Road & Bridge Department
Impact Fee
Independent Fee Calculation Manual

April 2008 - Final Draft

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Figures, Forms, and Examples

GOALS

The general goal of this manual is to provide instruction for establishing an optional independent fee calculation for development for the Rio Blanco County Road Impact Fee.

The core unit of traffic impact used to determine the road impact fee price for a particular development is the 18 kip Equivalent Single Axle Load (ESAL), a fourth power function of axle weights representing impacts on road structure as established in *Guide for Design of Pavement Structures,* American Association of State Highway and Transportation Officials. Calculating the proposed development's total 18 kip one pass ESAL requires an empirically determined weight (scale needed) or an estimated weight of each axle for each vehicle type to be generated by the proposed development. The bulk of this manual and the effort required to develop an independent fee calculation are directed at establishing the proposed development's ESAL.

Once ESAL are established, calculating the fee amounts requires only a few easy steps.

HOW TO USE THIS MANUAL

This manual offers two tracks for estimating ESAL:

- Track 1 - A set of typical configurations that can be used to estimate empty and full axle weights and ESAL
- Track 2 - A methodology for estimating equivalent single axel loads for non-typical configurations or loads.

Track 1 is by far the least labor intensive option and is recommended if the development meets the criteria discussed below. While most proposed developments will be able to use Track 1, using both tracks can be a viable approach to estimating total ESAL. In some cases the development may be entirely atypical and will require a full calculation using Track 2.

Using Forms Included to Organize the Independent Fee Calculation

The best way to approach the independent fee calculation is to use the blank forms provided in this manual to organize calculations. The forms are structured in the same manner as the examples, allowing the applicant to read the general description of each step, look at an example, and fill out the blank forms leading to an accurate independent impact fee calculation.

Track 1 analysis can be organized using Form 1.1.

Track 2 analysis can be organized using Forms 2.1, 2.2, and 2.3.

How to Choose a Track?

The degree to which the traffic generated by a proposed development is represented by the typical vehicle configurations listed in Figures 2 - 7 is fundamental factor determining whether a proposed development's ESAL can be estimated using Track 1. To determine whether a Track 2 component is necessary, read Track 1 from this point through Figure 7 and evaluate the vehicles types to be used by the proposed development against the typical configurations. If the typical configurations generally reflect all vehicle types and loads to be generated by the development, a Track 1 calculation will suffice. For vehicle types or loads not represented by the typical configurations, refer to Track 2. Both tracks can be combined to evaluate a single development's ESAL (i.e. Track 1 ESAL + Track 2 ESAL = Development Total ESAL).

Definitions and Usage of Terms in This Manual

Axle: An axle can refer to one single axle or to a group of axles, such as a tandem axle, which is an adjacent group of 2 single axles functioning together.

Axle Weight: The weight born by an axle.

Construction Phase: The period of time during which a proposed development is being built.

Configuration: Refers to a vehicle type (car, pickup, tractor semitrailer, etc.) and the weight of each axle. A single vehicle can have several configurations depending on the various types of loads. Example- a loaded truck and an empty truck would be 2 configurations.

Energy Development: A form of non-residential development aimed at developing energy resources.

ESAL: Equivalent Single Axle Load. A fourth power function of axle weights representing impacts on road structure as established in *Guide for Design of Pavement Structures,* American Association of State Highway and Transportation Officials.

Non-Residential: Refers to all commercial, lodging, industrial, warehousing, public facilities, and other residential land uses requiring structures and improvements that are not residential

Operations and Maintenance Phase: The period of time during which a development operates and is maintained after construction. Due to the nature of capital improvements planning, the operations and maintenance phase is no longer than 15 years under the road impact fee structure.

Payload: The weight in addition to the weight of the vehicle itself, the load in or on the vehicle.

Square Footage: Useable floor area within a structure. Square footage can refer to structures without roofs or walls in some cases. Example- an outdoor performance venue.

Variation: Refers to the number of trips over time for a particular configuration or set of configurations.

Vehicle Trip: A vehicle trip is a one way trip for one vehicle of any sort from origin to destination. Vehicle trips are generally considered in terms of a time variable, such as average daily vehicle trips, annual vehicle trips, and even peak hour (rush hour) vehicle trips.

TRACK 1 - CALCULATE ESAL USING TYPICAL VEHICLE CONFIGURATIONS

Track 1 Forms

All steps in Track 1 can be organized into *Form 1.1* located near the end of the Track 1 description.

Step 1 - Vehicle Type List

The first step in estimating a proposed development's ESAL generation is to list the types of vehicles driving to and from the site in a manner that provides relevant information for determining ESAL (often called configurations). The list should contain the vehicle types needed during both the construction phase and the ongoing operations/maintenance of the proposed development.

ESAL are a function of the weight and type of axles associated with a particular vehicle, so a basic understanding of axle types is necessary to then establish a vehicle type list.

Axle Types

A single axle can have either 2 or 4 wheels. Any vehicle contains at least one single axle because steering axles are always single axles.

A **tandem axle** refers to a combined set of two adjacent axles. Tandem axles usually have 8 wheels.

A **triple axle** refers to a combined set of three adjacent axles. Tandem axles usually have 12 wheels. Some triple axles involve a slider, an optional axle that optionally drops down to convert a tandem axle to a triple axle for heavy loads.

Typical Axle Weight of Typical Vehicle Configurations

Each typical truck configuration includes baseline empty and loaded weights and configurations. Configurations are based on the sources summarized in Table 41.

Figure 1 - Typical Configuration Sources

2 Axle Single Unit	*Typical Empty configuration from Colorado Port of Entry, Loma District; http://www.internationaltrucks.com*
3 Axle Single Unit	*Comprehensive Truck Size and Weight Study, Summary Report, Table 6, Federal Highway Administration ;*
Tractor-Semi Trailers	*Comprehensive Truck Size and Weight Study, Summary Report, Table 6, Federal Highway Administration; Full Scale Testing of 5 Axle Semis, Center for Surface Transportation Technology, Canada Research Center, 2004*

Using *OPTI Truck* weight distribution software by Sun Engineering, 2003, Analysts established axle weight distributions that in Figures 2 - 7 based on the typical configurations established using the sources cited above.

Energy Development Example Vehicle Type List Using Typical Configurations

Description

Produced water treatment facility designed to treat produced water for other uses or disposal.

Construction Phase

Single unit 3 axle trucks: dump trucks and concrete trucks

Tractor-semi trailers (5 axle): construction equipment hauling

Pickups: construction worker commuting

Operations and Maintenance of Proposed Development

Tractor-semi trailers (5 axle): Water hauling, maintenance equipment hauling

Pickups: Plant operator commuting

Nonresidential Example - Vehicle Type List Using Typical Configurations

Description

Winter motor sports shop open November-April.

Construction Phase

Single unit 3 axle trucks: dump trucks and concrete trucks

Tractor-semi trailers (5 axle): construction equipment hauling,

Pickups: construction worker commuting

Operations and Maintenance

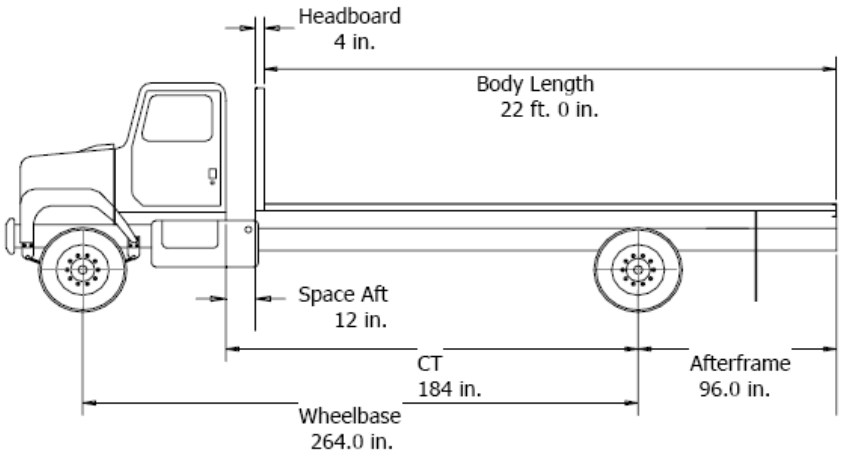
Single unit 2-axle trucks: delivery trucks

Tractor-semi trailers (5 axle):: delivery trucks

Pickups: employees, customers

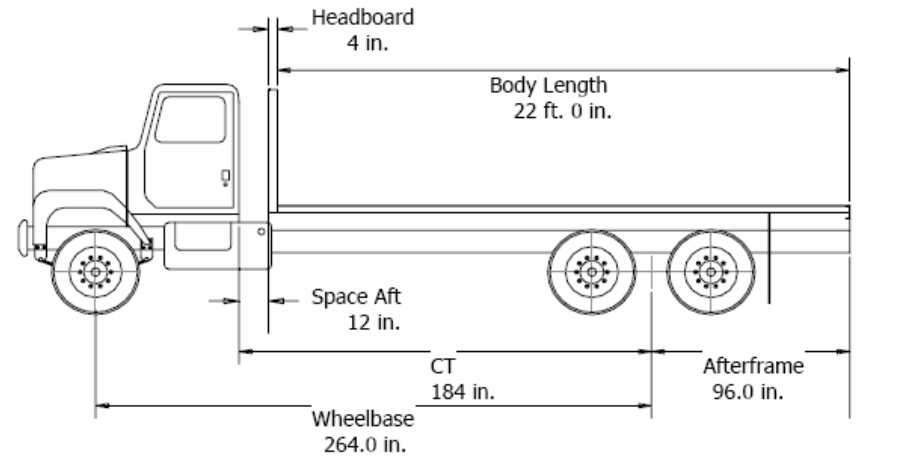
Passenger Cars: employees, customers

Figure 2 - 2 Axle Single Unit Typical Configuration and Axle Weights



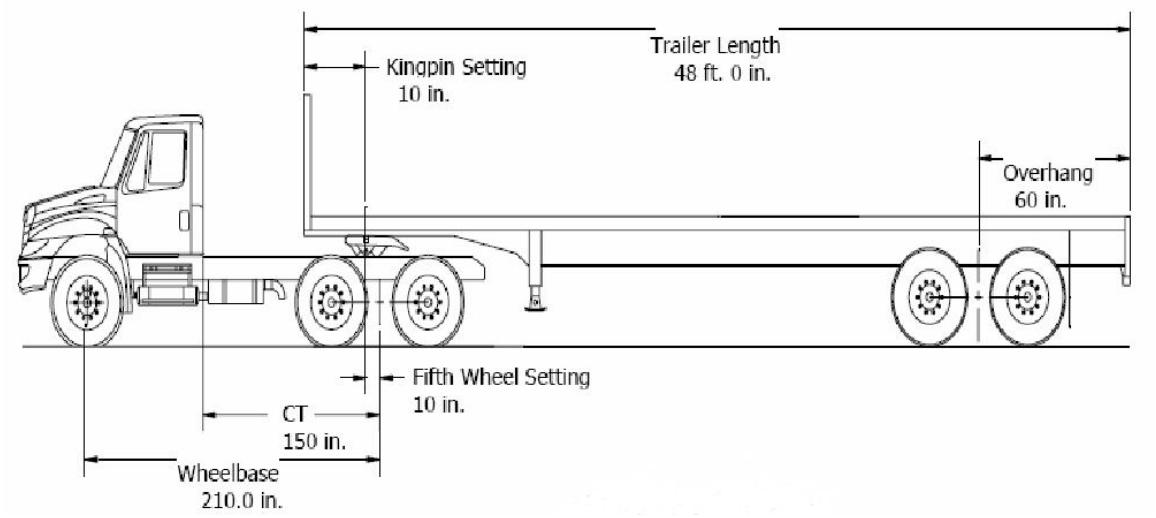
	Total load (lbs)	Front Axle Load (lb)	Rear Axle Load (lb)
Empty Axle Weights (All Lift Axles Up)	17000	9650	7350
Total Payload (Known Payload)	13500	1841	11659
Loaded Axle Weights (Lift Axles at Capacity)	30500	11491	19009

Figure 3 - 3 Axle Single Unit (tandem rear axle) Typical Configuration and Axle Weights



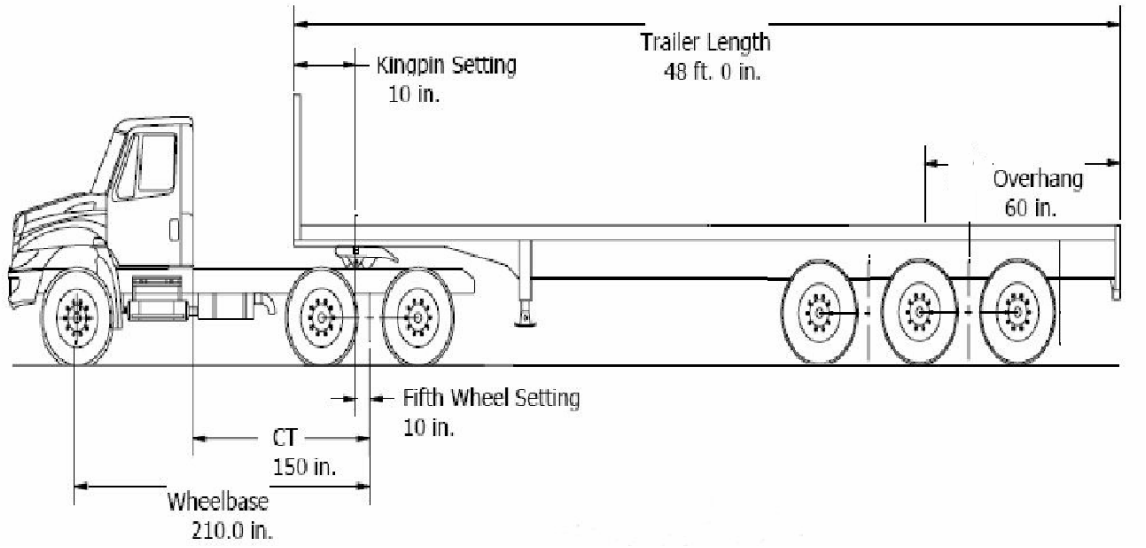
	Total load (lbs)	Front Axle Load (lb)	Rear Axle Load (lb)
Empty Axle Weights (All Lift Axles Up)	22600	13150	9450
Total Payload (Known Payload)	31400	4282	27118
Loaded Axle Weights (Lift Axles at Capacity)	54000	17432	36568

Figure 4 - 5 Axle Tractor-Semi Trailer Typical Configuration and Axle Weights



	Weight (lbs)	Front Axle Load (lb)	Rear Axle Load (lb)	Tandem Axle Load (lb)
Empty Axle Weights	30500	10286	10074	10140
Total Payload (Known Payload)	49500	1062	21242	27196
Loaded Axle Weights	80000	11348	31316	37336

Figure 5 - 6 Axle Tractor-Semi Trailer Typical Configuration and Axle Weights



	Weight (lbs)	Front Axle Load (lb)	Rear Axle Load (lb)	Triple Axle Load (lb)
Empty Axle Weights	30500	10286	10074	10140
Total Payload (Known Payload)	49500	1062	21242	27196
Loaded Axle Weights	80000	11348	31316	37336

Figure 6 - Empty Typical Configurations

	Empty Total Weight	Single Axle Weight (steering)	Single Axle Weight (rear)	First Tandem Axle Weight	Second Tandem Axle Weight	Triple Axle Weight
2 Axle Single-Unit	17000	9600	7400			
3 Axle Single-Unit	22600	13100		9500		
Five Axle Tractor-Semitrailer	30500	10300		10100	10100	
Six Axle Tractor-Semitrailer	31500	10600		10400		10400
Pickup	7000	4000	3000			
Passenger Car	4000	2000	2000			

Figure 43 - Loaded Typical Configurations

	Empty Total Weight	Single Axle Weight (steering)	Single Axle Weight (rear)	First Tandem Axle Weight	Second Tandem Axle Weight	Triple Axle Weight
2 Axle Single-Unit	30500	11500	19000			
3 Axle Single-Unit	54000	17400		36600		
Five Axle Tractor-Semitrailer	80000	11200		33600	35200	
Six Axle Tractor-Semitrailer	80000	11200		33600		35200
Pickup	7000	4000	3000			
Passenger Car	4000	2000	2000			

Step 2 - Variations in Number of Vehicle Trips and Duration:

To accurately tally ESAL for an entire project it is necessary to list each variation in number of vehicle trips and duration for the proposed development. Applicants for an independent fee calculation can read the description of the steps and the accompanying examples to fill out Form 1.1.

A development can result in several variations in the number of vehicle trips and duration that it generates those trips. For example, a development may result in 50 dump truck trips to haul in construction materials in the first year (3 axle single unit, 50 trips per year, 1 year duration) and water trucking resulting in 24 vehicle trips per year for 8 years (3 axle single unit 24 vehicle trips per year, 8 year duration).

Construction phase: Project construction is temporary, but can continue for multiple years depending on the scope of the proposed development. Even a short construction duration (say 2 months) would be listed in the ESAL Tally Sheet as a 1 year vehicle trips.

Operations and Maintenance (15 years Maximum): Most development is built to last for decades, but the realistic planning horizon for addressing impacts of future development is of a shorter duration than the lifespan of the development itself. The capital improvements planning horizon is 15 years into the future, so the maximum duration for maintenance and operations should be 15 years. If the development would generate traffic for shorter durations, those may also be listed for each vehicle type.

Estimate annual vehicle trips for empty and full loads (no difference for pickups and passenger cars). Below are the annual trips per year calculated from the average daily trips for basic non-residential land use categories. Table x is an optional resource, proposed developments may consult other sources to determine annual vehicle trips.

Figure 8 - Nonresidential Land Use Trip Generation

	Average Daily Vehicle Trips / 1,000 sq. ft.	Annual Trips per 1000 sq. ft.
Shopping Center	21.46	7833
Office / Institutional	5.51	2011
General Commercial	6.38	2329
Light Industrial	3.49	1274
Warehousing	2.48	905
Manufacturing	1.91	697

Energy Development Example - Vehicle Trip and Duration Variations

Description

Produced water treatment facility

Construction

Construction includes dump trucks and concrete trucks, which will arrive loaded and depart empty, meaning these trucks will create an equal number of empty and full trips.

Construction equipment will also be hauled on and off site during construction, meaning the trucks will be loaded both ways.

Construction workers will also come and go, mostly in pickups, for the duration of construction (1 year).

Vehicle Type	Variation	Empty Vehicle Trips per Year	Loaded Vehicle Trips per Year	Empty ESAL per Trip	Loaded ESAL per Trip	ESAL per Year	Duration (Yrs)	Total ESAL
2 Axle Single-Unit				0.11	1.744	0		0
				0.11	1.744	0		0
				0.11	1.744	0		0
3 Axle Single-Unit	Dump trucks for construction pad	20	20	0.344	2.38	0	1	0
	Concrete trucks (construction)	4	4	0.344	2.38	0	1	0
				0.344	2.38	0		0
Five Axle Tractor-Semitrailer	Construction equipment hauling		45	0.091	2.634	0	1	0
	Water hauling (ongoing)	12	12	0.091	2.634	0	15	0
	Maintenance equipment hauling 2 yrs		20	0.091	2.634	0	2	0
Six Axle Tractor-Semitrailer				0.087	1.629	0		0
				0.087	1.629	0		0
				0.087	1.629	0		0
Pickup	Operator Commuting	500		0.004	0.004	0	15	0
	Construction Commuting	1000		0.004	0.004	0	1	0
				0.004	0.004	0		0
Passenger Car				0.0008	0.0008	0		0
				0.0008	0.0008	0		0
				0.0008	0.0008	0		0
GRAND TOTAL								**0**

Operations and Maintenance

The water treatment plant still requires some hauling away of wastewater as long as it remains in service. The maximum duration is 15 yrs due to the capital facilities planning horizon, and is set accordingly.

Twice during the planning horizon (once every 5 years), the facility will need to be maintained, involving the delivery of maintenance equipment. Maintenance will take less than one year each time. Equipment hauling is loaded in both directions, so all vehicle trips are counted as loaded.

A plant operator will attend the plant for 250 days per year, resulting in 500 vehicle trips total in a pickup for as long as the plant operates (maximum duration, 15 years)

Nonresidential Example - Vehicle Trip and Duration Variations

Description

Winter motor sports shop open November-April.

Construction

Construction includes 4 dump truck loads of fill and 4 concrete trucks to build the slab, which will arrive loaded and depart empty, meaning these trucks will create an equal number of empty and full trips.

Construction equipment will also be hauled on and off site during earthmoving, meaning the trucks will be loaded both ways.

Construction workers will also come and go, mostly in pickups, for the duration of construction (1 year).

Independent Road Impact Fee Calculation ESAL Tally Sheet

Vehicle Type	Variation	Empty Vehicle Trips per Year	Loaded Vehicle Trips per Year	Empty ESAL per Trip	Loaded ESAL per Trip	ESAL per Year	Duration (Yrs)	Total ESAL
2 Axle Single-Unit	Inventory Delivery	6	6	0.11	1.744	0	15	0
				0.11	1.744	0		0
				0.11	1.744	0		0
3 Axle Single-Unit	Dump trucks (construction)	4	4	0.344	2.38	0	1	0
	Concrete trucks (construction)	4	4	0.344	2.38	0	1	0
				0.344	2.38	0		0
Five Axle Tractor-Semitrailer	Construction equipment hauling		6	0.091	2.634	0	1	0
	Inventory Delivery	3	3	0.091	2.634	0	15	0
				0.091	2.634	0		0
Six Axle Tractor-Semitrailer				0.087	1.629	0		0
				0.087	1.629	0		0
				0.087	1.629	0		0
Pickup	Construction Commuting	500		0.004	0.004	0	1	0
	Customers	3000		0.004	0.004	0	15	0
	Employee Commuting	450		0.004	0.004	0	15	0
Passenger Car	Employee Commuting	450		0.0008	0.0008	0	15	0
	Customers	3000		0.0008	0.0008	0	15	0
				0.0008	0.0008	0		0
GRAND TOTAL								**0**

Operations and Maintenance

The motor sports store will receive occasional deliveries from loaded delivery trucks. The store is normally supplied by a transport company that drives single unit trucks but 3 times per year the shop receives a tractor-semi-trailer shipment of over the snow vehicles. Deliveries will continue as long as the shop exists, but the maximum is 15 years, so duration is defaulted to the maximum

The shop expects to be open 150 days per year with an average of 20 customers per day and 3 full time employees each day the shop is open. 50% of the trips generated by customers and employees are expected to be pickups and 50% passenger cars.

Step 3 - Calculate ESAL Using Typical Configurations

Since the number of vehicle trips and duration of these vehicle trips has been established in Step 2, it is now possible to calculate the proposed development's ESAL using typical configurations. The American Association of State Highway and Transportation Officials *Guide for Design of Pavement Structures* (Tables D.1. and D.2.) provides methodology and empirical data for calculating ESAL based on axle weights for vehicles of all types. The ESAL for typical configurations have been compiled by RPI Analysts and are summarized in Figures 9 and 10 for empty and loaded vehicles.

Form 1.1 has been populated with the ESAL for typical configurations. The mathematics to determine the *ESAL per Year* for <u>each</u> vehicle type, vehicle trips, and duration variation established in Step 1 follow:

$$\text{ESAL per Year} = (\text{Empty Vehicle Trips per Year} \times \text{Empty ESAL per Trip}) + (\text{Loaded Vehicle Trips per Year} \times \text{Loaded ESAL per Trip})$$

Next, calculating the total ESAL for <u>each</u> vehicle type, vehicle trips, and duration variation can be accomplished as follows:

$$\text{Total ESAL per Variation} = \text{ESAL per Year} \times \text{Duration in Years}$$

Finally sum all ESAL by variation to get the grand total,

$$\text{DevelopmentTotalESAL} = \sum_{\text{VariationA}}^{\text{VariationZ}} \text{TotalESALPerVariation}$$

See the examples to further clarify this process.

Figure 9 - Empty Truck ESAL for Typical Configurations (One Vehicle Trip)

	Empty Total ESAL	Single Axle ESAL (steering)	Single Axle ESAL (rear)	First Tandem Axle ESAL	Second Tandem Axle ESAL	Triple Axle ESAL
2 Axle Single-Unit	0.11	0.079	0.031			
3 Axle Single-Unit	0.344	0.338		0.006		
Five Axle Tractor-Semitrailer	0.091	0.079		0.006	0.006	
Six Axle Tractor-Semitrailer	0.087	0.079		0.006		0.002
Pickup	0.004	0.002	0.002			
Passenger Car	.0008	.0004	.0004			

Figure 43 - Loaded Truck ESAL for Typical Configurations (One Vehicle Trip)

	Loaded Total ESAL	Single Axle ESAL (steering)	Single Axle ESAL (rear)	First Tandem Axle ESAL	Second Tandem Axle ESAL	Triple Axle ESAL
2 Axle Single-Unit	1.744	0.174	1.57			
3 Axle Single-Unit	2.38	1		1.38		
Five Axle Tractor-Semitrailer	2.634	0.174		1.08	1.38	
Six Axle Tractor-Semitrailer	1.542	0.174		1.08		0.288
Pickup	0.004	0.002	0.002			
Passenger Car	.0008	.0004	.0004			

Energy Development Example - Final ESAL Calculations

ESAL per Year = (Empty Vehicle Trips per Year × Empty ESAL per Trip) + (Loaded Vehicle Trips per Year × Loaded ESAL per Trip)

Independent Road Impact Fee Calculation ESAL Tally Sheet

Vehicle Type	Variation	Empty Vehicle Trips per Year	Loaded Vehicle Trips per Year	Empty ESAL per Trip	Loaded ESAL per Trip	ESAL per Year	Duration (Yrs)	Total ESAL
2 Axle Single-Unit				0.11	1.744	0		0
				0.11	1.744	0		0
				0.11	1.744	0		0
3 Axle Single-Unit	Dump trucks for construction pad	20	20	0.344	2.38	54.48	1	54.48
	Concrete trucks (construction)	4	4	0.344	2.38	10.896	1	10.896
				0.344	2.38	0		0
Five Axle Tractor-Semitrailer	Construction equipment hauling		45	0.091	2.634	118.53	1	118.53
	Water hauling (ongoing)	12	12	0.091	2.634	32.7	15	490.5
	Maintenance equipment hauling 2 yrs		20	0.091	2.634	52.68	2	105.36
Six Axle Tractor-Semitrailer				0.087	1.629	0		0
				0.087	1.629	0		0
				0.087	1.629	0		0
Pickup	Operator Commuting	500		0.004	0.004	2	15	30
	Construction Commuting	1000		0.004	0.004	4	1	4
				0.004	0.004	0		0
Passenger Car				0.0008	0.0008	0		0
				0.0008	0.0008	0		0
				0.0008	0.0008	0		0
GRAND TOTAL								**814**

Total ESAL per Variation = ESAL per Year × Duration in Years

Description: Produced water treatment facility.

$$\text{DevelopmentTotalESAL} = \sum_{\text{VariationA}}^{\text{VariationZ}} \text{TotalESALPerVariation}$$

Non-residential Example - Final ESAL Calculations

Description- Winter motor sports shop open November-April.

Independent Road Impact Fee Calculation ESAL Tally Sheet

Vehicle Type	Variation	Empty Vehicle Trips per Year	Loaded Vehicle Trips per Year	Empty ESAL per Trip	Loaded ESAL per Trip	ESAL per Year	Duration (Yrs)	Total ESAL
2 Axle Single-Unit	Inventory Delivery	6	6	0.11	1.744	11.124	15	166.86
				0.11	1.744	0		0
				0.11	1.744	0		0
3 Axle Single-Unit	Dump trucks (construction)	4	4	0.344	2.38	10.896	1	10.896
	Concrete trucks (construction)	4	4	0.344	2.38	10.896	1	10.896
				0.344	2.38	0		0
Five Axle Tractor-Semitrailer	Construction equipment hauling		6	0.091	2.634	15.804	1	15.804
	Inventory Delivery	3	3	0.091	2.634	8.175	15	122.625
				0.091	2.634	0		0
Six Axle Tractor-Semitrailer				0.087	1.629	0		0
				0.087	1.629	0		0
				0.087	1.629	0		0
Pickup	Construction Commuting	500		0.004	0.004	2	1	2
	Customers	3000		0.004	0.004	12	15	180
	Employee Commuting	450		0.004	0.004	1.8	15	27
Passenger Car	Employee Commuting	450		0.0008	0.0008	0.36	15	5.4
	Customers	3000		0.0008	0.0008	2.4	15	36
				0.0008	0.0008	0		0
GRAND TOTAL								**577**

Step 4 - Calculate Road Impact Fee

Having estimated the grand total ESAL for the proposed development, the fee can be determined by multiplying the grand total ESAL by the adopted fee per ESAL (see current Rio Blanco County Road Impact Fee Schedule).

Total ESAL for Proposed Development × Road Impact Fee per ESAL = Road Impact Fee for Proposed Development

The examples below contain the fee current in 2008. Check the current fee schedule for the most up to date fee per ESAL.

Energy Development Example - Final Impact Fee Calculation

Independent Road Impact Fee Calculation ESAL Tally Sheet

Vehicle Type	Variation	Empty Vehicle Trips per Year	Loaded Vehicle Trips per Year	Empty ESAL per Trip	Loaded ESAL per Trip	ESAL per Year	Duration (Yrs)	Total ESAL
2 Axle Single-Unit	Inventory Delivery	6	6	0.11	1.744	11.124	15	166.86
				0.11	1.744	0		0
				0.11	1.744	0		0
3 Axle Single-Unit	Dump trucks (construction)	4	4	0.344	2.38	10.896	1	10.896
	Concrete trucks (construction)	4	4	0.344	2.38	10.896	1	10.896
				0.344	2.38	0		0
Five Axle Tractor-Semitrailer	Construction equipment hauling		6	0.091	2.634	15.804	1	15.804
	Inventory Delivery	3	3	0.091	2.634	8.175	15	122.625
				0.091	2.634	0		0
Six Axle Tractor-Semitrailer				0.087	1.629	0		0
				0.087	1.629	0		0
				0.087	1.629	0		0
Pickup	Construction Commuting	500		0.004	0.004	2	1	2
	Customers	3000		0.004	0.004	12	15	180
	Employee Commuting	450		0.004	0.004	1.8	15	27
Passenger Car	Employee Commuting	450		0.0008	0.0008	0.36	15	5.4
	Customers	3000		0.0008	0.0008	2.4	15	36
				0.0008	0.0008	0		0
GRAND TOTAL								**577**

Road Impact Fee per ESAL	**$9.07**	Impact Fee for Proposed Development	**$5,238**

Description: Produced water treatment facility

Non-Residential Example - Final Impact Fee Calculation

Description- Winter motor sports shop open November-April.

Independent Road Impact Fee Calculation ESAL Tally Sheet

Vehicle Type	Variation	Empty Vehicle Trips per Year	Loaded Vehicle Trips per Year	Empty ESAL per Trip	Loaded ESAL per Trip	ESAL per Year	Duration (Yrs)	Total ESAL
2 Axle Single-Unit				0.11	1.744	0		0
				0.11	1.744	0		0
				0.11	1.744	0		0
3 Axle Single-Unit	Dump trucks for construction pad	20	20	0.344	2.38	54.48	1	54.48
	Concrete trucks (construction)	4	4	0.344	2.38	10.896	1	10.896
				0.344	2.38	0		0
Five Axle Tractor-Semitrailer	Construction equipment hauling		45	0.091	2.634	118.53	1	118.53
	Water hauling (ongoing)	12	12	0.091	2.634	32.7	15	490.5
	Maintenance equipment hauling 2 yrs		20	0.091	2.634	52.68	2	105.36
Six Axle Tractor-Semitrailer				0.087	1.629	0		0
				0.087	1.629	0		0
				0.087	1.629	0		0
Pickup	Operator Commuting	500		0.004	0.004	2	15	30
	Construction Commuting	1000		0.004	0.004	4	1	4
				0.004	0.004	0		0
Passenger Car				0.0008	0.0008	0		0
				0.0008	0.0008	0		0
				0.0008	0.0008	0		0
GRAND TOTAL								**814**

Road Impact Fee per ESAL	**$9.07**	Impact Fee for Proposed Development	**$7,381**

Form 1.1 ESAL Tally Sheet and Impact Fee Calculation

Vehicle Type	Variation	Empty Vehicle Trips per Year	Loaded Vehicle Trips per Year	Empty ESAL per Trip	Loaded ESAL per Trip	ESAL per Year	Duration (Yrs)	Total ESAL
2 Axle Single-Unit				0.11	1.744			
				0.11	1.744			
				0.11	1.744			
3 Axle Single-Unit				0.344	2.38			
				0.344	2.38			
				0.344	2.38			
Five Axle Tractor-Semitrailer				0.091	2.634			
				0.091	2.634			
				0.091	2.634			
Six Axle Tractor-Semitrailer				0.087	1.629			
				0.087	1.629			
				0.087	1.629			
Pickup				0.004	0.004			
				0.004	0.004			
				0.004	0.004			
Passenger Car				0.0008	0.0008			
				0.0008	0.0008			
				0.0008	0.0008			
GRAND TOTAL								

× Road Impact Fee per ESAL	= Impact Fee for Proposed Development	

TRACK 2 - ESTIMATING EQUIVALENT SINGLE AXLE LOADS FOR NON-TYPICAL CONFIGURATIONS OR LOADS

Goal

First, a review of the two tracks for estimating axle weights offered in this manual:

- **Track 1** - A set of typical configurations that can be used to estimate empty and full axle weights and ESAL

- **Track 2** - Track 2 is a methodology and an array of base data sets for estimating ESAL for non-typical loads and configurations. Track 2 methodology parallels Track 1, except that track 2 requires that the applicant develop custom configurations for those deemed non-typical.

The only reason for using track 2 to estimate ESAL is if the proposed development will generate traffic *not* generally reflected by the typical vehicle configurations summarized in Figures 2 - 7. If the typical vehicle configurations generally reflect the traffic generated by the proposed development, Track 1 is recommended as a much less labor intensive approach, requiring less primary research done by the applicant.

Using both Track 1 for elements of the proposed development's traffic that are generally reflected by the typical vehicle configurations and Track 2 for traffic not reflected by the typical configurations generated by the project can be a viable approach to estimating total ESAL. The final step requires summing ESAL estimated using Track 1 and those estimated using Track 2.

Step 1 - Vehicle Configuration List

The first step in estimating a proposed development's ESAL generation is to list the types of vehicles driving to and from the site in a manner that provides relevant information for determining ESAL (often called configurations). The list should contain the vehicle types needed during both the construction phase and the ongoing operations/maintenance of the proposed development. In order to use Track 2 methodology to establish ESAL and the road impact fee, at minimum the applicant must know the total vehicle weight.

ESAL are a function of the weight and type of axles associated with a particular vehicle, so a basic understanding of axle types is necessary to then establish a vehicle type list.

Axle Types

A single axle can have either 2 or 4 wheels. Any vehicle contains at least one single axle because steering axles are always single axles.

A **tandem axle** refers to a combined set of two adjacent axles. Tandem axles usually have 8 wheels.

A **triple axle** refers to a combined set of three adjacent axles. Tandem axles usually have 12 wheels. Some triple axles involve a slider, an optional axle that optionally drops down to convert a tandem axle to a triple axle for heavy loads.

Establishing the vehicle configuration list must include the individual axle weights by axle type. Form 2.1 provides a template for listing the configurations. This manual offers two methods for establishing the configurations as required by Form 2.1:

1) Where both the total vehicle weight and the individual axle weights are known by the applicant, establishing the vehicle configuration is a matter of organizing the information into the template contained in Form 2.1.

2) Where the total vehicle weight is known, but the individual axle weights are unknown, the applicant may be able to estimate the distributions according to the axle weight distributions contained in the ensuing subsection: *Tools for Estimating Axle Weights*

The same vehicles commonly require listing 2 configurations, one empty and one loaded. In order to use Track 2 methodology to establish ESAL and the road impact fee, at minimum the applicant must know the total vehicle weight.

Tools for Estimating Axle Weights

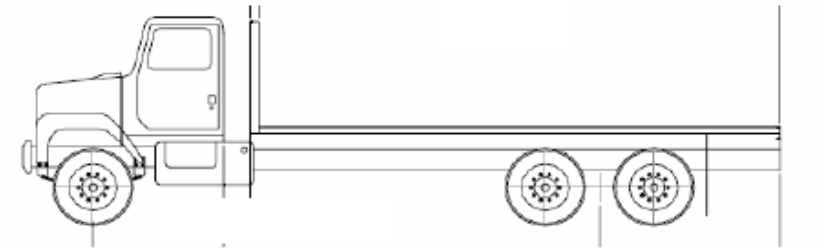
Using OPTI Truck weight distribution software by Sun Engineering, 2003, Analysts established axle weight distributions based on the typical configurations established in Track 1 above. Where the total empty and loaded vehicle weights are known, but the axle weights are not known, the axle distribution percentages below can provide the basis for an estimated individual axle weight.

IMPORTANT NOTE: Axles are counted from the front to the rear. For example on a 5 axle tractor semitrailer, the drive axle on the tractor is the "First Tandem Axle" while the tandem axle on the semitrailer is the "Second Tandem Axle".

Figure 11 - Single Unit Single Axle Weight Distributions

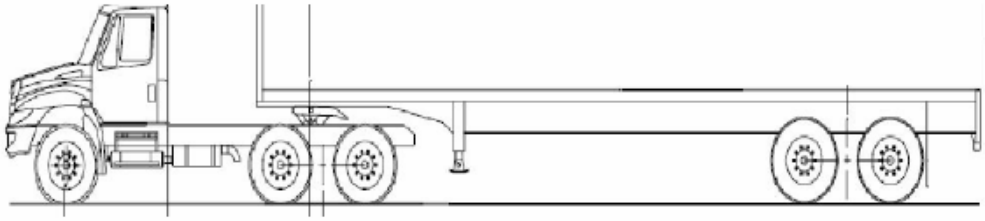
2 Axle Single-Unit	Empty	Loaded
First Single Axle	56%	38%
Second Single Axle	44%	62%

Figure 12 - Single Unit Tandem Axle Weight Distributions



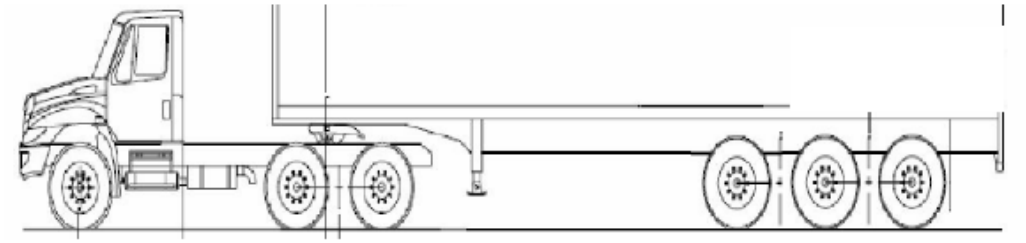
3 Axle Single-Unit	Empty	Loaded
First Single Axle	58%	32%
First Tandem Axle	42%	68%

Figure 13 - 5 Axle Tractor Semitrailer Axle Weight Distributions



Five Axle Tractor-Semitrailer	Empty	Loaded
First Single Axle	34%	14%
First Tandem Axle	33%	42%
Second Tandem Axle	33%	44%

Figure 14 - 6 Axle Tractor Semitrailer Axle Weight Distributions



Six Axle Tractor-Semitrailer	Empty	Loaded
First Single Axle	34%	14%
First Tandem Axle	33%	42%
First Triple Axle	33%	44%

Example Custom Configurations

Description: Gas Processing Facility and Pipeline

Construction: The construction phase requires a custom configuration calculation because the Track 1 typical configurations do not adequately reflect three vehicle configurations:

1) Component transport vehicle are seven axle combinations with a 4 axle semi trailer weighing 120 kips when loaded. The applicant knows the loaded axle weights from weigh station records.

2) Typical configurations do not cover 4 axle semi trailers, so the empty configurations for component transport vehicles must also be calculated using custom configurations. The applicant knows the empty axle weights from the vehicle's shop manual.

3) Pipe trucks weigh many tons more than the typical configurations when loaded. Empty pipe truck ESAL can be calculated using the typical configurations in Track 1. Because the applicant is sub-contracting the pipeline, they do not have empirical weights for pipe trucks. In lieu of empirical weights, the applicant used the axle weight distributions in Figures 11-14 to estimate axle weights:

95 kips × 14 % = 13300, and 95 kips × 42% = 39900, and 95 kips × 44% = 41800

Maintenance: Maintenance traffic is adequately reflected by the typical configurations in Track 1 and are estimated using the streamlined methodology offered by that track.

	Total Weight	1st Single Axle Weight	2nd Single Axle Weight	3rd Single Axle Weight	1st Tandem Axle Weight	2nd Tandem Axle Weight	3rd Tandem Axle Weight	1st Triple Axle Weight	2nd Triple Axle Weight	3rd Triple Axle Weight
Component Transport Loaded	120000	10909	17455		39273			52364		
Component Transport Empty	50000	12997	5180		16285			15539		
Pipe Trucks Loaded	95000	13300			39900			41800		

Form 2.1 - Custom Configurations Axle Weights

Configuration Description	Total Weight	1st Single Axle Weight	2nd Single Axle Weight	3rd Single Axle Weight	1st Tandem Axle Weight	2nd Tandem Axle Weight	3rd Tandem Axle Weight	1st Triple Axle Weight	2nd Triple Axle Weight	3rd Triple Axle Weight
n_1										
n_2										
n_3										
n_4										
n_5										
n_6										
n_7										
n_8										
n_9										

Step 2 - Look Up ESAL and Sum by Configuration

Having established the axle weights for each configuration, it is now possible to consult the tables D.1, D.2, and D.3 from *Design of Pavement Structures*, American Association of State and Highway Officials, Published by American Association of State and Highway Officials (AASTHO), 1993 to estimate that axle's ESAL.

Analysts have extracted the data from the AASTHO tables cited above given a structural number of 5 and p_t = 2. AASTHO offers ESAL estimates per trip in one ton increments, so to establish ESAL, axle weights must be rounded to the ton.

Figure 15 - One Trip ESAL by Axle Weight from AASTHO ESAL Tables

Axle Weight (kips)	ESAL Single Axle	ESAL Tandem Axle	ESAL Triple Axle
2	0.0002	0	0
4	0.002	0.0002	0.0001
6	0.009	0.001	0.0003
8	0.031	0.003	0.0007
10	0.079	0.006	0.002
12	0.174	0.013	0.003
14	0.338	0.024	0.006
16	0.603	0.042	0.009
18	1	0.069	0.015
20	1.57	0.109	0.024
22	2.35	0.164	0.035
24	3.4	0.239	0.051
26	4.77	0.33	0.071
28	6.52	0.466	0.098
30	8.7	0.627	0.131
32	11.5	0.829	0.173
34	14.9	1.08	0.225
36	19	1.38	0.288
38	24	1.73	0.364
40	30	2.16	0.454
42	37.2	2.66	0.561
44	45.7	3.24	0.686
46	55.7	3.91	0.831
48	67.3	4.68	0.999
50	81	5.56	1.19
52		6.56	1.41
54		7.69	1.66
56		9	1.94
58		10.4	2.25
60		12	2.6
62		13.8	2.99
64		15.8	3.42
66		18	3.9
68		20.5	4.42
70		23.2	5
72		26.2	5.63
74		29.4	6.33
76		33.1	7.08
78		37	7.9
80		41.3	8.79
82		46	9.8
84		51.2	10.8
86		56.8	11.9
88		62.8	13.2
90		69.4	14.5

Example - Lookup ESAL for Custom Configurations

Description: Gas Processing Plant

	Total ESAL per Trip	1st Single Axle ESAL	2nd Single Axle ESAL	3rd Single Axle ESAL	1st Tandem Axle ESAL	2nd Tandem Axle ESAL	3rd Tandem Axle ESAL	1st Triple Axle ESAL	2nd Triple Axle ESAL	3rd Triple Axle ESAL
Component Transport Loaded	4.4290	0.0790	1.0000		2.1600			1.1900		
Component Transport Empty	0.1104	0.0174	0.0090		0.0420			0.0420		
Pipe Trucks Loaded	2.9520	0.3380			2.1600			0.4540		

Form 2.2 - Custom Configurations ESAL

Configuration Description	Total Weight	1st Single Axle ESAL	2nd Single Axle ESAL	3rd Single Axle ESAL	1st Tandem Axle ESAL	2nd Tandem Axle ESAL	3rd Tandem Axle ESAL	1st Triple Axle ESAL	2nd Triple Axle ESAL	3rd Triple Axle ESAL
n_1										
n_2										
n_3										
n_4										
n_5										
n_6										
n_7										
n_8										
n_9										

Step 3 - Calculate Custom Configurations' Total ESAL

In order to calculate total ESAL the applicant must estimate the number of trips per year each configuration would travel to construct/maintain the proposed project.

Construction Phase: Project construction is temporary, but can continue for multiple years depending on the scope of the proposed development. Even a short construction duration (say 2 months) would be listed in the ESAL Tally Sheet as a 1 year vehicle trips.

Operations and Maintenance (15 years Maximum): Most development is built to last for decades, but the realistic planning horizon for addressing impacts of future development is of a shorter duration than the lifespan of the development itself. The capital improvements planning horizon is 15 years into the future, so the maximum duration for maintenance and operations should be 15 years. If the development would generate traffic for shorter durations, those may also be listed for each vehicle type.

The mathematics to determine the *ESAL per Year* for <u>each</u> configuration follow:

$$\text{ESAL per Year} = \text{Configuration } n_n \text{ Vehicle Trips per Year} \times \text{Configuration } n_n \text{ ESAL per Trip}$$

Next, calculating the total ESAL for <u>each</u> vehicle type, vehicle trips, and duration variation can be accomplished as follows:

$$\text{Total ESAL per Configuration} = \text{ESAL per Year} \times \text{Duration in Years}$$

Finally sum all ESAL by variation to get the grand total,

$$\text{DevelopmentTotalESAL} = \sum_{\text{Variation}-n1}^{\text{Variation}-nn} \text{TotalESALPerConfiguration}$$

See the examples to further clarify this process.

Resources for Estimating Vehicle Trips

Helpful Sources: *Trip Generation 7 Edition*, Institute of Transportation Engineers, 2003; *Design of Pavement Structures*, American Association of State and Highway Officials, Published by American Association of State and Highway Officials (AASTHO), 1993; *Highway Capacity Manual*, Transportation Research Board, 2000; *Policy on the Geometric Design of Highways and Streets*, American Association of State and Highway Officials, Published by American Association of State and Highway Officials (AASTHO), 2004;

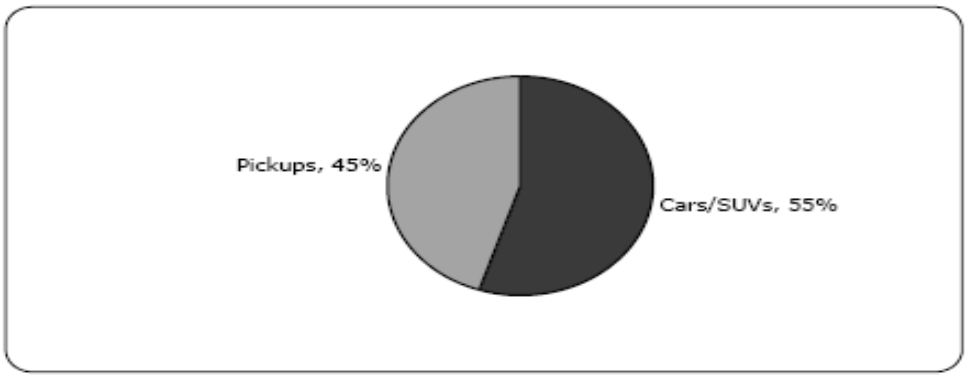
Average daily trips as used in the Rio Blanco County Impact Fee Support Study integrate the mean pass-by adjustment of 50% to account for combined trips. The driveway volume could be calculated by dividing the average daily trips per 1000 sq. ft. below by .5.

Figure 16 - Average Daily Trips per 1000 Sq. Ft. of Nonresidential Floor Area

	Average Daily Trips/1,000 sq. ft.
Shopping Center	21.46
Office / Institutional	5.51
General Commercial	6.38
Light Industrial	3.49
Warehousing	2.48
Manufacturing	1.91

The vehicle types for passenger vehicle traffic (pickups, cars, and SUVs) can be implied by the 5 of each owned by residents in Rio Blanco County.

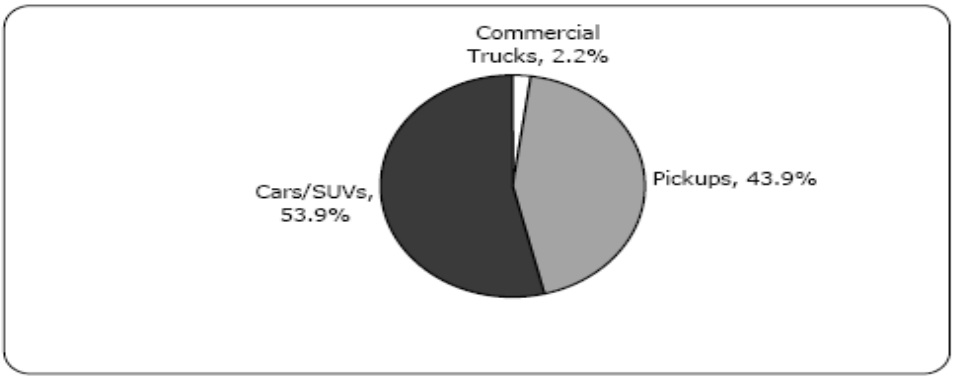
Figure 17 - Car & SUVs vs. Pickups Owned in Rio Blanco County



Source: Colorado Department of Revenue Annual Report 2005

In considering non-residential land uses, it is important to ascertain the amount of commercial truck traffic generated by a proposed development.

Figure 18 - Trucks, Cars., SUVs and Pickups for Non Residential Land Uses



Sources: ITE Trip Generation Handbook 2003, Colorado Dept. of Revenue

Example - Calculate Total ESAL for Custom Configurations

Description: Gas Processing Plant

Construction Phase: Component transport will be phased over one year and will involve 30 round trips, 30 loaded and 30 empty

Pipeline construction will take 2 years with 1-2 trucks hauling pipe per month for a total of about 75 loads per year. The empty pipe truck ESAL are calculated using Track 1 typical configurations.

Operations and Maintenance: Calculated entirely using typical configurations.

Configuration	Vehicle Trips per Year	ESAL per Trip	ESAL per Year	Duration (Yrs)	Total ESAL
Component Transport Loaded	30	4.429	132.87	1	132.87
Component Transport Empty	30	0.1104	3.312	1	3.312
Pipe Trucks Loaded	75	2.952	221.4	2	442.8
Total ESAL from Custom Configurations					**579**

Step 4 - Calculate Road Impact Fee

Having estimated the grand total ESAL for the proposed development, the fee can be determined by multiplying the grand total ESAL by the adopted fee per ESAL (see current Rio Blanco County Road Impact Fee Schedule).

[Total ESAL from Track 1 + Total ESAL from Track 2] × Road Impact Fee per ESAL = Road Impact Fee for Proposed Development

The examples below contain the fee current in 2008. Check the current fee schedule for the most up to date fee per ESAL.

Example - Final ESAL and Fee Calculations

Description: Gas Processing Plant and Pipeline

Configuration	Vehicle Trips per Year	ESAL per Trip	ESAL per Year	Duration (Yrs)	Total ESAL
Component Transport Loaded	30	4.429	132.87	1	132.87
Component Transport Empty	30	0.1104	3.312	1	3.312
Pipe Trucks Loaded	75	2.952	221.4	2	442.8
				Total ESAL for Custom Configurations	**579**

ESAL Calculated Using Track 1 Typical Configurations	603
+ ESAL Calculated Using Track 2 Custom Configurations	579
=Total ESAL for Proposed Development	1182
×Road Impact Fee per ESAL	$9.07

=Road Impact Fee for Proposed Development	**$10,721**

Form 2.x - Proposed Development Total ESAL and Road Impact Fee Calculation

Configuration Description	Vehicle Trips per Year	ESAL per Trip	ESAL per Year	Duration (Yrs)	Total ESAL
Grand Total ESAL for Custom Configurations					

ESAL Calculated Using Track 1 Typical Configurations	
+ ESAL Calculated Using Track 2 Custom Configurations	
=Total ESAL for Proposed Development	
×Road Impact Fee per ESAL	

=Road Impact Fee for Proposed Development	