McPeak
Lecture 14
PAI 723

Costs and Benefits.

Many projects or policies have a temporal dimension to the flow of costs and benefits.

> A common pattern in infrastructure, education, and basic research is an up-front cost that generates a future flow of benefits.

We need a way to evaluate the efficiency of these projects to help us decide what to select and what to reject.

CBA is a tool to evaluate different uses of societal resources.

> Do the benefits to society exceed the costs to society?

Values in the future are going to be expressed in present value.

We will use a discount rate r.

The overall assessment on efficiency grounds is the Kaldor–Hicks criterion.

> It is an efficient use of society's resources if it is potentially possible through redistribution of outcomes to meet the Pareto optimality definition.

The analysis is done from the point of view of what is the best use of society's resources to meet society's needs.

It is *ex ante* analysis of future scenarios.

Analysis is on a timeline before decision point t = 0. It is based on predictions about what will happen including and after t = 0.

It is comparing counterfactual future scenarios "with" a policy or project compared to other alternative future(s); at least one is "without" the policy or project as the status quo.

> This "without" scenario has the sense of what happens if we keep doing in the future what we are doing now.

One measure we may use of social welfare is national income.

In this case, for society as a whole, increasing national income is the objective. Anything that reduces national income is a cost and anything that increases it is a benefit.

Anything that reallocates it from one party to another is a transfer.

Compare to financial analysis where a dollar is a dollar. There, we would worry about tax taking money from us to give to them. Here it is not an issue.

[return to DWL argument and can use example of user fees in the commons]

Transfers:
Tax payment.
Subsidy.
Credit payments.

These don't create or diminish national income, they just move it from one party to another.

We have multiple claimants on a given resource.

What is done with the money that is loaned (loan money to buy fertilizer, fertilizer is a cost increased output is a benefit) may impact national income, but the loan payment that divides up the value of the product harvested does not.

Real resource flows are critical to identify. A tax is a claim on a real resource flow. A loan payment is a claim on a flow.

We are looking to identify uses of the best use of societal resources.

Steps to Cost-Benefit analysis.

1) Define the situation
2) Identify and value the costs
3) Identify and value the benefits
4) Discount future cost and benefits to identify net present value
5) Consider the implications of the choice made on NPV income terms for other objectives (equity for example)
6) Sensitivity analysis.
7) Interpret results

1) Defining the situation:

What is the community whose resources are relevant to the program being evaluated?

What is the spatial extent of the proposed project?

What are the current resources in this community in terms of: money, property, labor, environmental amenities, and government services for the community?

What will happen if the project is not implemented?
Identify and value the costs and benefits that arise with the project and compare to the situation without the project.

Who has “standing”?

Who Has “Standing”?

Dam is here

Manantali Dam, Mali

1. Hydro-power for urban residents in Dakar, Nouakchott, Bamako
2. People upstream of dam now have lands under water
3. People downstream recessional flood cultivation disrupted
4. Fishery downstream disrupted
5. Farmer–herder conflict in 1989 near Bakel
6. Expulsion of people from Mauritania to Senegal
7. Expulsion of people from Senegal to Mauritania

Since CBA is a question of what is best use of society’s resources, need to analyze all who experience benefits and costs

“With” and “without” is not the same as “before” and “after”.

Incremental net benefit with and without project.

Patterns:
With grows at a faster rate than without.
With stops a decline that will happen without.
With leads to an increase, without a decrease.

2) Identify and value the costs

Physical goods. Materials that are easy to identify.
Labor. People working and getting paid for it.
Land. The place where the project is taking place.

Consider contingency allowances. Recognizing that there will be changes in physical conditions or prices over the course of the project and putting that in. Ranges? Probabilities?

Intangibles. Traffic delays, noise… Externalities.

[omit taxes, debt service, sunk costs]

To value costs, we return to the concept of economic cost.

Here we may need to move from market cost since we have now considered externalities and other market distortions.

The shadow price of an input reflects its value to society as a whole; the full social accounting of the marginal cost of using the input.

If there are market imperfections, it is not the same as the market price.

If the market is perfectly competitive and there are no externalities, then it is the same as the market price (the next best alternative as reflected in the market definition).

Price floor example.

Consider the cash cost for a project where some of the labor will be paid minimum wage.

We can think of the labor costs of the minimum wage laborers as consisting of two parts; the opportunity cost of the labor plus the transfer of rents, which are payments to the laborer above what they would require to work (their reservation wage) due to the rent creating policy of a minimum wage.

In answering the question of what is the best use of societal resources, the reservation wage is the appropriate valuation, not the minimum wage.

Externality example.

Consider the case where there is a marginal cost of an externality so that $MC^S = MC^P + MC^E$ for the supply curve of a good that we will be using as in input.

In answering the question of what is the best use of societal resources, the market price is not the appropriate valuation, the socially optimal price is.

3) Identify and value the benefits

New production or increased production from current level.

Quality improvement.

Ability to access higher return markets.

Cost reduction.

Avoided losses.

These (again in the absence of externalities) can be valued through market prices.

Some benefits are difficult to reflect in market prices (civic pride, reduction in pollution,…). To approximate these, we use a variety of techniques to estimate the community's willingness to pay.

How do we evaluate the benefit of a saved life?

We need a way to put a value on avoided deaths—the value of a statistical life.

- Morally we may have qualms but as a practical matter it is something we need to work with.

- What kinds of situations would call for us to use this value?
    - Changes in things like speed limits, drinking age, seatbelt rules, pesticide rules

    - The US DOT sets the value at 9.4 million
    - The US EPA sets the value at 10 million

  In June 2020, Imperial College in London released a study that non-pharmaceutical COVID-19 interventions (shutting down) saved around 3.1 million lives in Europe

    - We can use this value 3.1 m * 10 m = 3.1E + 13

The size of the EU economy annually is reported by the World Bank is 1.6 E + 13 (2018)

Not adjusted for characteristics of the person who has the life saved.

Think of it as a willingness to pay for a marginal change to mortality risk.

- It has been measured as a stated preference in a survey.
- It has been measured as a revealed preference by contrasting the wage premium that is associated with riskier occupations.
  - Hedonic wage analysis where likelihood of death on the job is a characteristic
  - A criticism is that it establishes as a reference largely blue-collar white males in the United States
    - Is that applicable globally?

It has also been measured by lifetime earnings potential lost.

Value of a DALY: disability adjusted life year that combines years of life lost and years lost to disability (WHO)

- This measures health outcomes that lead to death but also ones that have less than fatal outcomes
- There is a case made that a reasonable approximation of one DALY can be the gross national income (GNI) per capita in a country.
- Then the total DALY estimate from a policy change times the GNI would be a possible value to use.
    - Could also use the same logic with predicted years of life lost / saved.

Sometimes there is confusion about what is a cost and what is a benefit.

Common counting mistakes:

Counting direct benefits but overlooking associated costs.

If we build the mall, all the benefits of the profits from the new shops are counted as a benefit.

> But what part of this profit is displaced commerce rather than new commerce (Pre-Carousel there was Camillus Mall, Shoppingtown, Fairmount Fair, Pen-Can, Tri-County,…Now only pieces of these remain.)

Counting labor as a benefit. Wages are a cost, not a benefit. Job creating might be an objective, but it is not a benefit. The wages paid to the workers are a cost, what the workers produce when we pay them is a benefit.

Double counting. Building the road leads to a decrease in commuting time. This leads to an increase in house values that capture this benefit. You can count the value of the decrease in commuting time or the increase in the asset values but not both at the same time since they are reflecting the same change brought about by the project.

4) Discount future cost and benefits to identify net present value

Many projects have benefits and costs that will be realized over time.

How do we compare these values, and arrive at a single measure of the flow of costs and benefits over time?

We compute a single measure of these flows as the present value. We discount future benefits and future costs to arrive at a single statement of the net present value of benefits minus costs.

Why do we discount?

Impatience. Having it now is more valuable than in the future. Longer time to be with the benefit, and also "conditional continuation probability" factors in here.

Inflation. Dollar today is not the same as a dollar in the future.

Opportunity cost. I could have invested the money and earned returns, so this is the economic standard by which I should evaluate future returns.

General form for discounting:

r is the discount rate going one way and interest rate going the other, usually expressed in annual terms.
Define future value by FV, and present value by PV.
t is a time index, and in our case is indexed in years.

$$FV_t = PV_0 \cdot (1+r)^t \text{ or } \frac{FV_t}{(1+r)^t} = PV_0$$

If I promise to pay you \$100 20 years from now, and the discount rate is 6%, what is the present value? In other words, what amount could you give me now, I invest in a sure bet 6% rate of return bond, and have it pay off \$100 in 20 years?

$\$100/(1+.06)^{20}=\$31.18$

If it is current year, $\$100/(1+.06)^0 = 100$, since anything raised to the zero power =1 by convention.

If it is a stream of payments, we sum them over time.

$$PV_t = X_t + \frac{X_{t+1}}{(1+r)^1} + \frac{X_{t+2}}{(1+r)^2} + \frac{X_{t+3}}{(1+r)^3} + \ldots + \frac{X_{t+s}}{(1+r)^s}$$

[For future reference: if payments are equal over time, and it is over an infinite time horizon, we can use the following result.

$$\sum_{k=1}^{m} a^k = \frac{a^1 - a^{m+1}}{1-a}$$

$$\sum_{s=1}^{\infty} \frac{1}{(1+r)^s} = \frac{\frac{1}{(1+r)^1} - \frac{1}{(1+r)^{\infty}}}{1 - \frac{1}{(1+r)}} \quad \frac{\left(\frac{1}{1+r}\right) - 0}{\left(\frac{1+r-1}{1+r}\right)} \quad \frac{1}{r}$$

Distinction between the nominal rate of interest and the real rate of interest.

The nominal rate includes inflation.

The real rate is in terms of inflation adjusted units.

$$1 + \tilde{i} = (1+i)(1+\gamma) = 1 + i + \gamma + i\gamma$$

That means the real rate of interest is nominal rate of interest – inflation divided by 1+ rate of inflation. Roughly speaking, we can use nominal rate minus inflation rate to get real rate if inflation is “small”.

$$\tilde{\imath} = i * (1+\gamma) + \gamma$$

So

$$\frac{\tilde{\imath} - \gamma}{(1+\gamma)} = i \quad roughly\ \tilde{\imath} - \gamma = i$$

Real present value discounts for both real interest rates and inflation.

If your future monetary values are stated in real terms, you do not discount for inflation. They have already been discounted.

If your future monetary values are stated in nominal terms, you need to discount for both inflation and real rate of interest.

Is the contract you signed for a $100 bill to be handed to you each year, or for the equivalent of $100 in today's money to be handed to you each year?

The discount rate you choose depends on whether the values you are using for costs and benefits are in real or nominal terms.

Inflation rate is 5%. Nominal rate of interest is 8%.

$(1+.08) = (1+.05)(1+i)$, real interest rate is 2.9%.

Is promise to pay $100 bill next year? Then 100/(1.08), worth $92.59 today.

Is promise to pay the equivalent of $100 next year? Then 100/1.029), worth $97.18 today.

How do we choose r? A different r may change the relative evaluation.

The <u>discount rate</u> reflects the relative value a person places on future consumption compared to current consumption.

- Lower values show a greater preference for future consumption.
  - Example: suppose I will give you $100 today *or* $100(1+r) next year.

Today	R	Next year
$100	0%	$100
$100	2%	$102
$100	5%	$105
$100	10%	$110

  - The point at which you become indifferent between the two choices is your *discount rate*.

Why the discount rate matters

- Discounting affects the value placed on future benefits and costs.
  - Higher discount rates place less importance on future benefits / costs. A lower discount rate increases future values in terms of current values.

  Recall:

$$\frac{FV_t}{(1+r)^t} = PV_0$$

- Consider a program with 20 years of benefits at $1/year.
  - PV = $20.00 with 0% discount rate
  - PV = $15.90 with 3% discount rate
  - PV = $13.50 with 5% discount rate
  - PV = $11.60 with 7% discount rate
  - PV = $9.50 with 10% discount rate

What about using market interest rates?

Economists sometimes use the rate of return at the U.S. Treasury.

- Investors looking for a safe return invest in government securities.

Daily Treasury Yield Curve Rates (Nominal)

DATE	3-mo	6-mo	1-yr	2-yr	3-yr	5-yr	7-yr	10-yr	20-yr	30-yr
11/01/1990	7.28	7.38	7.32	7.68	7.88	8.15	8.42	8.57	8.63	8.70
11/01/1995	5.48	5.49	5.46	5.52	5.62	5.74	5.86	5.98	6.36	6.29
11/01/2002	1.44	1.43	1.42	1.46	1.76	2.14	2.92	3.54	4.01	5.07

https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yield

A problem occurs if, when comparing two options, one is riskier. Using a risk-free rate favors the riskier project.

Another alternative is to consider where the funds for a project come from.

If some of the funds come from the private sector, we should consider the opportunity cost of using those funds.

This is a good estimate of the opportunity cost of the capital you are using. Rate of return on capital is around 10%, so we use 10%.

The Office of Management and Budget explains benefit cost methods using a 7% real discount rate.

This rate approximates the marginal pre-tax rate of return in the private sector. As a default, they identify 7% as the suggested real discount rate.

In a 'best practices' document from 2003 they suggest looking at both a 3% and 7% real discount rate in analysis and note that specific cases may need to look outside this range.

Might the social discount rate deviate from market rates such as we saw for the treasury bills on the previous page?

Social discount rate – the interest rate at which society is willing to trade future consumption for present consumption.

Some economists argue that the opportunity cost of foregone future consumption might differ from the opportunity cost revealed in the markets.

Reasons social discount rates may differ from market rates

1) Concern for future generations / missing market with future generations.
   - The market rates we saw for treasury bills are for a market among the current generation.
   - Future generations are absent from these markets
   - Private sector may save too little, because it does not have a reason to be factoring in the preferences of future generations.
   - Thus, Governments act as an advocate for future generations, who are not represented in the marketplace, but will be citizens of the Government which governs this generation and future generations.

2) Market inefficiency
   - Investments create knowledge, a positive externality (spillovers / leaks).
   - Thus, one can argue that firms under-invest.

Discounting is not all that good for multi-generational analysis. Discounting on far time horizons wipes out large values in the future to very small values in present value terms.

Estimate by Costanza et al. (1997) of the value of the annual flow of goods and services from the environment. 33 trillion.

Years	5% discount	10% discount
1	31390571008524	29859634795187
10	20015511770517	12140021558658
100	222352250970	1498197682
200	1498197682	68018
300	10094777	3
400	68018	0
500	458	0
600	0	0

Discounting can lead to outcomes that are "pretty grim" for future generations.

Sometimes you see a 10% rate by convention.

Example: Compare costs of paving a road and gravelling a road. Present Value Cost computation.

Gravelling costs $28,000 to do now, and requires $2,000 per year upkeep for the next 10 years.

Paving costs $35,000 to do now, and requires $1,000 per year upkeep over the next 10 years.

Discount rate is 10%. Say this is the nominal rate of return on capital, and these values are nominal values (signing a contract).

	Gravel	Pave
Now (t=0)	28,000	35,000
1	$2{,}000/(1+.1)^1=1{,}818$	$1{,}000/(1+.1)^1=$ 909
2	$2{,}000/(1+.1)^2=1{,}653$	$1{,}000/(1+.1)^2=$ 826
3	$2{,}000/(1+.1)^3=1{,}503$	$1{,}000/(1+.1)^3=$ 751
4	$2{,}000/(1+.1)^4=1{,}366$	$1{,}000/(1+.1)^4=$ 683
5	$2{,}000/(1+.1)^5=1{,}242$	$1{,}000/(1+.1)^5=$ 621
6	$2{,}000/(1+.1)^6=1{,}129$	$1{,}000/(1+.1)^6=$ 564
7	$2{,}000/(1+.1)^7=1{,}026$	$1{,}000/(1+.1)^7=$ 513
8	$2{,}000/(1+.1)^8=$ 933	$1{,}000/(1+.1)^8=$ 467
9	$2{,}000/(1+.1)^9=$ 848	$1{,}000/(1+.1)^9=$ 424
10	$2{,}000/(1+.1)^{10}=$ 771	$1{,}000/(1+.1)^{10}=$ 386

Present Value Cost
GRAVEL: $40,289
PAVING: $41,144

Gravel is less costly than paving in PV terms.

Note sometimes we don't estimate benefits, and just look at least cost method of achieving a given benefit – cost effectiveness approach. This is generally what you are doing in the memo.

If we add in benefits, we can arrive at net present value.

Assume the impacted population is of size 1000. Also assume we did a study that indicates that the average monetary value per year (the MWTP) for the population of 1000 of an improved road is $8 if paved and $6 if gravel (each). So the total annual benefits of the gravel road are $6000 and total annual benefits of the paved road are $8000.

$$NPV_{paving} = 8{,}000 \cdot \sum_{t=1}^{10} \frac{1}{(1+r)^t} - 35{,}000 - 1{,}000 \cdot \sum_{t=1}^{10} \frac{1}{(1+r)^t}$$

$$= 7{,}000 * \sum_{t=1}^{10} \frac{1}{(1+r)^t} - 35{,}000$$

$$NPV_{gravel} = 6{,}000 \cdot \sum_{t=1}^{10} \frac{1}{(1+r)^t} - 28{,}000 - 2{,}000 \cdot \sum_{t=1}^{10} \frac{1}{(1+r)^t}$$

$$= 4{,}000 * \sum_{t=1}^{10} \frac{1}{(1+r)^t} - 28{,}000$$

If the discount rate = 6%, then NPV_{paving} = $16,520, while NPV_{gravel}=$1,440.

If the discount rate = 10%, then NPV_{paving} = $8,012, while NPV_{gravel}=-$3,422.

Note that as the discount rate increases, future (net) benefits have less weight against the current period costs. Choice of discount rate can influence which project is selected in Cost Benefit analysis (though not in this case).

Another measure is sometimes used; the internal rate of return (IRR). What r leads to PV benefits equal to PV costs?

For the paving project, just over 15% makes NPV=0. For the gravel project, it is a bit over 7%.

Solve for the r that makes:

$$7{,}000 \cdot \sum_{t=1}^{10} \frac{1}{(1+r)^t} = 35{,}000$$

$$4{,}000 \cdot \sum_{t=1}^{10} \frac{1}{(1+r)^t} = 28{,}000$$

Also note we can consider the benefit cost ratio, under the rule that if it is greater than one, the benefits outweigh the costs.

$$\text{B} - \text{C ratio}_{\text{paving}} = \frac{8{,}000 \cdot \sum_{t=1}^{10} \frac{1}{(1+r)^t}}{35{,}000 + 1{,}000 \cdot \sum_{t=1}^{10} \frac{1}{(1+r)^t}}$$

The ratio is 1.40 at a discount rate of 6% for the paving project.

4) Consider other factors that weigh in the decision: Equity, impact on sub-groups, things like this.

While the average benefit is indeed $6 or $8 for our community members, this is highly skewed, as only 500 people have vehicles. Car owners value the paved road at $16 each and gravel at $12 each, while non-car owners value both types of road at $0. The other members will not have any direct benefit from road improvement, but will have to pay the costs.

The gravel road will not be strong enough for the family farm to drive their tractor on so they will not benefit from this, but will benefit from the paving.

The paved road would allow year round access to a maternity while the gravel road would make the maternity inaccessible during parts of the rainy season when it washes out.

5) Uncertainty and Sensitivity of results.

Uncertainty: For both cost and benefits, how do you handle uncertainty, as they are values in the future and who knows how things will play out?

Concept of expected value.
First, identify a set of mutually exclusive contingencies that cover all possibilities.
Second, assign costs and benefits that go along with each of the contingencies.
Third, assign a probability to each of the contingent outcomes (and these probabilities should sum to one).
Fourth, compute expected value as the probability times the value.
Fifth, discount to calculate net present value.

Say we are building a dam that costs 25 million dollars in present value dollars.

The dam prevents flood damage in rare flood events that can cause 100 million dollars damage per event.

Two such events have happened in the last 100 years, so the chance of a flood in any given year is 2% with a 98% chance there will be no flood.

Each year following construction, there is a 98% chance we built it and no flood occurs, a 2% chance we built it and it prevents 100 million in damages due to a flood.

The expected value of having the dam is the value of averted damages, so 98% chance no value, 2% chance 100 million, or .98*0+.02*100 = 2 million.

Discount rate, we use 10%. The discounted expected value of the benefit stream is $\left[\sum_{t=0}^{20} \frac{1}{(1.10)^t} * (.98 * 0 + .02 * 100)\right]$=17 million, so NPV=17-25= -8 million.

Say we think climate change is occurring, and that flood events are more likely, say 3 out of 100 years, or 3% per year. Now the present value of benefits is 25.5 million, so NPV=25.5-25 or 0.5 million. $\left[\sum_{t=0}^{20} \frac{1}{(1.10)^t} * (.97 * 0 + .03 * 100)\right] - 25$

Or say we use the original 2% but a lower discount rate of 0.05. Now benefits are equal to costs at 25 million each for NPV of 0. $\left[\sum_{t=0}^{20} \frac{1}{(1.05)^t} * (.98 * 0 + .02 * 100)\right]$-25

Sensitivity of results:

As you have seen by now, changed assumptions can lead to changed assessment.

With regard to the discount rate, it is sometimes useful to identify where is the “crossing point” where changing values lead you to move from selecting one outcome to instead decide on another outcome.

If we keep the original values, it is never going to make more sense to gravel than pave given these values.

If we change our original problem and make the cost of gravelling cheaper (say it is 18,000 rather than 28,000) we choose paving when r is less than 12% and gravel when r is greater than 12%.

Recall the Contingent Valuation example. What if the values we came up with for our benefits are off? Say the costs were as reported in the original problem, but the benefits of the gravel and paved road were overstated by half (like in the windmill example). So instead of a WTP of 8 for the paved road and 6 for the gravel road we have 4 for the paved road and 3 for the gravel road.

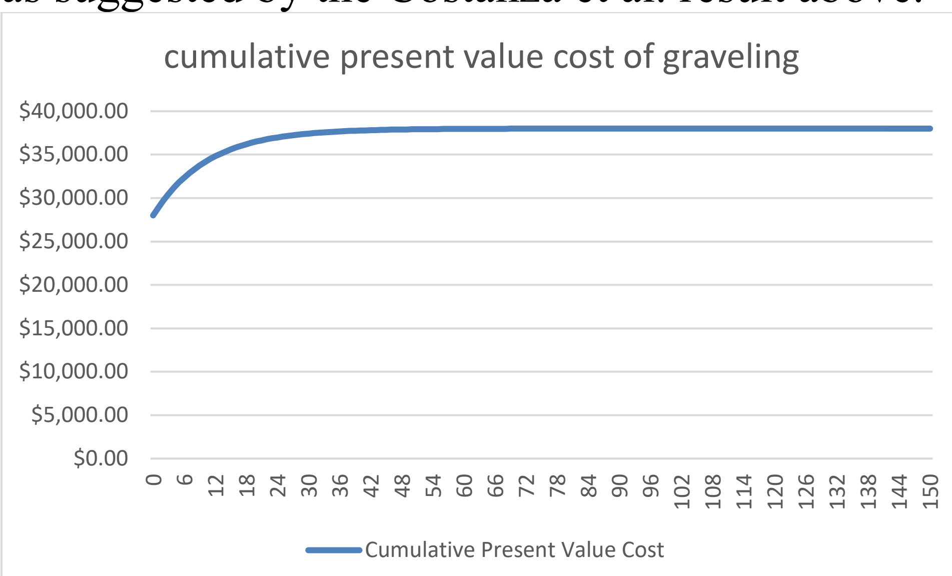
NPV for the gravel road is -$20,640, while for the paved road it is -$12,920.

Neither project makes sense at a discount rate of 10% - alternative uses of the resources offer better options.

One other source of uncertainty is the length of the time horizon. Why is the time horizon 10 years?

If for example we use the 6% rate and have a horizon of 2 years, it is better to gravel than pave (recall we picked pave). If it is anything more than 10 years, we have understated the NPV (for example, the paved road NPV if it lasts 20 years is 2.7 times as large as the NPV if it lasts 10 years).

Longer time horizons tend to flatten out future costs and benefits as suggested by the Costanza et al. result above.



Years

6) Interpreting results.

Look at NPV, and if you want other perspectives, the internal rate of return and the benefit cost ratio.

Consider how sensitive the results are to your assumptions and how sure you are of your assumptions.

Consider the NPV result as statement of economic efficiency and balance this against other objectives that may be important: equity, targeting specific sub-groups, righting historical wrongs, political stability – whatever.

Realize that as a producer of this information, how important it is for you to act carefully and ethically.

Realize that as a consumer of this information that the careful ethical approach is not always adopted.

Examples of use in development:

https://www.mcc.gov/where-we-work/err/mali-compact

https://www.mcc.gov/where-we-work/err/senegal-compact