NYU | TANDON SCHOOL OF ENGINEERING

M.S. MANAGEMENT OF TECHNOLOGY

CAPSTONE

NYC DDC TOWN +GOWN

INTRODUCTION

WHO WE ARE

Department of

Technology Management & Innovation

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SPRING 2021

NYC DOT

FALL 2021

UTILIDOR WORKING GROUP

Transportation Monitoring

Infrastructure Resilience

SPRING 2022

NYC *DDC*

Assessing the Economic Impact of Roadway Reconstruction Projects on Surrounding Neighborhoods

Creating a Culture of Innovation in Public Construction Agencies

Cross-Systems Cost/Benefit Analysis for Sustainability and Resiliency Projects

FALL 2022

URBAN RESOURCE RECOVERY WORKING GROUP

Closing Construction + Demolition Waste Material Loops in a NYC Circular Economy Model

Innovative Technology Management for Integrated and Proactive Use of NYC’ s State of Good Repair Database

Impact of Infrastructure Failure

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Cost-Benefit Analysis of Closing Concrete Material Loop

Sponsored by Town+Gown: NYC and Urban Resource Recovery Working Group

Capstone Team - Fall 2022

11/30/2022

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Cost-Benefit Analysis of Closing Concrete Material Loop

Presentation Overview:

- Capstone Project Background
- Cost-Benefit Model
    - Cost-Benefit Model Process Map
    - Case Study
    - Technology
    - Case Study Model Elements
        a. Economic Impact
        b. Environment Impact
        c. Social Impact

Capstone Project Background

Scope of Work

- Town+Gown: NYC DDC and the Urban Resource Recovery Working Group (URR WG)

- Cost-Benefit Model for the recovery and re-use of construction and demolition waste (CDW) in both direct and indirect manner described in the URR WG's Closing Loops City Program Initiative(CLCPI)

- Case study using recycled concrete aggregate(RCA) data from NYC DOT's crusher operations.

- Provide a template for reuse and recovery of other CDW materials to promote a Circular Economy.

Why Recover/Reuse Recycled Concrete Aggregate?

- Save money on construction projects from material substitution and related transportation costs;
- Reduce amount of transportation and related GHG emission (Greenhouse Gas: Carbon Dioxide, Methane);
- Reduce the need of mining natural aggregates;
- Reduce amount of demolished concrete going into landfills.
- Generate annual cost saving of $774k.

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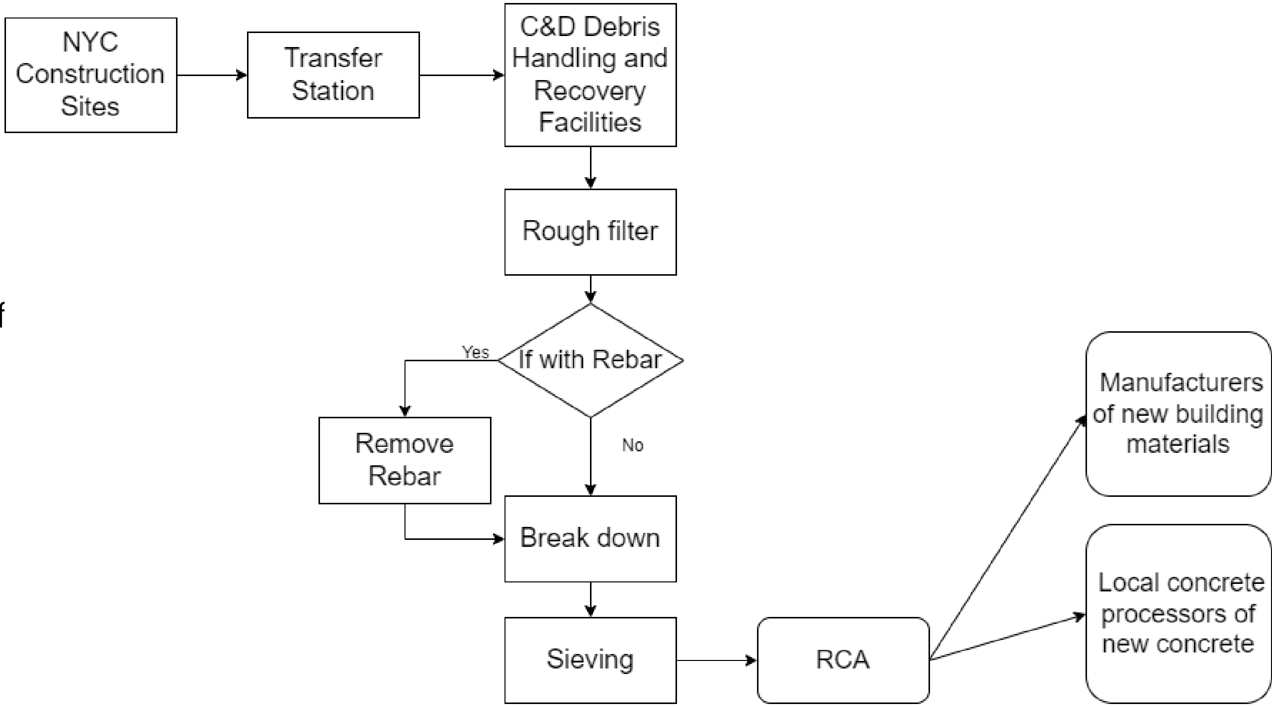
Cost-Benefit Model Process Map

Below is a general process map that include concrete CDW from public and private projects

CDW concrete can go two routes in this high level process map:

Indirect re-use of RCA (from public and private projects):

- By manufacturers of new building materials
    - o Limited technology
- By local concrete processors of new concrete per end-use specifications
    - o Possible investment in new equipment and/or technology changes at the processor level with continuous and reliable supply of RCA



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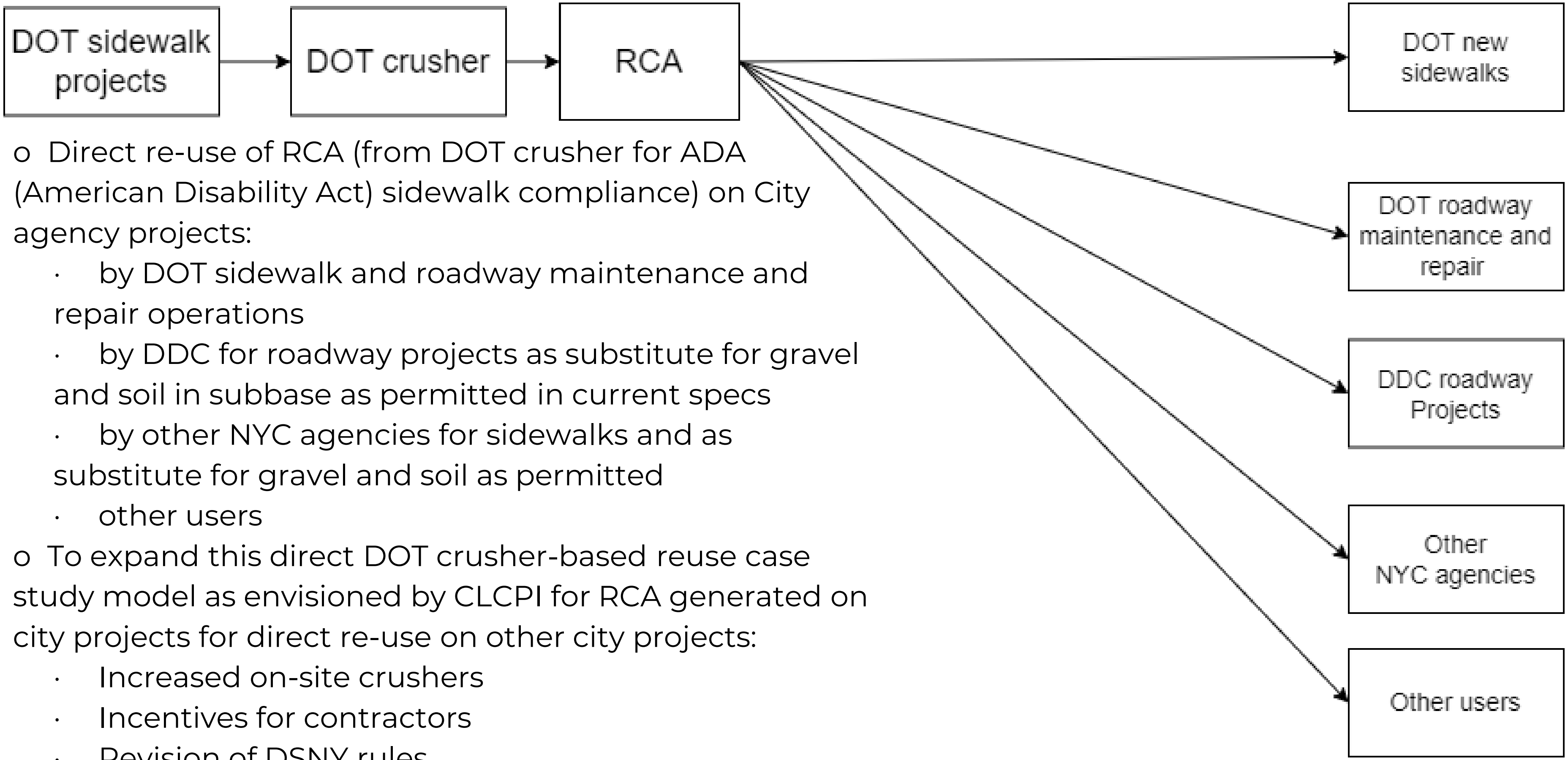
Cost-Benefit Model - Case Study

Below is the specific process map for DOT crusher.



- Direct re-use of RCA (from DOT crusher for ADA (American Disability Act) sidewalk compliance) on City agency projects:
  - by DOT sidewalk and roadway maintenance and repair operations
  - by DDC for roadway projects as substitute for gravel and soil in subbase as permitted in current specs
  - by other NYC agencies for sidewalks and as substitute for gravel and soil as permitted
  - other users
- To expand this direct DOT crusher-based reuse case study model as envisioned by CLCPI for RCA generated on city projects for direct re-use on other city projects:
  - Increased on-site crushers
  - Incentives for contractors
  - Revision of DSNY rules

Cost-Benefit Model - Technology

New Crusher Techniques

- Advantages of on-site crusher
  - Reduces cost of disposal of waste materials
  - Mobility and efficiency
- Disadvantages of on-site crusher
  - Ash and dust
  - Noise issue

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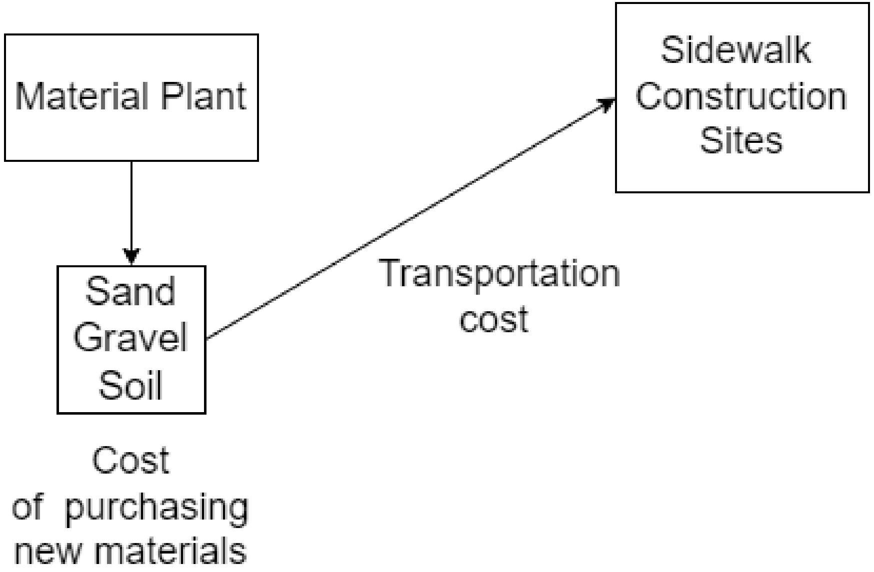
Cost-Benefit Model - Technology

New Crusher Techniques

- Major types of crushers
  - Primary crushing stage: Jaw crusher
  - Cone and gyratory crusher
  - Impact crusher

Cost-Benefit Model - Elements for Case Study

Case 1 Process Map

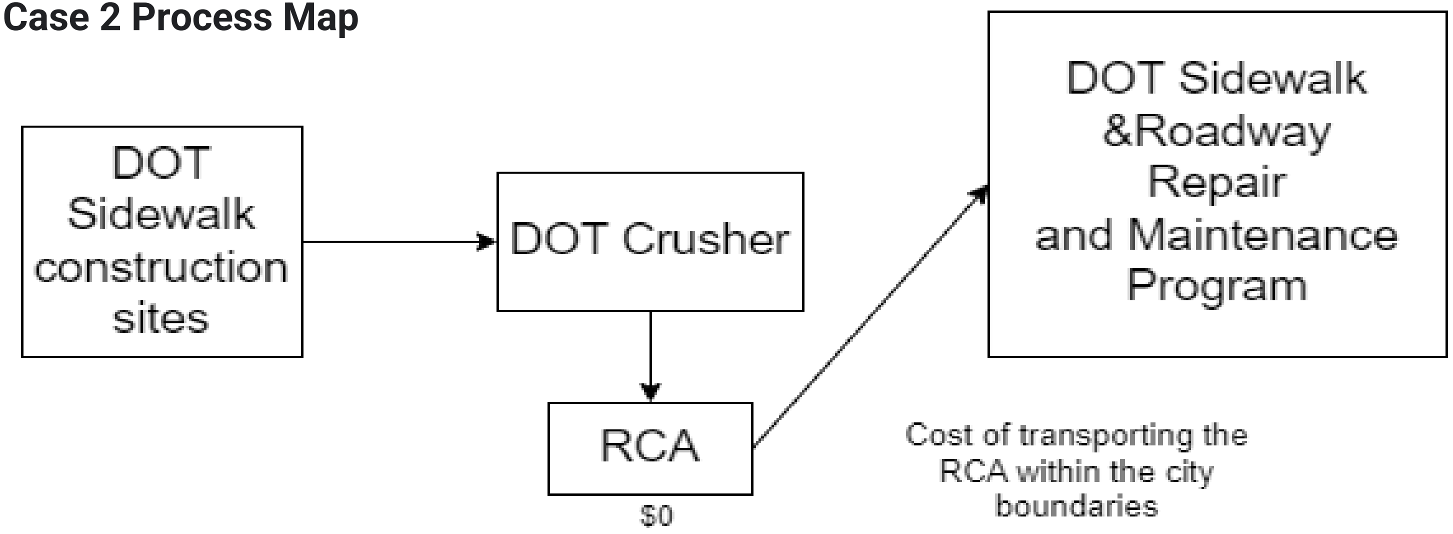


Purchase natural building materials

- Cost of purchasing new materials
- Transportation cost includes transportation cost from out-of-city factory and in-city transportation cost

Cost-Benefit Model - Elements for Case Study

Case 2 Process Map



Processed at NYC DOT's crusher generating recycled concrete aggregate(RCA)

- Assume the costs to construct and operate the crusher as sunk costs.
- Costs modeled only for transporting RCA within the city boundaries

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Economic Cost Formula

Suitable for general process

Transportation Cost

- We can obtain the unit transportation cost of construction waste from available materials, or estimate the unit transportation cost based on the transportation cost of a particular project. The calculation formula is as follows:

$$T = \frac{Pt}{Qu \times D}$$

T - Unit transportation cost ($/km/t)

Pt - transport cost converted according to the quota in the case of transport distance D ($);(From Transfer Station)

Qu - fixed unit transport weight (t);(From Transfer Station)

D - transport distance (km).(From CUSP)

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Economic costs savings(Materials)

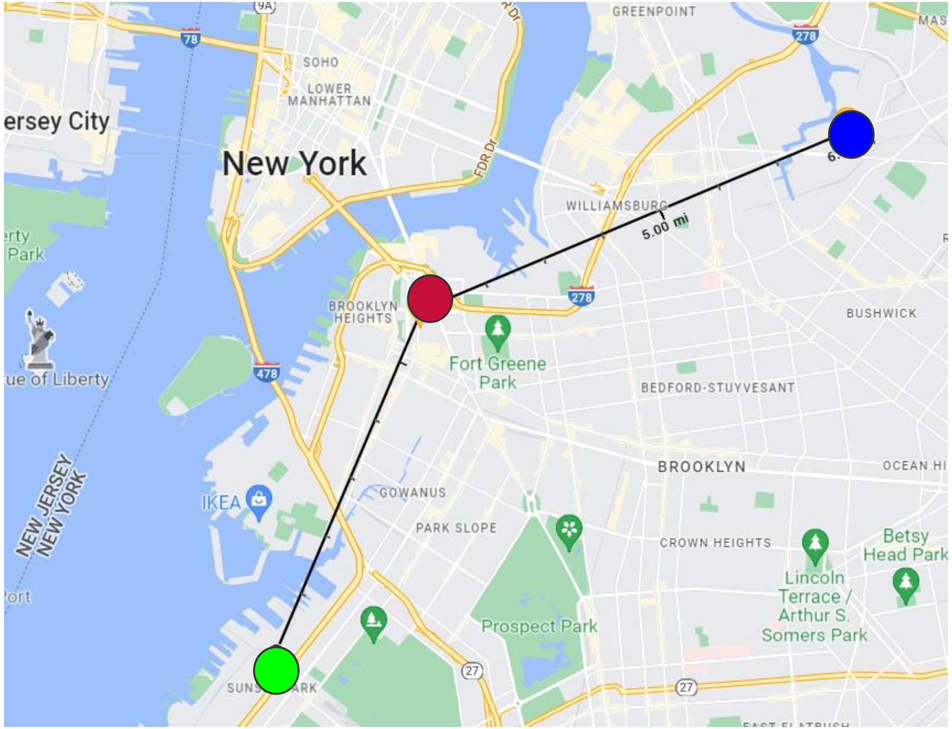
Market Price for new materials

- Sand: $102/Yard
- ¾ Stone: $110/Yard
- ⅜ Stone: $115/Yard
- All the prices are without transportation cost
- Total cost per yard:(Have Connected Tec-crete for data)
- (In U.S dollars per yard)

Out-of-city factory transportation cost for new materials

- Tec-crete provides information on transportation cost from out-of-city factory: They don't charge per mile, the total "trucking driver & delivery"cost comes out to around $20/yard

Economic costs savings(Transportation)



DOT has sidewalk construction sites all over the city, DOT staff suggested that we randomly choose a section of the road for our study. So we chose the road in front of tandon as our destination.

The other two addresses are RCA bank (green dot) and material factory (blue dot).

Based on the estimated similar distances from the two locations to the destination, we assume the same transportation costs for this case within the NYC boundary.

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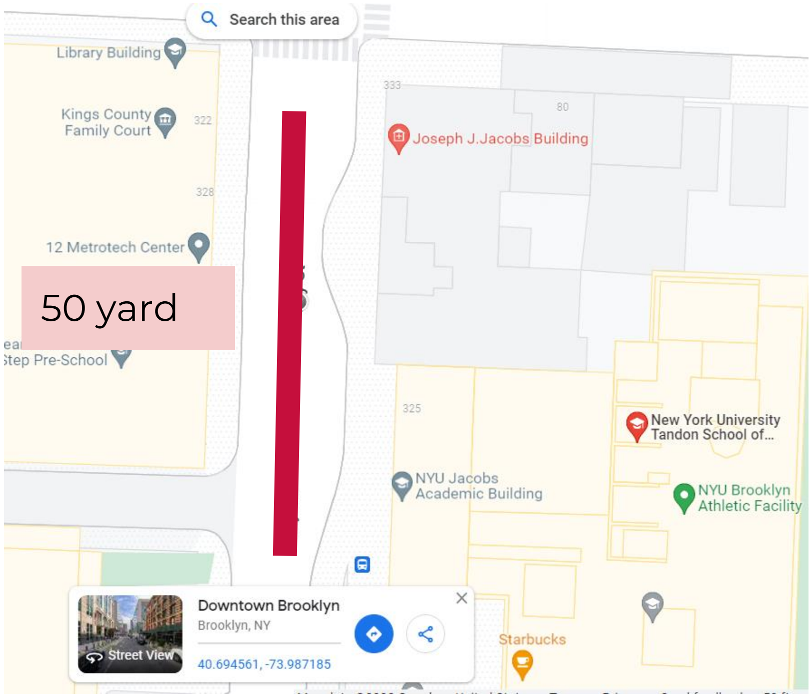
Cost-benefit model - calculation for case study



We assume that 50 yards of raw materials are needed to repair the road.

Total cost = transportation cost + material cost

Case 1: Buy materials
C1 = transportation costs within the NYC boundary + ($109/yard+$20/yard） * 50 yards

Case 2: Use RCA
C2 = transportation costs within the NYC boundary + 0

Total project saving
= C1 - C2
= ($109/yard+$20/yard） * 50 yards
= $6450

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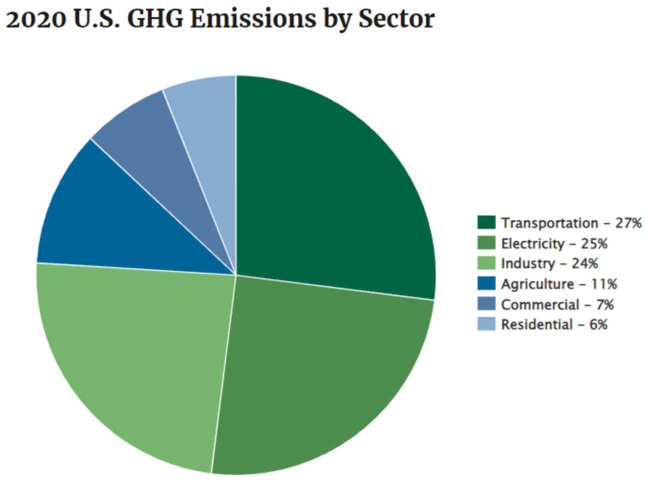
Case Study Model Elements -Environment Impact

- Reduce the stockpiling of waste concrete and land occupation.
- Reduce the demand for new concrete raw materials and the consumption of natural resources.
- Reduce carbon dioxide emissions during raw material production.
- The transportation of sand and gravel produces the most amount of carbon dioxide, which we will focus on in our calculation.



Environment Cost Formula

Total consumption of diesel for transportation

The main source of pollutants in the process of material transportation is the combustion process of diesel fuel.

The unit diesel fuel consumption of transport vehicles is closely related to the unit integrated diesel fuel consumption of load carrying, transport weight and distance. The calculation formula is shown below.

$$E_r = \mathrm{Q} \times \mathrm{D} \times Q_r$$

E_r: Total consumption of diesel for transportation (L)

Q: Quantity of materials (t)

D: Transportation distance (km)

Q_r: Diesel consumption per unit load ($\mathrm{L}\cdot km^{-1}\cdot t^{-1}$)

Cost-benefit model - calculation for case study

Data obtained from research：

- Paving material weighs 2,000-3,000 pounds / yard
- A self-unloading truck with a load of 25 tons, its unit bearing fuel consumption is 1.368L/(100km*t).
- According to the U.S. Environmental Protection Agency (EPA), diesel fuel produces approximately 0.43 kg of CO_2 emissions per liter.

Cost-benefit model - calculation for case study

Case 1:

Buy materials

Out-of the city : 16.09 km

In city: 8.52 km

The total distance : 24.6 km

E_{r1} = 62.5 tons * 24.6 km * 0.01368 L$\cdot km^{-1} \cdot t^{-1}$

= 21.2L

Q_{w1} = 21.2 L * 0.43 kg /1000 = 9.1*10^{-3} ton

Case 2:

Use RCA

In city: 6.43 km

The total distance : 6.4 km

E_{r2} = 62.5 tons * 6.4 km * 0.01368 L$\cdot km^{-1} \cdot t^{-1}$

= 5.5L

Q_{w2} = 5.5 L * 0.43 kg /1000 = 2.4*10^{-3}ton

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Cost-benefit model - calculation for case study

Greenhouse gas emissions have risen dramatically

- Carbon dioxide is a major component
- Contribute to global warming and increase risk of droughts and floods

Carbon dioxide removal pathways are methods for removing carbon dioxide pollution from the atmosphere. The government has announced an initiative to support the development of these pathways and has set a goal of reducing the cost of CO_2 removal to less than $100 per net metric ton.

So here we assume a treatment price of $100 per metric ton of CO_2.

Case 1: Buy materials

C1 = 0.0091t * $100/t
= $0.91

Total project saving
= C1 - C2
= $0.67

Case 2: Use RCA

C2 = 0.0024t * $100/t
= $0.24

Benefits of reducing CO2 emissions

- Brings Carbon Tax Saving/Revenue
- Save carbon credits that can be sold through the exchange to create revenue
- Carbon Credit price is various:
- Carbon Credit price for transportation category (World Bank)
    - Price Range: $2.2 - $6.8
    - Average Price: $2.9 per metric ton

Carbon Credit Pricing by Type

Project Type:	Volume Sold (MtCO2e):	Average Price:	Price Range:
Wind	12.8	$1.9	$0.3 - $18
REDD+	11	$3.3	$0.8 - $20+
Landfill methane	7.9	$2	$0.2 - $19
Tree planting	3	$7.5	$2.2 - $20+
Clean cookstoves	3	$4.9	$2 - $20+
Run-of-river hydro	1.5	$1.4	$0.2 - $8
Water/purification	1.2	$3.8	$1.7 - $9
Improved forest management	0.8	$9.6	$2 - $17.5
Biomass/biochar	0.7	$3	$0.9 - $20+
Energy efficiency - industrial-focused	0.7	$4.1	$0.1 - $20
Biogas	0.6	$5.9	$1 - $20+
Energy efficiency - community-focused	0.6	$9.4	$3.3 - $20+
Transportation	0.5	$2.9	$2.2 - $6.8
Fuel switching	0.5	$11.4	$3.5 - $20+
Solar	0.3	$4.1	$1 - $9.8
Livestock methane	0.2	$7	$4 - $20+
Geothermal	0.1	$4	$2.5 - $8
Agro-forestry	0.1	$9.9	$9 - $11

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Social impact inside NYC

S.No.	Impacts of construction waste	Mean	Std. Deviation	Rank
EC1	Project cost overrun	4.21	.931	1
EN1	Pollution of the environment by discharging chemicals and other materials	4.14	.967	2
EC2	Reduction in Profit and failure of construction firms	4.00	1.090	3
EN2	Excessive consumption of raw material and resources depletion	3.99	1.210	4
SE1	Public health and safety risks	3.97	1.179	5
EN3	Pollution of soil by chemicals and other materials	3.93	1.121	6
EC3	Delay of project time or time overrun	3.91	1.100	7
EC4	Spending costs to landfill fee for disposing of waste	3.90	1.079	8
EN4	Sustainability reduction of construction sectors	3.87	1.006	9
EN5	Generate waste that causes water pollution	3.83	1.239	10
EN6	Land occupancy or land consumption for dumping waste	3.81	.997	11
SE2	Traffic congestion	3.79	1.034	12
EC5	Transportation charges to transport waste	3.77	1.253	13
EN7	Effect on biodiversity and destruction of the living environment	3.76	1.233	14
EC6	Lower the GDP contribution of construction firms	3.74	1.359	15
SE3	Disease-associated with high levels of air pollutants	3.73	1.350	16
EN8	Severe effects on the welfare of the waste disposed communities	3.67	1.176	17
EC7	Increase price of raw materials	3.66	1.361	18
EN9	Emission of greenhouse gases into the atmosphere causes climate change	3.61	1.487	19
EN10	*Increase in illegal dumping* ***b******	*3.60*	*1.459*	
EN11	Dust generation to the surrounding	3.47	1.411	20
SE4	Flooding due to blockages by waste debris	3.43	1.420	21
SE5	Disagreement between construction parties	3.40	1.232	22
SE6	Losing reputability and caused conflicts with the community	3.37	1.374	23
EC8	Reduce the crop productivity	3.21	1.371	24

- Construction waste doing negative impacts on local community:
  - threats to public health and safety (mean 3.97),
  - traffic congestion (mean 3.79)
  - disease-related to excessive levels of air pollutants (mean 3.73).
- Construction in the city could improve quality of life. We hope to reduce the opportunity cost of constructing the city so we can make more urban infrastructure improvements.
  - By decreasing the costs from substitution and transportation of construction waste.

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Source: Analysis of the socio-economic and environmental impacts of construction waste and management practices. Heliyon, 8(3), e09169.

Social impact

- Economic impact -> social impact:
  - The cost of RCA is typically lower than the cost of natural aggregate materials & The use of RCA can help extend the life of existing concrete structures
  - E.g. the Americans with Disabilities Act Standards for Accessible Design. The economic savings make it easier for the city to pay for the project.
- Environmental impact -> social impact:
  - Reduce the amount of waste that is sent to landfills and reduce the need for new aggregate materials
  - The production of RCA requires less energy and produces fewer greenhouse gas emissions

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Cost-benefit model - calculation for case study

- According to Marshall Burke, associate professor from Stanford University, “The social cost of carbon is the cost of the damages created by one extra ton of carbon dioxide emissions. The main components of social cost includes changes in agricultural productivity, damages caused by sea level rise, and decline in human health and labor productivity”
- Social Cost of CO2 for NYC : $121 per metric ton of CO2

Case 1: Buy materials

C1 = 0.0091t * $121/t
= $1.1011

Case 2: Use RCA

C2 = 0.0024t * $121/t
= $0.2904

Total project saving
= C1 - C2
= $0.8107

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So what's the annual situation?

12,000 miles of sidewalk

Need **6000 yards** of paving material

Case study : 50 yards materials needed

Economic costs savings: $6450

Environmental costs savings: $ 0.67

Social costs savings: $0.81

Total project saving = $6451.48

One-year sidewalk repair project in NYC: 6000 yards materials needed

Economic costs savings: $774,000

Environmental costs savings: $80.4

Social costs savings: $97.2

Total saving = $774,177.6

Summary

Economic Impact

- High level process map
- DOT case study map
- Crusher Technology - On site crusher
- Case scenarios process maps
- Calculation for economic cost

Environment Impact

- Transportation accounted for the largest portion in 2020
- GHG will be less if RCA transport in-city
- Calculation for environment cost

Social Impact

- Positive vs negative impacts
  - Health, traffic, diseases
  - Waste reductions, less energy and emission, cost savings.
- Calculation for social cost

Future Possibilities

- Indirect reuse of RCA
  - Concrete pavers/block for landscaping
  - Concrete floor tiles, and countertops
- Explore other materials
  - Glass
    - Reuse glass to produce high-valued products.

Thanks