Transportation constitutes nearly 20% of household expenditures, 30% of U.S. greenhouse gas (GHG) emissions, and 70% of domestic petroleum consumption. In a world of limited resources, volatile materials prices, energy security issues, and multiple environmental concerns, it is imperative to understand and accurately model how transportation investments and policies impact stakeholders' and society's bottom lines. Economic practice and theory require familiarity with a variety of costs and benefits. So do transportation engineering and planning practice. This chapter presents the most common cost and benefit concepts encountered in transportation economics. A transportation project's or policy's economic value can be estimated by anticipating its potential costs and benefits. Table 1.1 lists the typical costs and benefits considered in this chapter's transportation context, and Figure 1.1 illustrates them. Economists regularly refer to variable and fixed costs, and Figure 1.1 illustrates this complementary relationship, with dashed lines around capital and operating costs indicating that these can be either variable or fixed in different contexts. Further, the figure illustrates that all costs can be categorized as internal or external costs, and this chapter describes their inter-relationships.

1.2 Internal Costs and Benefits

Broadly speaking, **internal costs** are those borne by system operators and/or users while **external costs** are those borne by non-users. Internal costs include construction, maintenance, operation, and road user costs (e.g., fuel and registration fees). External costs, such as noise and air pollution costs borne by members of the community other than the transportation system users, are discussed later in this chapter. In computing internal costs, an appreciation for the difference between real accounting costs and opportunity costs is necessary. The former are real, experienced, monetary costs, while the latter are potential, missed benefits, as described below.

Accounting Cost:

Accounting costs refer to transactions when real monetary changes occur. These costs are represented in traditional engineering project cost estimates—including but not limited to construction, maintenance, and operation costs. These costs can occur once, as in the case of initial project costs (like ROW acquisition and design), or be regular and continuous, as in the case of operations, maintenance, and rehabilitation. Distinctive accounting-cost concepts are presented in the following sections

Capital vs. Operating Costs

In transportation, **capital costs** typically refer to *fixed capital costs* for facilities and *mobile capital costs* for vehicles. **Operating costs** are incurred for goods and services used to maintain and operate a facility, vehicle, or service. The benefit counterpart to operating costs is *operating revenues* (as well as *savings* in operating costs). Accounting techniques effectively merge capital and operating costs by including depreciation of capital goods within operating expenses. Categories of operating costs are essentially the same across all modes, whereas capital costs differ,noted inTable1.2.

Mode	Capital Costs	Operating Costs
Automobiles	Vehicle, roadway, traffic	
	signals	
	Fuel,	
		labor, maintenance,supplies
Railroads	Rail cars, tracks, stations, rail	
	yards, signal systems	
Airlines	Airports, traffic control	
	systems	
	Ships Ports, ships	

Estimating Capital Costs

Transportation planners and engineers must assess a number of capital costs when estimating project expenditures during the planning phase. In addition to standard construction costs, funding must be allocated for project design, environmental process activities, and ROW acquisition. The FHWA also recommends that a 5–10% contingency be included in projects to account for unforeseen changes, though a contingency of up to 15% may be used for projects particularly susceptible to "scope creep." Low-risk projects must have well-defined scopes and schedules and properly identified risks and uncertainties. For projects entailing substantial risk and/or uncertainty, the FHWA recommends that ranges be used for early estimates. For example, a planning stage estimate could state project cost as $15 million, with a 95% confidence interval or probable range of $14 million to $18 million. Two basic procedure types are used to estimate project construction costs: detailed bid item estimates and broader conceptual estimates. *Bid item estimates* are conducted by estimating quantities and prices of specific items that contractors will bid on. An engineer may estimate, for example, that a project will require 300 linear feet of 36 in. diameter corrugated metal pipe (CMP) as one bid item. The engineer must then determine the price per foot of 36 in. CMP. He or she may do this by reviewing historical projects that used 36 in. CMP, emphasizing recent installations in nearby and similar locations with similar quantities of 36 in. CMP and similar project sizes. The FHWA cautions against using historical bid prices unless the projects are for similar work and similarly sized. As an alternative or supplement to estimating based on historical bid prices, the engineer may estimate the price that a potential contractor will purchase 36 in. CMP for and anticipate the labor and equipment costs required to install it. Regardless of whether historical bid prices or materials and labor are used to generate estimates, engineering judgment should be used for all assumptions. However, detailed bid item estimates are often time consuming and the individual quantities may be hard to obtain before substantial design work has been completed.

Conceptual cost estimates are typically appropriate for sketch planning because they require a lower level of detail. A conceptual estimate is similar to a bid item estimate in that quantities of specific items are estimated and assigned a cost per unit. The difference lies in

the magnitude and number of the quantities being estimated. A large project would look at the number and characteristics of new lane miles, on and off ramps, signalized intersections, bridges, and other *major* items. The costs of smaller items are figured into the larger ones. For example, a conceptual estimate would estimate the cost of a "50-foot by 3-mile resurfacing using 6 inches of asphalt treated base and 4 inches of asphalt" instead of estimating individual quantities and prices for tons of asphalt, tons of asphalt-treated base course, square feet of pavement removal, concrete manhole collars, and other items that may be measured in a bid item estimate. For example, generic cost-per-mile models developed by the Florida Department of Transportation estimated the 2012 cost of new construction of a twolane divided urban interstate with median, barrier walls, and full inside and outside shoulders to be $8.9 million per mile, and the cost of a rural arterial widening from two lanes to four lanes with shoulders to be $2.0 million per mile. The FHWA recommends that certain items such as traffic control, environment mitigation, and utility relocation be estimated separately from the base project and itemized within the final estimate. Design and ROW costs must also be anticipated. Design is often calculated as a percentage of project costs. Agencies typically assign a default design cost percentage, then adjust it up or down based on the project's complexity. Also, design cost percentages for very small projects are generally higher because various administrative overhead costs typically apply, regardless of project size. ROW costs can be estimated during the planning process by first estimating the amount and location of new ROW required and then ascertaining whether any structures will be taken (e.g., parking lots and billboards). General property values (per square foot or acre) can then be applied for an early estimate of acquisition costs. Regression models using past ROW acquisition cost data (e.g., from TxDOT's ROW Information System database) can also be developed, and their parameter estimates used, as provided under TxDOT projects 0-6630 and 0-4079, and as discussed in the Case Studies section of this Reference.

Estimating Operating Costs Changes in operating costs may be determined by using standard values for expected operation and maintenance costs. Agencies often estimate standard maintenance costs for each foot-mile or lane-mile of pavement. Items such as road signs, guardrail, luminaire heads, and signal indications may have design lives shorter than the project life, so their replacement should be factored into maintenance costs. For projects with substantial new electrical features, daily electricity demands for illumination, signals, and intelligent transportation system applications must also be included. In general and in the short run, capital costs tend to be considered **fixed costs**, while operating costs tend to be considered **variable costs**. As discussed in a later section of this chapter, all costs are variable in the long run, though the time horizon for which that is true varies by project type. All facilities eventually need to be replaced or updated, and the costs for doing so can be considered variable costs over the long term, or fixed capital costs at/near the time of their application.

COST ANALYSIS OF AIR TRANSPORTATION

Cost is the amount invested by the producer on four factors of production to produce a good or services. Cost is classified into various types, they are money cost, real cost, opportunity cost etc.

Money cost means the amounts invested in the form of money in the process of production of a good or services by the producer is known as money cost. Whereas the sacrifices done by the labour are known as real cost, opportunity cost means next best alternative cost.

There are some other types of costs known as implicit and explicit cost. Costs which are not expressed in the books of accounts are known implicit cost, costs which are expressed in the books of accounts are known as explicit cost. Cost invested over a period of time is known as historical cost. There are other types of costs which are known as economic costs or accounting costs, they are fixed costs, variable cost, total cost, average fixed cost, average variable cost, average total cost or average cost.

Let us understand the different types of costs invested in air transportation sector and how they can be classified. The list of various types of cost invested in the air transportation sector

1) Flying operation expenditure
2) Direct maintenance expenditure
3) Passenger services expenditure
4) Aircraft servicing
5) Reservation and sales of ticket
6) Advertisement and publicity
7) General and administrative expenditure

Flying operation expenditure includes crew wages, fuel expenditure. Direct maintenance covers the cost of labour and material directly related to maintenance and repair of aircrafts which includes periodical overhauls and other flight equipment, the other cost invested by air transportation sector is maintenance burden, and maintenance burden means overhead cost related to the upkeep and repair of flight equipment and other property. Passenger service expenditure covers the cost of food provided to the passengers and provision of cabin attendance or any other services provided for the comfort of the passengers. Aircraft service expenditure refers to routine service such as washing the aircraft, cleaning the cabin passenger but not mechanical servicing. This aircraft servicing expenditure also includes landing fees, reservation and sales of tickets as well as advertising and publicity expenditure comes under selling cost. That means cost invested to increase the demand for their service or product. General and administrative costs are the expenditures made for general administration of the organisation or for any other purpose to run the organisation.

The above classification of cost in air transportation is one type but there are other types of classification of cost in air transportation. One of the other ways of classification cost in air

transportation is 1) capacity cost 2) overhead cost 3) traffic related cost. The expenditures made for the maintenance of aircrafts, for landing fees fuel expenditure, pilot salaries, cabin crew wages etc. comes under capacity cost. Overhead costs are the costs which are invested by the service provider to maintain the office administrative functions or any other type of general administration. Whereas the traffic related costs are the expenditures made on ticketing, passenger facilities, and baggage handling charges, aircraft services and terminal expenses.

The above classifications are made based on accounting system but practically speaking the air transportation costs are further classified into various types to make managerial decisions. They are common cost, separable cost, fixed cost, variable cost, fully allocated cost, out of pocket cost, direct operating cost, terminal cost, and Line haul cost.

Separable cost / discrete cost

Expenditure made by the service provider for a particular purpose like facilities provided for the passengers in the cabin attendant wages, ticketing or sales costs comes under separable cost or discrete cost. These are all the expenditures which we can discrete them from other type of expenditures which cannot be specified.

Common cost/ Non-discrete cost

This non-discrete costs or common cost cannot be logically understood for what purpose the cost is made. For example pilot and crew expenditure is the best example for this non-discrete cost. Because pilot or crew expenditure is made for both passenger as well as fright transportation but we never expressed this cost in such a way that pilot wages for passenger flight or for cargo flight.

Separable cost / discrete cost

Cost which are incurred for a specific purpose or the cost which can be expressed specifically that they have incurred for a specific purpose are known as separable cost or discrete cost. The expenditure made by the service provider for a particular purposes like provision of special food, drinks, these expenditures are logically separable from other type of non-discrete cost.

Out of pocket cost /frontier cost/ marginal cost

The cost invested by the service provider to provide an additional service Or It is an additional amount invested to provide service for an extra passenger. In air transportation it is almost all considered as marginal cost. For example if suddenly one extra passenger boarded the flight then the cost invested to provide the service to that extra passenger is known as out of pocket cost or frontier cost. Just adding one passenger to the same flight will not change the frontier cost but if the service provider wants to increase the number of flights then that rise in consumption of fuel, pilot charges, terminal charges, in turn this increases frontier cost.

Constant cost/ static cost / fixed cost

The static costs are the cost which does not varies according to change in the traffic. For example cost invested on the fixed assets and certain type of general administrative costs comes under this static cost. These costs are called as static costs because they are fixed in nature and do not vary in short period and according to traffic.

Dispatched cost

The cost incurred to carry a particular unit of traffic or passenger is known as dispatched cost or fully allocated cost. This includes frontier cost as well as static cost for example, if any passenger booked a round trip ticket for a tourism purpose where the return trip ticket can be used only after few days whenever the passenger wants to return. if the passenger wants to board to a flight then the service provider has to meet this surprise expenditure. That means a service provider has to provide food and other services (frontier cost) to that passenger and at the same time the service provider has to use his administrative staff also (static cost) to provide him boarding pass and other things.

Line haul cost

Line haul costs are the expenditures which are directly related to the time and mileage while the aircraft is flight. This includes pilot and other crew wages fuel cost etc. if the time and mileage is more then it leads to raise in this line haul cost.

Terminal cost

The terminal costs are the amount spent by the service providers like, aircraft servicing, expenditure on reservation, or any other expenditures made at airport. This terminal costs are not related to mileage or time, but they are related to number of passengers or freight but the amount spent by the service provider on warehouse to keep the freight comes under overhead cost. At the same time the amounts spent by the service provider to pick-up and book the freight to mobilise it to the warehouse and aircraft comes under terminal cost. This terminal costs are also known as ground cost.

Direct operational cost / trip cost

As already we discussed in the previous concept the expenditures which are incurred by the service providers when the aeroplane is in flight such as pilot and cabin crew wages, fuel cost etc. this does not includes ground cost. Perhaps ground cost some times is also considered as indirect operational cost.

Indirect operational cost

The costs which are spent by the service provider irrespective of amount of traffic are known as indirect operating cost. As we discussed in the previous concept the ground costs are the terminal costs are also considered as indirect operational cost.

Seat mile cost / a unit's trip cost

The total amount which service provider has to spent transport a unit of freight or a single passenger This seat mile cost is higher in case of short haul flights when compare to long haul flights.

In the above paragraphs we discussed various terms and types of costs which are used in the air transportation economics. Now we will try to fit these costs into the framework of micro economic cost theory.

In micro economic theory cost analysis play a major role in understanding markets and to take business decisions. Cost concepts are classified in a different way basing on the nature of cost. i.e. to a given change in the quantity of output and time how cost is responding is considered and basing on the response of the cost basically it is classified into two types, Fixed cost and variable cost. By using these two types of costs we can derive the other various types of costs which are used in micro economics or in business economics.

There are different factors which are influencing the cost. The influence of some of factors can be identifiable in the behaviour of the cost. This can be understood with the help of cost function.

Cost function

A cost function is the functional representation of the relationship between cost and cost factors like price of inputs, size plant, and level of technology.

$$C = f(F, Q, P, T)$$

C stands for the costs,

f denotes functional relationship,

F refers to the factor-input prices,

O stands for the rate of output,

P refers to the size of plant, and

T stands for the state of technology.

In short period to any given change in these factors if the cost remains same then it is called as total fixed cost and if the cost is also varying according to the change in the factors then it is called as total variable cost. Now we will try to discuss more about total fixed cost and total variable cost.

Total fixed cost (TFC)

The fixed can also be defined as the cost which does not alters in short period. This total fixed cost will not change with a change in the output in short period. The main characters

of fixed cost are a) it does not alter in short period, b) Even though there is no production of good or services the producer has to bare the fixed cost. Examples for fixed costs are infrastructure expenditure. In air transportation sector the expenditure made on overheads or any other fixed assets will come under fixed cost, at the same time cost invested to purchase the aircrafts also comes under fixed cost, but the fixed cost will remain constant only in short period, if the producer is going to change his production function in long run then he has to increase his infrastructure, for instance if service provider running with one aircraft, and he wants to increase the number of services, then he has to purchase another flight or he has to increase the infrastructure. Thus it leads to a raise in the total fixed cost in long run.

Total variable cost (TVC)

Cost which alters in short period is known as variable cost or otherwise we can define total variable cost as a cost which is invested on variable assets. For example; fuel cost, passenger service cost, terminal cost, pilot crew charges are variable costs. The main characters of variable cost are; it changes according to change in the output in short run, if there is no output, variable cost does not exists for example, if the service provider cancelled a trip then he need not spent any amount on fuel or on crew.

If the service provider wants to increase number of trips then he require to use more fuel and at the same time he requires more number of pilot and cabin crew thus it leads to increase in variable cost with an increase in the number of trips.

This TVC will not increase in the same proportion, initially it increases at a decreasing rate (slow manner) but after a point it starts raising at an increasing rate (rapidly) this is because of operation of law of variable proportions.

Total cost

The sum of total fixed cost and total variable cost is known as total cost.

$$TC = TFC + TVC$$

In air transportation sector total cost is the sum of total fixed cost and variable cost like fuel, pilot and crew charges, terminal expenditure, passenger service expenditure, aircraft service expenditure.

The unique character of total cost is the TC becomes equal to TVC in short period because fixed cost remains constant in short period. That means in short period anyhow overhead cost, general administration cost remains same, but passenger services expenditure, fuel expenditure, terminal cost will vary according to change in the traffic or number of trips. Because of this relation varies in the same proportion as TVC

The behaviour of TC, TFC, and TVC is explained in the following table and diagram.

QUANTITY	TFC	TVC	TC
0	100	0	100
1	100	15.15	115.15
2	100	18.8	118.8
3	100	21.25	121.25
4	100	23.75	123.75
5	100	27.05	127.05
6	100	30	130
7	100	33.65	133.65
8	100	40.75	140.75

From the above hypothetical schedule and graph we can find out the following important characteristics of TC, TVC, and TFC. In the above figure TFC is the total fixed cost which is the horizontal straight line because the TFC remains same throughout the short period , TVC is indicating total variable cost curve when the service provider is not providing any trip or services to passengers then he need not spend anything on fuel or on passenger services then TVC is zero so it starts from origin.

Here TC indicates total cost. The TC curve starts above from origin, in another way it starts from the point where TFC curve is starting. Remember that Total cost is the aggregation of Total Fixed cost and Total variable cost and the distance between TC curve and origin indicates Total fixed cost.

Basing on TC, TVC and TFC we can derive other types of costs Average cost, Marginal cost etc. we have already came across these types of costs, perhaps called with different terms in air transportation sector. Now we are going study the micro economic analysis of other various types of costs along with terms and examples from air transportation sector. To understand the other types of costs we are using the following hypothetical cost schedule.

Average fixed cost

Per unit fixed cost is known as average fixed cost, the other way to explain the average fixed cost is, 'it is the minimum fixed cost required to provide a service per one unit of traffic i.e. either for one passenger or particular unit of freight'. For example if service

provider wants has to provide trip even to a single passenger he has to maintain a minimum general administration and an aircraft.

The average fixed cost can be calculated by dividing the total cost with number of units of traffic.

AFC = Average fixed cost

TFC = Total fixed cost

Q = Units of traffic (passengers or freight)

Average fixed cost tends to decline with every increase in the output because whatever the fixed cost invested by the service provider get spread over in number of units, therefore average fixed cost tends to decline.

Average fixed cost curve is a negative sloping curve falling from left to right downward. (Graph)

Average variable cost

It is the minimum variable cost required to provide service for a single unit of traffic. This average cost can be calculated with the following equation.

AVC =

AVC = Average variable cost

TVC = Total variable cost

Q = Quantity

This average variable cost initially declines with an increase in the output but once if the service provider is able to run the trip with full occupancy then after every increase in his service increases average variable cost. For example the service provider is providing aircraft from city to A to B he is incurring the cost of **X** on fuel he has to incur this cost even if one passenger is travelling or more than one passenger is travelling. the average variable cost tends to decrease with every increase in the number of passengers. Once after reaching full occupancy then for further increase in the service again the service provider has to spend some required amount of variable cost.

AVC curve is slightly 'U' shaped curve. That 'U' shape of the AVC curve indicates initially average variable cost tends to decrease later it tends to rise. (Graph)

Average cost / Average total cost

Average cost is the sum of average total cost and average variable cost. AC can be calculated with the following equation.

$$\Longrightarrow AC = AFC + AVC$$

This AC is derived from the summation of AFC and AVC, even this AC curve is also derived by super imposition of average variable cost curve over average fixed curve. ATC curve is a 'U' shaped curve because AC curve is determined by AFC and AVC curves respectively. Initially because of the pre-dominance of AFC, though the AVC is raising but ATC tends to decline. But after certain point due to the expansion of output AFC continues its fall but AVC starts rising rapidly. Because of the rising trend of AVC, AC starts rising, again AC-curve attains a positive slope. In total initially AC-curve is a negative sloping curve later it attains positive slope, so it is 'U' shaped curve. Another important point about the ATC behaviour is while it is diminishing it diminishes rapidly but while raising it rises slowly. (Graph)

Marginal cost

Additional cost invested to produce one additional unit is known as marginal cost. "Frontier cost" or "Out of pocket cost" in air transportation sector comes under marginal cost.

$$MC = TC_n - TC_{n-1}$$

MC = marginal cost

TC_n = Total cost of n^{th} unit

TC_{n-1} = total cost of last but one unit

Marginal cost is the rate of change in the total cost. The marginal cost is the slope of total cost curve at corresponding quantity. We can derive MC curve from TVC curve also, though AVC and MC curves can be derived from TVC, but AVC and MC curves will not be the same. MC curve is a 'U' shaped curve as we discussed at 'Average total cost' ATC curve is also 'U' shaped curve but there is a difference in the behaviour of MC, initially MC declines slowly but after a point it starts rising rapidly. (Graph)