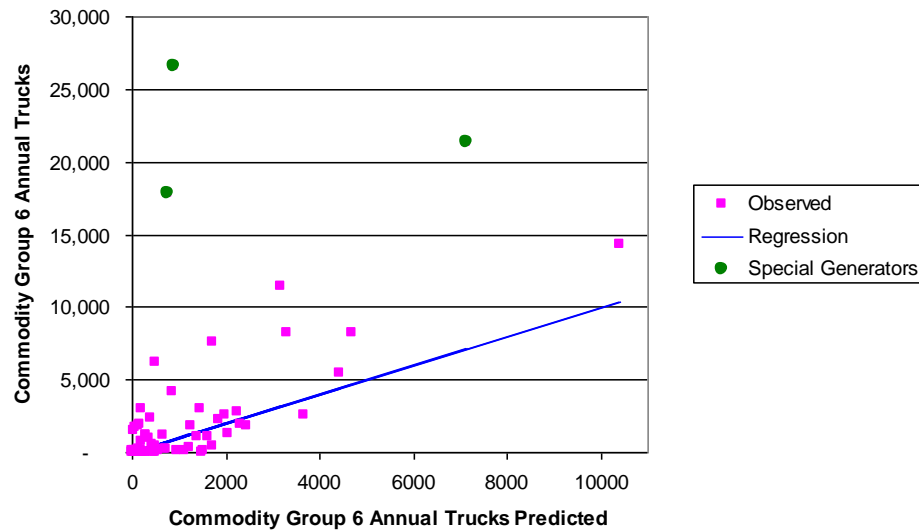
- Examples
  - » 'Durable manufacturing' production
    – observed vs. predicted
  - » 'Farm' attraction
    – observed vs. predicted

- Outliers identified as special generators

- GeoFreight database (BTS) used to locate TAZs of freight terminals for that special generator tonnage

External Trip Distribution

- Internal truck trip ends (for 'I' in IE & EI) from trip generation

- Need to identify External truck trip ends
  - » Total truck trip ends from MAG's external station truck counts
  - » TRANSEARCH annual flows, converted to daily truck trip table, used as initial "Seed Table"
  - » TransCAD's IPF used with "Seed Table" with counts as targets to find non internal truck trip table
    - • Identify E trip ends of IE & EI flows for use in trip distribution
    - • Retain E-E flows for later use
  - » Distribute EI and IE trips using gravity model

Integration & Validation

Integrate Internal & External Models

- Internal truck trips added to External truck trips to produce total truck trip tables by truck type

- Internal and External truck model scripts integrated with MAG's passenger travel model scripts

- Calibration and validation of truck model was done with 2008 base year travel model

Base Year Validation
Selected Cities

City	Counts*			Integrated Model			Integrated Model - Counts	
	Medium (Class 5-7)	Heavy (Class 8-13)	Medium & Heavy	Medium (Class 5-7)	Heavy (Class 8-13)	Medium & Heavy	Medium & Heavy	Medium & Heavy %
Avondale	3,758	2,325	6,083	2,133	5,774	7,907	1,824	30%
Chandler	5,785	11,394	17,179	4,916	12,911	17,827	648	4%
Gilbert	4,639	3,766	8,405	1,916	5,134	7,049	-1,356	-16%
Glendale	18,290	14,229	32,519	5,463	14,475	19,938	-12,581	-39%
Mesa	8,096	19,211	27,307	5,713	16,211	21,925	-5,382	-20%
Peoria	3,535	3,115	6,650	2,065	4,315	6,380	-270	-4%
Phoenix	76,129	143,961	220,090	80,054	192,551	272,605	52,515	24%
Scottsdale	10,016	27,503	37,519	10,113	24,478	34,591	-2,928	-8%
Surprise	14,189	6,076	20,265	5,116	8,962	14,077	-6,188	-31%
Tempe	5,693	16,332	22,025	7,394	16,245	23,639	1,614	7%
All Others	5,254	5,736	10,990	3,608	9,542	13,150	2,160	20%
TOTAL	155,384	253,648	409,032	128,491	310,598	439,088	30,056	7%

* Includes class counts on arterials only

Forecasts

- Developed growth factors from TRANSEARCH forecasts for
  - » External station targets
  - » Special generators
  - » E-E flow tables

- Using forecast year NAICS2 data and growth factors, derived truck volumes for forecast years

- MAG currently using these truck forecasts for conformity analysis

Future Possible Model Improvements

- Collect freeway classification counts based on FHWA classes

- Develop screenlines for trucks

- Acquire GPS data for trucks to –
  - » Update internal truck model
  - » Develop trip chaining model

- Use new TRANSEARCH data to update external truck model

- Use TRANSEARCH's STCC50 to identify 'secondary' traffic (to/from warehouses, DCs, IMXs, airports)