Example of a Common Resource: Highway Congestion

Assume that up to 5 cars can travel on a given section of I-5 without impeding the other cars, the average travel time (AC) = 30 mins (Seattle to Everett)

Simplifying assumption, to get to Everett from Seattle on an alternate route: Hwy 99 or arterials takes 1 hour regardless of congestion.

Every car after the 5^{th} car that enters the freeway slows the current cars down by 3 minutes. This is an externality because the marginal driver only considers the time it saves on travel time, and not the fact that it adds to congestion. Personally, when you decide to enter the freeway, is your decision to enter or not enter due to your altruism or due to your schedule?

AC(n) = average cost (travel time) per commuter given the number of cars
TC(n) = total travel time of all commuters given the number of cars.
MC(n) = marginal cost of adding one more car. The change in total travel time / change in number of cars.

Some algebra

$TC(n) = n\ AC(n)$ Eqn (1)

$TC(n+1) = (n+1)\ AC(n+1)$ Eqn (2)

$MC(n+1) = TC(n+1) - TC(n)$ Eqn (3)

Plug (1) and (2) into (3)

$MC(n+1) = (n+1)AC(n+1) - n\ AC(n)$

$= AC(n+1) + n\ AC(n+1) - n\ AC(n)$

$= AC(n+1) + n\ (AC(n+1) - AC(n))$

MC(n+1) = avg time for latest car + externality exerted on cars currently on highway

Given the assumptions on travel time, we can generate the following table of commuting on I-5.

n cars	avg travel	total travel	Marginal travel
4	30	120	30
5	30	150	30
6	33	198	48
7	36	252	54
8	39	312	60
9	42	378	66
10	45	450	72
11	48	528	78
12	51	612	84
13	54	702	90
14	57	798	96
15	60	900	102
16	63	1008	108

How many people will merge onto the freeway?

15 cars. Commuters are only concerned on how long it takes them to commute. Listening to the traffic report they decide whether or not to join the freeway by considering the current average travel time. They merge until the AC = one hour, the amt of time it takes on hwy 99. The 15 car is indifferent between I-5 and hwy 99, and will join the freeway. We get the common property outcome, nobody bears the full cost of their actions (we have an externality).

The 15^{th} car's MC = 102 minutes = 60 minutes + 14*3
It saves no time on the freeway, and slows other cars down by 42 minutes.

The efficient level of cars = 8 cars.

8^{th} car's MC = 60 = travel time (39 minutes) + slows down other cars (7 *3 = 21 mins)
Here, the amount it saves over hwy 99 is 21 minutes. 60 – 39 = 21 minutes.
The marginal benefit of time saved = the cost it exerts on the other drivers! Similar to our results when we look at markets for goods; we have efficiency when the marginal benefits of consumers equal the marginal costs to the firms.

How would we get this efficient use of the freeway?

Charge a toll. The toll puts a price on congestion.
Say the policy maker finds out that on average the commuters make $6.00/hr, think of this as the opportunity cost of commuting. (This average wage was picked for the simplicity any other wage would just increase the amount for the optimal toll).

- ⇨ $0.10 a minute.
- ⇨ 8^{th} car saves 21 mins
- ⇨ Optimal toll = 0.10 * 21= $2.10

Toll / car	N Cars	Total toll
$3.00	5	$15.00
$2.70	6	$16.20
$2.40	7	$16.80
$2.10	***8***	***$16.80***
$1.80	9	$16.20
$1.50	10	$15.00

Note that this optimal per car toll, in addition to getting the socially optimal amount of traffic , also maximizes the total toll amount collected.