



**Pushing the Recycling Envelope:  
Construction and Demolition Waste**

ACS Manhattan Room  
@150 William Street, 19<sup>th</sup> Floor  
November 30, 2017, 8:30 a.m. to Noon

## AGENDA

**8:30—8:45 a.m. Registration, Introduction and Welcome**

**8:45—10:15 a.m. Panel 1—State of Academic Research**

***Environmentally-Conscious Strategizing for Construction and Demolition Waste Management***, Ardavan Yazdanbakhsh, Assistant Professor of Civil Engineering, City University of New York/City College, Grove School of Engineering

- ***Technical Barriers to the Use of CDW in Construction***, Matthew Adams, Assistant Professor and Co-Director, Materials and Structures Laboratory (MatSLab), Department of Civil and Environmental Engineering, New Jersey Institute of Technology
- ***The Strategic Benefits of CDW Recycling***, Iddo Wernick, Lecturer, Masters in Sustainability program at City University of New York/City College
- ***Waste and Recycling Informatics*** *Masoud Ghandehari, Associate Professor, Civil and Urban Engineering, New York University Tandon School Engineering, and Center for Urban Science and Progress*

**10:15—10:30 a.m. Break**

**10:30—11:30 a.m. Panel 2—Practical Considerations and Impediments and Ideas for Future Research to Advance the Recycling**

- Christopher Diamond, Director of the Office of Sustainable Design, Architecture and Engineering, Public Buildings Division, New York City Department of Design and Construction
- Joseph Hogan, Vice President of Building Services, Associated General Contractors of New York State
- Kate Kitchener, Director of Policy and Programs, Bureau of Recycling and Sustainability, New York City Department of Sanitation
- Mark Seaman, Senior Economist, New York City Department of Transportation

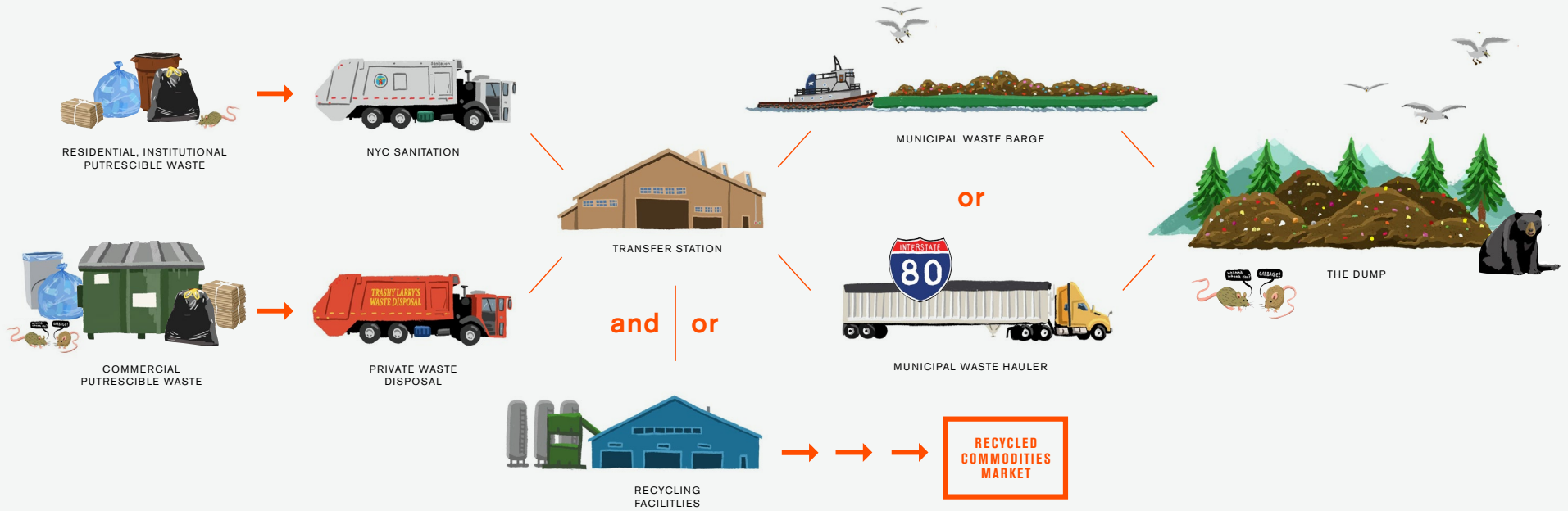
**11:30—11:45 a.m. Questions and Answers**

**11:45 a.m.—Noon Concluding Remarks**

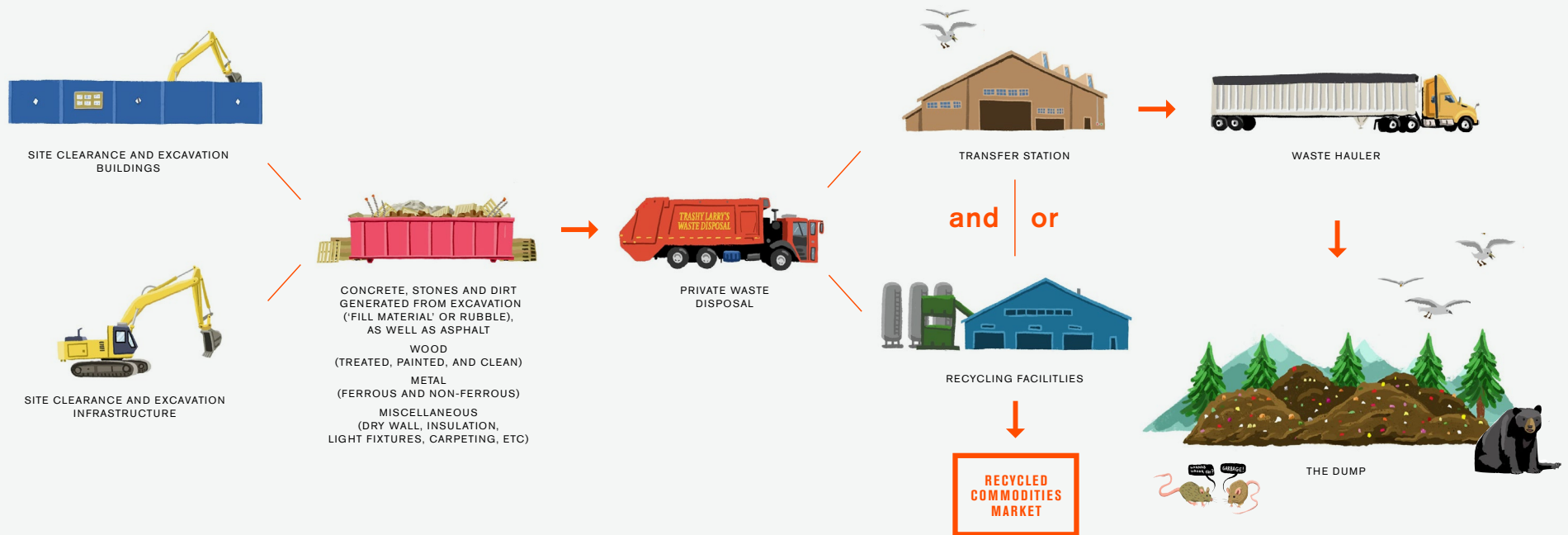
**Introduction to CDW.** Considerations of recycling waste in the City depend on the nature of the waste that is being considered. The New York City Department of Sanitation (DSNY) is responsible for collecting most putrescible waste generated by residential and institutional buildings, including hospitals, colleges and universities, located within the City. Private carters are responsible for collecting putrescible waste generated by commercial establishments and “construction and demolition waste” (CDW) generated from new construction or renovation and rehabilitation of buildings and infrastructure. The term “putrescible waste” is intended to include all waste material that is likely to rot or decompose. Recent analysis estimates that DSNY “handles around 12,000 tons of waste per day, about 50 percent of the city’s total waste,”<sup>2</sup> leaving the remainder of the City’s putrescible waste stream for private carters, which are regulated, in part, by the City.<sup>3</sup> The publicly and privately carted putrescible waste streams are considered, as a whole, to be the municipal solid waste (MSW) stream.

CDW, which is “managed almost exclusively in NYC by private transfer stations and processors,” is distinct from the MSW stream.<sup>4</sup> CDW “includes concrete, stones and dirt generated from excavation (sometimes referred to as ‘fill material’ or rubble), as well as asphalt, wood (treated, painted and clean), metal (ferrous and non-ferrous), and miscellaneous materials (dry wall, insulation, light fixtures, carpeting, etc.).”<sup>5</sup> CDW can also contain hazardous wastes such as “asbestos, lead paint and mercury from florescent lamps.”<sup>6</sup> A research project in Town+Gown, completed in academic year 2015-2016, using DSNY’s data on transfer stations located within the City’s jurisdictional limits, found that, on average, over 8,500 tons of mineral CDW are handled every day by the transfer stations located within the City’s jurisdictional limits.<sup>7</sup>

# Municipal Solid Waste Stream



# Construction and Demolition Waste System



**CDW and the City.** In 2003, the New York Department of Design and Construction (DDC) released its *Construction and Demolition Waste Manual*, which was intended to be served as “an introduction and resource handbook for construction and demolition (C&D) waste reduction, reuse and recycling on New York City Projects.”<sup>8</sup> While the guidelines within the *Manual* “are addressed to all the participants in projects for the NYC Department of Design and Construction,” “[i]ts basic goal is to assist design and construction professionals to prevent construction waste and divert from landfills the C&D waste that is generated.”<sup>9</sup> The *Manual* defines C&D Waste as “that part of the solid waste stream that results from land clearing and excavation, and the construction, demolition, remodeling and repair of structures, roads and utilities.”<sup>10</sup> The percentage represented by CDW in the City’s solid waste stream is considered to be “at the high end of the range” among other localities, which is thought to be due to the fact that the City is older and more developed than most, with “older building stock and, hence a relatively high degree of renovation activity” and the reality that “for almost every new building that goes up, an older one must come down.”<sup>11</sup>

DSNY Rules designate elements of CDW as recyclable and further require that CDW recyclables be “source separated from other waste streams.”<sup>12</sup> CDW begins when the “contractor collects the debris in containers, usually rented or provided by the hauler” who “takes the container to a waste transfer station and/or processing center.”<sup>13</sup> There are two types of processing centers—one that accepts “specific, separated, materials such as metal” and the other that extracts “recyclables before sending the balance to a transfer station.”<sup>14</sup> In contrast, waste transfer stations tend to “transfer the waste into larger trucks, which take it to landfills” though “large

transfer station companies also have processing facilities and hauling services.”<sup>15</sup> Contractors may also “haul their own waste and recyclables . . . [and] many recyclers of specific materials will arrange to pick them up at the construction site.”<sup>16</sup>

The particulars of processing and recycling CDW, in any geographical area depend to a high degree on the nature of the market for the component commodities, which continually changes.<sup>17</sup> Under current market conditions, “[s]ource separation generally yields the highest recycling rate and the best price for materials”, and the construction site provides opportunities for source separation.<sup>18</sup> During demolition and excavation operations, “more C&D waste is generated and one contractor is scheduling the work”, with the waste generated as “relatively homogenous waste streams” and providing “opportunities for on-site segregation of metal or for the grinding, screening and reuse of concrete.”<sup>19</sup> The high cost of disposal in the New York metropolitan area for public and private projects has meant that there has historically been a level of separation of CDW, which has only improved over time. Scrap metals have a high value, so they were already sorted. If concrete is kept clean, it has a value for reuse for other purposes—mostly crushed as base material. Large pieces of wood, including pallets if they are not crushed in the waste hauling process, can also be reused. It is important to note that a significant portion of CDW becomes “alternative daily cover” (ADC), which supplements regular soil available at landfills to cover the putrescible waste in the landfills.

On the other hand, constraints of site logistics in a dense built urban environment such as New York City do impact the ability of owners and contractors to sort these materials on site (See *Recycling CDW “on the Ground”*

below). The *Manual's* suggested strategies to increase CDW recycling on City projects centered on the development and use of a C&D Waste Management Plan (WMP). During the design phase, a project manager would leverage the early design process to identify opportunities for salvage, reuse and recycling C&D Waste components and establish waste management goals during design progress meetings, with the end of developing a project-specific C&D Waste specification, which would contain specific C&D Waste management goals, for the project's bid package.<sup>20</sup> With the C&D Waste specification in place for the project during the construction phase, a project manager would work with the construction manager or the general contractor for the project "to develop an aggressive WMP, in accordance with the specification developed by the design team."<sup>21</sup> Beginning with a "walk-through of the site with the construction team, including the demolition contractor," to determine salvageable, reusable and recyclable materials, the project manager would monitor the contractor's compliance with the WMP throughout the construction phase, including all job meetings and site visits and review of contractor's recycling reports as compared to the WMP.<sup>22</sup>

When the *Manual* was released in 2003, the Leadership in Energy and Environmental Design (LEED) program, developed by the U.S. Green Building Council to increase environmental sustainability in building design, construction and operation, was still new. In 2006, the City embraced the LEED program for construction and renovation of its public building portfolio so that LEED standards for CDW were also incorporated for the City's public building projects. CDW reporting, which includes diversion rates, is required as part of the LEED certification process.<sup>23</sup>

While *New York City's Roadmap to 80 x 50*, the City's most recent articulated long-term sustainability plan required by the Charter,<sup>24</sup> focuses on waste, which is "the smallest contributor" among "the four sectors that contribute to GHG emissions in NYC,"<sup>25</sup> there are no specific references to CDW's presence in the City's waste stream or its contribution to the circular economy.<sup>26</sup> Within the waste sector, 78 percent of total GHG emissions comes from methane released from New York City's landfilled waste,<sup>27</sup> and 22 percent comes methane released from the wastewater treatment process.<sup>28</sup> "[S]ince organic material is the most significant generator of greenhouse gases among all waste categories," it is not surprising to find organic waste is a significant focus of the Roadmap.<sup>29</sup>

In contrast to organic waste, concrete waste does not decompose or contribute to GHG—concrete carbonates and *absorbs* CO<sub>2</sub> from the environment. It is the creation of concrete,<sup>30</sup> the transportation of the raw materials to create concrete, and the transportation of concrete CDW for processing, recycling and disposal that contributes to GHG emissions, pointing to recycling concrete as a way to reduce concrete's contribution to GHGs in the circular economy. The GHG profile of concrete, however, does not align well with the City's span of regulatory control. CDW is not part of the solid waste stream over which the City exerts significant regulatory control, including recycling mandates, leaving CDW recycling subject to New York State law requirements and market conditions, which means the economics of the commodities market determine what CDW elements and levels of CDW elements get recycled—or diverted—at any time.<sup>31</sup> Life cycle cost-benefit modeling, within a mixed market economy, is one tool that can help provide government, as regulator, with sufficient data to help determine options for potential intervention to increase recycling of CDW.

Finally, in addition to developing design guidelines for both vertical buildings and horizontal infrastructure, DDC has had a practice of implementing academic-based material field tests on its projects.<sup>32</sup> One recent field test, in 2016, related to use of a particular recycled CDW element—glass pozzolan—on a sidewalk reconstruction project in Queens.<sup>33</sup> Pozzolan is a by-product of recycling glass recycling, which, when finely ground and mixed with specific chemicals and water, can act like cement.<sup>34</sup> This analysis involved three cement mixes in the field, with two mixes using different levels of glass pozzolan and one mix using standard fly-ash, and comparatively analyzed their compressive strengths over a 90-day period after installation, as well as noting observable features in the finished product.

**Recent Developments in CDW.** New York State Department of Environmental Conservation (DEC) promulgated final regulations, effective on November 4, 2017, significantly revising the State's Solid Waste Management Regulations. These new regulations aim at strengthening the State's ability to protect water quality and establish design standards and operational criteria for solid waste management facilities in the State. Among the several areas covered by the new regulations are changes to the management of C+D debris and fill material. Aimed at reducing illegal dumping of C+D debris and fill material, the new regulations "require enhanced tracking for C+D debris and fill material gathered in New York City, as well as for certain fill material generated anywhere in the state."<sup>35</sup> They also "limit the exempt disposal of C+D debris and provide expanded allowance for the reuse of fill materials in environmentally protective situations."<sup>36</sup>

These regulations include reporting provisions with respect to waste. For example, all solid waste facilities engaged in "the management of solid waste beyond the initial collection process"<sup>37</sup> have comprehensive operating requirements, which include keeping, as part of their operating records, a "daily log of wastes received that identifies the waste type, quantity, date received, and planning unit where the waste was generated, and the quantity and destination of any waster, products or recyclables that are removed from the facility."<sup>38</sup> Specific requirements for facilities handling C+D debris include operational requirements as part of the permit process that include an ability to weigh or otherwise measure and record in cubic yards and tons, "[a]ll waste and recovered materials delivered to and leaving the facility."<sup>39</sup> Facilities handling C+D debris and recovery facilities have reporting requirements, in addition to the general requirements described above, which include "daily records of the quantity of recyclables sent from the facility by material type, including the quantity and destination of material used as alternative operating cover" and a C+D debris tracking document for materials including those that do not "qualify for a beneficial use . . ." under the regulations.<sup>40</sup> These new reporting requirements will, over time, not only create data for research purposes, but also create data at the State wide level, which would include multiple local economies, local markets and submarkets.

In addition, the regulations create a category called "beneficial use", which is "use of certain wastes as effective substitutes for commercial products or raw materials as determined by [DEC, which] cease to be solid waste when used according to [the regulations]."<sup>41</sup> The regulations expand the types of pre-determined beneficial uses, which expansion is intended to increase market opportunities for the covered CDW materials, including



concrete and asphalt. Among the regulations' pre-determined beneficial uses, which over time can help support the creation and expansion of CDW recyclable markets, are:

- ground granulated blast-furnace slag for use as a raw feed in the manufacture of cement and in concrete which meets an industry standard acceptable to [DEC]
- coal combustion fly ash which meets an industry standard acceptable to [DEC] for use in concrete, concrete products, light-weight block, light-weight aggregate and flowable fill
- flue gas desulfurization or other gasscrubbing byproducts when used to replace manufactured gypsum or manufactured calcium chloride, except for land application
- coal combustion bottom ash for use as an aggregate in portland cement, concrete, asphalt pavement, or roofing materials
- recycled aggregate or residue which meets a municipal or state specification or standard for use as commercial aggregate if generated from uncontaminated, recognizable concrete and other masonry products, brick, or rock that is separated from other waste prior to processing and subsequently processed and stored in a separate area as a discrete material stream
- recycled material or residue generated from uncontaminated asphalt pavement and asphalt millings which meets a municipal or state specification or standard for use as an ingredient in asphalt pavement or other paved surface construction and

maintenance uses if separated from other waste prior to processing and subsequently processed and stored in a separate area as a discrete material stream

- asphalt pavement and asphalt millings received at an asphalt manufacturing plant for incorporation into an asphalt product
- clay, till, or rock excavated as part of navigational dredging, which is separated from overlying navigational dredged material and used as fill or aggregate<sup>42</sup>

Finally, C+D debris is an enumerated waste stream that local solid waste management plans (LSWMPs) must include.<sup>43</sup> The new regulations require LSWMPs to perform a "qualitative assessment of alternatives and enhancements to the existing solid waste management program that will decrease the amount of waste managed through disposal and thermal treatment by increasing waste reduction, reuse and the recovery of recyclables to the maximum extent practicable over the term of the planning period."<sup>44</sup> Among the items a LSWMP's alternatives assessment must address are "programs to develop or improve local and regional markets for recyclables", "incentive-based pricing", "data collection and evaluation efforts", "local hauler licensing programs, including an assessment of laws preventing the commingling of recyclables with waste", and "C+D debris reduction, including deconstruction, reuse and recovery programs."<sup>45</sup> Among the items a LSWMP's alternative evaluation must address are administrative/technical impacts, which can include "any *available life-cycle analysis* (emphasis added) data", and jurisdictional impacts.<sup>46</sup>

In addition, a collaborative group recently released *Zero Waste Design Guidelines* (ZWDG), focusing specifically on CDW associated with buildings, not horizontal infrastructure.<sup>47</sup> While this collaboration followed an overall interdisciplinary methodology used by a past collaboration that led to the 2010 Active Design Guidelines, the CDW analysis and recommendations followed, instead, the interdisciplinary methodology used in the sustainable energy sector.<sup>48</sup> Though the ZWDG aims at vertical building structures, the principles and strategies have broad application to CDW generated by both vertical buildings and horizontal infrastructure. These broader strategies include “maximizing asset utilization through programming”, including designing flexible spaces in which (or on which) uses can evolve over the long life-span of a built object, which strategy works in tandem with “designing for deconstruction at the end of component life cycles”, and leveraging existing and emerging design and construction technologies such as designing for off-site construction, which “has been shown to create less waste by reducing errors and rework”, and using building information modeling (BIM) or other three-dimensional modeling, which permits “virtual coordination, thereby minimizing on-site construction errors.”<sup>49</sup>

**State of Academic Research—Limits of Life Cycle Assessment.** The several goals for the many studies focusing on the environmental impact of CDW management include:

- comparing the environmental impacts of producing recycled concrete aggregate (RCA) by processing CDW and producing natural (virgin) aggregate (NA)

- comparing the environmental impacts of producing concrete with only NA as aggregate and concrete incorporating RCA, and
- comparing the impact of landfilling mineral CDW (MCDW) with that of processing MCDW into RCA for use as paving materials in road construction.

These studies do not account for all the parameters that affect the impact of waste management. In order to understand the environment in which recycling CDW takes place, it is necessary to develop life cycle assessment (LCA) frameworks in order to account for all the potential strategies for landfilling and recycling CDW into new products, and the environmental consequences of selecting each strategy on the demand for the materials that are replaced or affected by recycled materials.

Nevertheless, LCA studies provide valuable information about the environmental potential of recycling CDW. In urban areas, the landfills are often far from the construction and demolition sites, and the transportation of waste impose a significant environmental burden. In addition, land preparation and maintenance of landfills, as well as the re-cultivation of landfills after they reach the capacity, are other sources of environmental strain. CDW is often processed into RCA for use as unbound aggregate or fill material. If the quality of RCA is as good as that of the virgin material that it replaces, the environmental impact of using the recycled product is likely to be lower, depending on transportation distances and the applied waste processing technique. RCA can be used as a replacement of NA in concrete. This may lead to reduction in the compressive strength of concrete, which needs to be compensated for by using additional cement, potentially leading to increased environmental impact.

Selection criteria for a CDW management strategy/policy would be primarily based on practicality and cost effectiveness. However, when there are different options for practical and cost effective options, properly structured LCA needs to be performed to compare the environmental impacts of pursuing the potential strategies.

***State of Academic Research—Barriers to Recycling CDW.*** A significant amount of research has been completed in the past years on recycling CDW for use in new construction. While some materials, such as steel and aluminum, have always found a willing and profitable market, other materials have not fared so well despite academic research indicating that they will produce acceptable new materials. One such example is recycled concrete for use as aggregates in new concrete. Research has shown that concrete made with RCA can easily achieve normal concrete strengths (4 – 6 ksi) with only minimal changes to mixture designs. Research has also shown that RCA may actually be beneficial in some cases to improve performance of concrete.<sup>50</sup> Despite this, many engineers still see the material as being subpar and are worried about the consequences of using RCA in their mixtures.

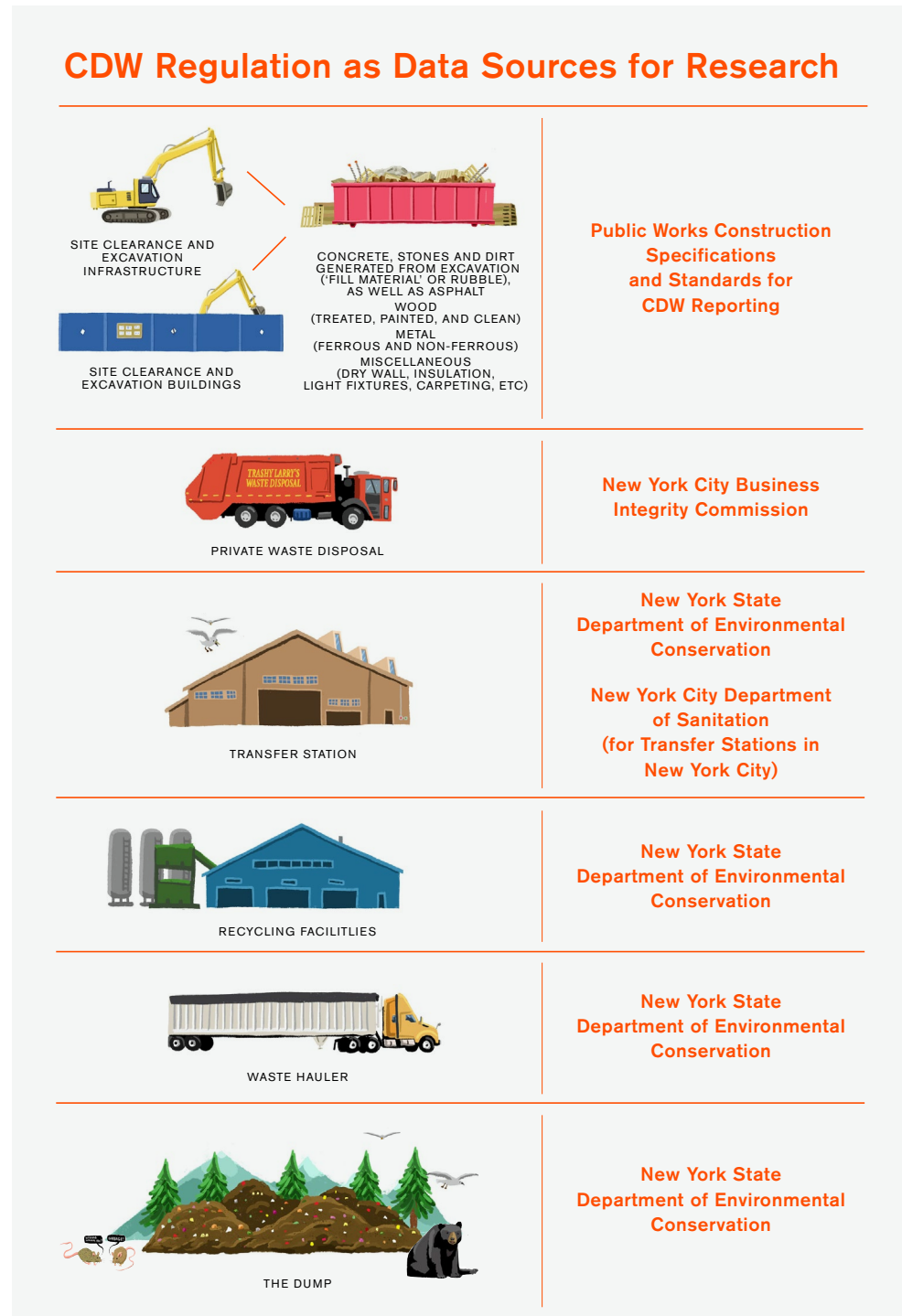
One reason that construction owners and engineers may be reluctant to use recycled materials is the lack of standards and specifications provided by government agencies that allow their use.<sup>51</sup> The construction industry operates in a conservative, risk-adverse environment,<sup>52</sup> and many engineers will not use a material unless specifically allowed or directed by the government standards and specifications. As an example, with respect to concrete specifications within the New York City context, there are two separate processes—one for roadway infrastructure projects and another for public building

projects. On the roadway infrastructure side of the built environment, DDC maintains the material specifications and standards for both the New York City Department of Transportation (DOT) and the New York City Department of Environmental Protection, two of DDC's client agencies on their roadway reconstruction projects.<sup>53</sup> On the public building side of the built environment, the material specification and standards process is similar to that in the private sector. For example, with respect to concrete in buildings, the building designer (either architect or structural engineer) is responsible for specifying the concrete mix necessary to meet the design specifications within the applicable regulatory context, including the building code. Unlike in infrastructure, there is no single material specification and standard for buildings, since buildings may differ, but there is a standard materials compliance process, written into design and construction contracts, for all buildings, consisting of on-site inspections, off-site materials testing and licensed professional certifications. This context can make creating a stable economically advantageous supply chain difficult to establish. It is possible that governmental agency owners, responsible for public infrastructure and public buildings, can help to establish or support these supply chains by allowing, through specifications and standards, the use of CDW elements as recycled material in new construction.<sup>54</sup>

Providing for and standardizing the use of CDW will help to reduce the significant environmental impact of transportation of CDW to landfills, reduce the need for new landfill construction, and reduce the need to harvest additional non-renewable resources. Beyond this, however, is the significant consumption of materials that occurs in major urban environments. As we continue to build, we need to produce more materials to support that construction. High quality aggregates for concrete, for example,

are becoming scarcer close to the urban areas which demand concrete, and so we must transport aggregates in from further and further away.<sup>55</sup> The transportation of material into urban environments has high environmental and economic impacts.

In addition, however, developing LCA models for CDW waste recycling can raise additional issues with respect to local recycling centers for CDW.<sup>56</sup> These would include the need to increase the efficiency of transfer stations and processing facilities and the need to increase the quality of recycled components, within an overall analytical context, creating the conditions for changes to policy and practice to reduce the amount of material that the users of the construction industry are bringing in from far away, and provide a high quality source of material nearby.



**State of Academic Research—Other Issues.** The benefits of recycling CDW can also be viewed from a strategic perspective. Current environmental assessment methods based exclusively on CO2 emissions fall short of demonstrating significant benefits to CDW recycling. Assessments limited to standard environmental impact categories show only slight benefits. The variation in the composition of CDW and the lack of jurisdiction to enforce source segregation frustrate efforts to set standards for material quality. The advantages of developing CDW recycling systems lay in further developing the framework for the recycling of bulk materials used in the urban built environment. Such a framework would involve adding other data sources to the life cycle cost benefit analysis of CDW recycling, such as:

- Urban congestion reduction metrics
- Health and well-being metrics
- Other quality of life metrics

Expanding the LCA model to become dynamic and account for a wider view of benefits and costs also requires the existence and/or creation of data suitable for necessary quantitative analysis and inclusion in the model, using tools used elsewhere for informatics, correlations and decision support systems for operations and management.

**Recycling CDW “on the Ground”:** As noted above, the high cost of disposal for public and private projects in dense urban locations, such as New York City, has meant under the conditions of the market for CDW recycled commodities, there has historically been a level of separation of CDW, which has only improved over time. The commodities market is only one economic condition,

however, that has an impact on CDW recycling rates. The economics of construction “on the ground” in a densely built urban environment is another issue area that has an impact on CDW recycling rates. In a densely urban environment, such as New York City, for example, space for staging on the construction site is limited, “often only available curbside,”<sup>57</sup> and transportation of construction materials and CDW in and out of the City is impacted by the DOT’s street use regulations and periodic truck traffic embargoes during peak holiday weeks. In addition, the general condition of high labor costs that increases the cost of construction in the City, also increases the cost of recycling CDW.<sup>58</sup> The split incentives between owners and tenants and between initial construction costs and ongoing operations and maintenance costs that apply in the sustainable energy area also apply to the area of recycling CDW.<sup>59</sup>

Construction issues differ broadly for horizontal infrastructure projects and vertical building projects. Horizontal infrastructure projects involve significant amounts of earthmoving and heavy construction, and the activity categories consist of:

- Earthmoving and trenching operations
- Excavation and lifting
  - Loading and hauling
  - Compacting and finishing
  - Production of aggregates
  - Production and pouring of portland cement concrete

- Production and laying of asphaltic concrete
- Paving and surface treatments
- Rock excavation
- Compressed air and water supplies<sup>60</sup>

The activity categories for vertical building structure construction consist of:

- Foundations
- Concrete construction
- Wood construction
- Steel construction
- Piping
- HVAC
- Electrical
- Telecommunications
- Exterior finish construction
- Interior finish construction<sup>61</sup>

## Capital Project Processes: Build

### Parade of Trades

Site Clearance  
and Excavation

Foundation

Steel Erection

Shell/Skin

Roof

Interior Flooring

Site Work

#### Earthmoving and heavy infrastructure construction

- Earthmoving and trenching operations
- Excavation and lifting
- Loading and hauling
- Compacting and finishing
- Production of aggregates
- Production and pouring of portland cement concrete
- Production and laying of asphaltic concrete
- Paving and surface treatments
- Rock excavation
- Compressed air and water supplies

#### Building construction

- Foundations
- Concrete construction
- Wood construction
- Steel construction
- Piping
- HVAC
- Electrical
- Telecommunications
- Exterior finish construction
- Interior finish construction

Source: F.H. (Bud) Griffis and John v. Farr, Construction Planning for Engineers, (New York, 2000) (McGraw-Hill Custom Publishing Textbook), p. 172.

While horizontal infrastructure construction differs from building structure construction in many ways, it is possible to see commonalities when looking at construction as a production function. The construction industry stands out among all other industries across a number of areas, in part because construction is less like factory production and more like product development conducted at a specific site requiring on-site assembly against a dynamic and complex “parade of trades” montage.<sup>62</sup> A construction project is a complex setting where multiple levels of “skill differentiation and hand-tool operations . . . converge at a unique site” and the “myriad of special-trades employers then direct these operations.”<sup>63</sup>

In the “parade of trades” montage—or the construction production function—the project is an assembled object, fixed-in-place where “the stations—or work crews—move through the emerging whole [building or infrastructure in the process of becoming]”.<sup>64</sup> This “parade of trades” process on a vertical building project (and to a lesser extent on a horizontal infrastructure project) also “involves a large number of specialty trades that generally work in a continuing and repeating sequence as they move from one floor to another, from the structural parade, the overhead work parade, the perimeter work parade, the enclosure work parade to the interior finishes work parade, which can impact access and create congestion.”<sup>65</sup> The concentration of work at the site will vary by trade and “the different parades [will] move through a building in different directions.”<sup>66</sup> In this setting, “[e]very project is somebody else’s subproject” in an atmosphere of “fast completion in a dynamic setting where frequent changes are not the exception but the rule.”<sup>67</sup>

Finally, to make matters more complicated, the construction process is an “undocumented process that takes place as an interplay between a complex and dynamic customer and a complex and dynamic production system at a temporary production facility.”<sup>68</sup> It may help to understand the construction process by looking at it as “product development and less like factory production, at a specific site that requires on-site assembly.”<sup>69</sup> The construction production function for buildings and infrastructure thus conceived is “a flow of information and materials (flow process) and as the generation of value for customers” in the context of “converting inputs to outputs (conversion process).”<sup>70</sup> Viewed in this manner, it becomes possible to identify and manage “previous work, space, crew, equipment, information, materials and external conditions such as the weather” as “flows toward . . . execution of a work package.”<sup>71</sup> The techniques of managing the “turbulence” in space, crew, equipment, information, materials and external conditions and using buffers to “facilitate reliable workflow by ensuring that there is always work packages ready”<sup>72</sup> can shed light on the root causes of many issues in construction ranging from schedule delays (and resulting increases in cost) to accidents—and possibly increasing the level of CDW source separation on site and increasing CDW recycling levels. Managing “the handing over of space from one trade to another”<sup>73</sup> and “flows of crew [shared with other construction projects] and equipment in a highly dynamic system”<sup>74</sup> requires both “managing bottom up and not top down only . . . while focusing the middle management’s own resources on managing the logistics . . .”.<sup>75</sup> Thus, the management process, which “take[s] place by a series of

conversations” can become a “learning process, where the crews and the organization as a whole are learning . . . about the object, the process and the objectives and also learning about each other.”<sup>76</sup> Thus, despite “frequent work team rotations, exposure to weather conditions, high proportions of unskilled and temporary workers . . .” and “. . . changes in topography, topology and work conditions . . . that make managing construction . . . more difficult than managing . . . in manufacturing plants,” it is, however, possible to assess and model conditions for construction to predict and thus manage risks to project schedule and safety.<sup>77</sup>

This “parade of trades” montage described above, however, takes place within the complex context of contractual relationships. The relationships among the owner<sup>78</sup> of construction and the *constructor network of firms*, is a contractual one. The constructor is actually a network of firms—typically referred to as a prime contractor and its subcontractors—related to each other by a series of contracts, much like the contract between the owner and the prime contractor(s).<sup>79</sup> These related contracts for a project are closely connected to each other throughout the construction process, and while the owner and the constructor are not in opposition to each other, they have different perspectives on the many functions they share, such as project management.

In the public project context,<sup>80</sup> based primarily on the design-bid-build service delivery methodology, the construction contract is between the owner and prime contractors, which contract includes General Condition

specifications such as CDW-related specifications. Many prime contractors do not “self-perform” all the work they commit to produce for the stated contract price, which means they will in turn contract with “sub-contractors” for portions of the contract work. The prime contractors’ construction contract contains provisions controlling how the prime contracts can sub-contract with the work, and the terms and conditions, including CDW specifications in the General Conditions, of the prime construction contract are replicated in the sub-contracts between the prime contractor and its sub-contractors. In construction contracts, however, practical operational construction procedures are often subsumed within the term “means and methods”, a term used in construction contracts to capture the contractor’s discretion, subject to all provisions of the construction contract, with respect to the manner and time of the contractor’s use of its labor, materials, temporary structures, tools, plant, and construction equipment that are necessary to accomplish the result intended by the construction contract.<sup>81</sup> One of the devils of increasing CDW recycling may be at this level of detail.



# Capital Project Processes: Design-Bid-Build

## Mandatory Separation of Designer and Constructor

Public owner must prepare separate specifications for three articulated subdivisions of work, which specifications shall be drawn as to permit bidding (GML § 101 (1) and (2); SFL § 135)



## Mandated Award to Proposer with Lowest Initial Price

Public owners must award contracts for public work to lowest responsible bidder (GML § 103 (1); SFL § 135)

*New York State also mandates multiple prime contracting, unless a project labor agreement is in place with respect to the project. (Cite to come)*

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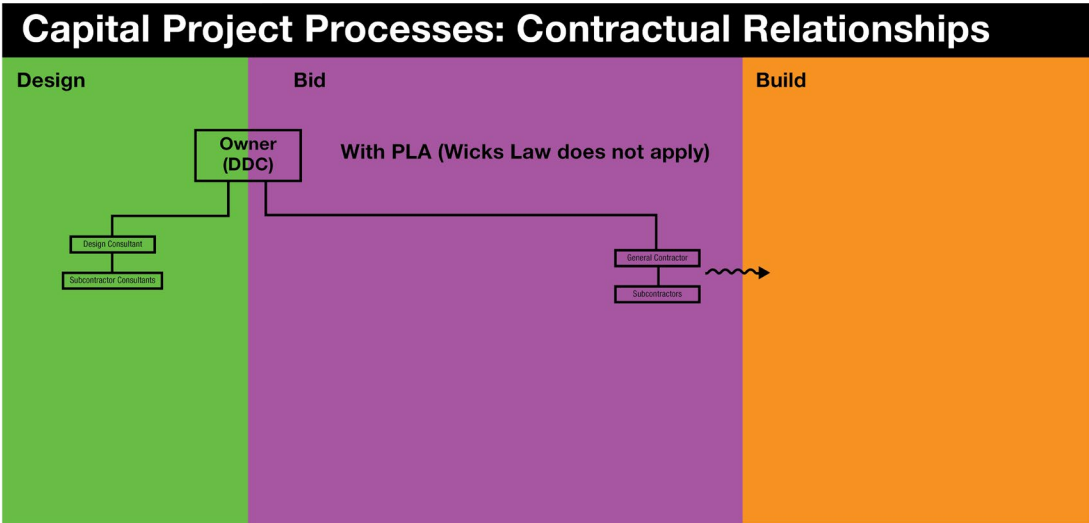
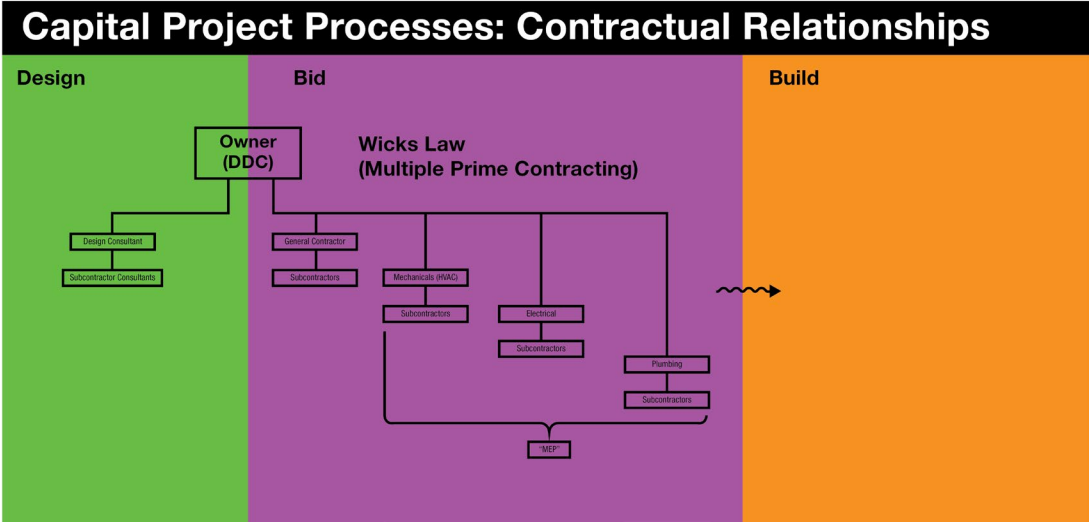
## Public Design-Bid-Build Methodology

*A few words on Design-Bid-Build and Multiple Prime Contracting.* Owners of public works in the State, which includes the City, are limited in the way they can deliver their projects due to the required procurement and contracting methods.<sup>82</sup> The way City construction agencies enter into contracts with construction firms to construct public works projects is both a procurement process under the law and also a service delivery method, often referred to as the “Design-Bid-Build”, in practice.<sup>83</sup> Design-Bid-Build not only refers to the separation of the Design phase from the construction—or Build—phase, it also refers to the method of solicitation—open competitive bidding with award to the contractor that proposes a responsive bid at the lowest price, which the construction agency deems to be a responsible vendor under applicable laws and rules.

In general, the Design-Bid-Build methodology requires any City construction agency, as project owner, to separate the *Design* process, the *Bid* process and the *Build*—or construction—process, which, under other methodologies, can be combined in different ways.

New York state law also generally requires public owners to separate project specifications into four component parts—one for general contractor work, one for electrical contractor work, one for mechanical (HVAC) contractor work, one for electrical contractor work and one for plumbing contractor work. These four types of contractors are often referred to as “prime trade contractors”, and the law requiring such separation of public project work into the four prime trade contracts is referred to

as the “Wicks Law”, which is a mandated multiple prime contracting method for public construction in the State.<sup>84</sup> Mechanical (HVAC), electrical and plumbing trades are also referred to collectively as “MEP” trades. Multiple prime contracting is most prevalent on vertical—or building—projects, which involve all MEP trades, and less prevalent on horizontal—or infrastructure projects, such as road reconstruction, which typically do not involve all MEP trades. In 2008, the State amended the Wicks Law to permit public Owners to avoid the requirement of multiple prime contracting when they enter into a project labor agreement—or PLA—for an individual project or a type of project. A PLA is a version of what is known as “pre-hire agreements” entered into by a public Owner, construction trade unions and contractor firms before the procurement of any construction services for a public project and it functions as “a comprehensive labor relations agreement — or ‘job site constitution’ — that governs over various area craft agreements, setting uniform terms and conditions, for a particular project.”<sup>85</sup> A PLA binds all bidders on capital projects subject to the PLA to the terms of the PLA.



## Abstracts of Town+Gown Projects

### ***Gypsum Recycling in PlaNYC 2030: Spaces for Government Intervention (2011-2012)***

Town: NYC DDC

Gown: Columbia/GSAPP

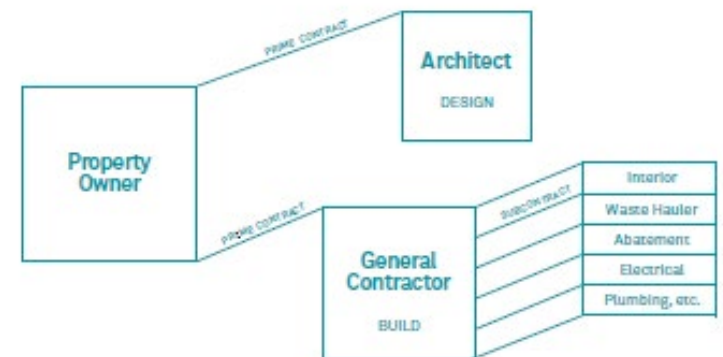
Researcher: Caroline Bauer

*Objective.* In the context of a master of urban planning thesis guided by the research question *How to Design Incentives for Sustainability Implementation?*, Caroline Bauer focused on gypsum recycling at two public owners in New York City, as a case study to assess how government, as regulator, can create incentives for desired behavior. While PlaNYC lists gypsum scrap recycling as a priority, it also notes the lack of gypsum recycling resources and infrastructure. This project specifically sought to identify the kinds of actions the City might take to incentivize gypsum recycling.

*Methodology.* Bauer conducted a literature survey related to both government regulation and gypsum production and recycling, in particular to document the lifecycle of gypsum wallboard from extraction to disposal. Bauer conducted two series of interviews, one of government officials to describe the culture in which decisions about recycling regulations and enforcement occur and another of supply chain participants to describe current practices related to gypsum use and recycling and the nature of the current market for gypsum recycling services. Bauer also analyzed standard contractual relationships on construction projects to identify the roles and responsibilities related to construction product inputs such as gypsum in order to conduct a proto cost benefit analysis of feasible incentives.

*Findings.* During the process of assessing the benefits and costs of the various incentive proposals identified, Bauer found that the original question of how the City should incentivize gypsum recycling shifted to whether the City should incentivize gypsum recycling. Gypsum is an abundant and cheap material to extract, recycled scrap is difficult to sell and synthetic gypsum has emerged as a “greener” and cheaper alternative to recycled gypsum. The nature of the material and the market for its production, which is at the national level, suggested that local government was not the appropriate or optimum actor for gypsum recycling regulation or incentives to increase recycling compliance. Bauer concluded that the City should re-examine whether gypsum recycling should remain a policy priority.

*Next Steps.* Bauer included recommendations on how other stakeholders in the supply chain could handle the material given its incompatibility with the transfer station and landfill environment. The methodology Bauer followed also provides a basis to develop a model for use in analyzing future local recycling proposals.



***Life Cycle Cost Analysis and Green Infrastructure in New York City Life Cycle Cost Analysis and Green Infrastructure in New York City (2013-2014)***

Town: NYC DDC, NYC DOT, NYC DEP, NYC OMB  
Gown: Columbia/SIPA  
Researcher: Christopher Eshleman

*Objective.* Earlier Town+Gown projects attempting to develop feasible life cycle cost benefit models ran into impediments largely due to the unavailability of cost data at the time. The first project focused on modeling NYC DOT's sustainable roadway design program, and the second project focused on modeling bioswales and permeable pavement gutters, two types of green infrastructure "add-ons" to standard roadway reconstruction projects. As both NYC DEP, with its 2010 Green Infrastructure Plan, and NYC DOT, with its sustainable roadway program, began to pilot and experiment with these "green infrastructure" elements, rudimentary cost and performance data began to become available, providing the necessary conditions to demonstrate the feasibility of developing *and using* a life cycle cost benefit analysis model during the City's capital budget planning and adoption processes.

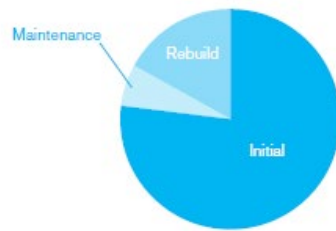
*Methodology.* Eshleman designed the model in the Excel program to be both simple and accessible. He incorporated standard capital asset life cycle methodology and theory into the model in order to permit capital planners and budget analysts to conduct cost effectiveness analysis in a way that would capture discounted initial and life cycle costs and physical performance. The costs included operations and maintenance costs and replacement costs of various project options, while the physical performance metrics included water capture under several rainfall scenarios. Eshleman used data from NYC DDC, NYC DOT and NYC DEP where available and comparable data from elsewhere as proxies.

*Findings.* Eshleman demonstrated that the model permitted a cost effectiveness analysis, for a one inch rainfall event, of a bioswale project in Brooklyn and a permeable pavement project in Queens. The initial use of the model suggested that the permeable pavement installation may be more cost efficient over its useful life than the bioswale when it comes to capturing water during major storms. The point of this initial use of the model, however, was not to conclude that the City should shift its policies in any particular direction, but to establish the feasibility of developing and using such a model in the City's annual capital planning and budgeting processes.

### Total Cost:

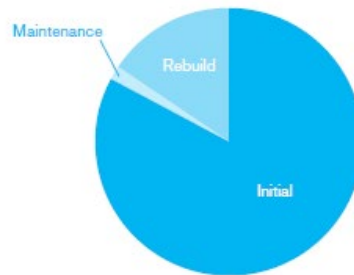
#### Bioswale

Pricier maintenance,  
cheaper construction



#### Permeable Pavement

Pricier construction,  
cheaper maintenance

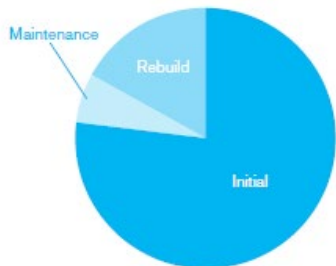


	Initial	Maintenance	Rebuild	Total
<b>Bioswale:</b>	\$36,500	\$2,870	\$7,941	\$47,311
<b>Pavement:</b>	\$58,027	\$1,106	\$10,773	\$69,906

### Cost Effectiveness:

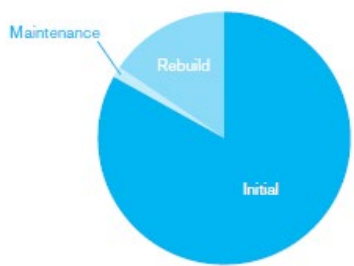
#### Bioswale

Pricier maintenance,  
cheaper construction



#### Permeable Pavement

Pricier construction,  
cheaper maintenance



	Initial	Maintenance	Rebuild	Total
<b>Bioswale:</b>	\$365	\$29	\$79	\$473
<b>Pavement:</b>	\$309	\$6	\$57	\$373

*Next Steps.* This most recent life cycle cost benefit modeling project to which actual cost data was applied in an initial test run, points to the feasibility of City agencies using life cycle modeling in capital planning and budgeting, certainly for green infrastructure, but also for all the elements of the roadway. Eshleman's model was not able to include all the benefits accruing from these types of features nor was it possible to test the range of rain events that are likely to occur in the context of climate change. However, were City line and oversight agencies to collaborate and begin using this type of model for capital planning and budgeting purposes, they could adapt it to include other benefits and expand the range of rainfall volumes and speed of runoff.

***Replacing Natural Aggregates with Recycled Aggregates for Concrete Making in NYC—An Environmental Impact Assessment Study (2015-2016)***

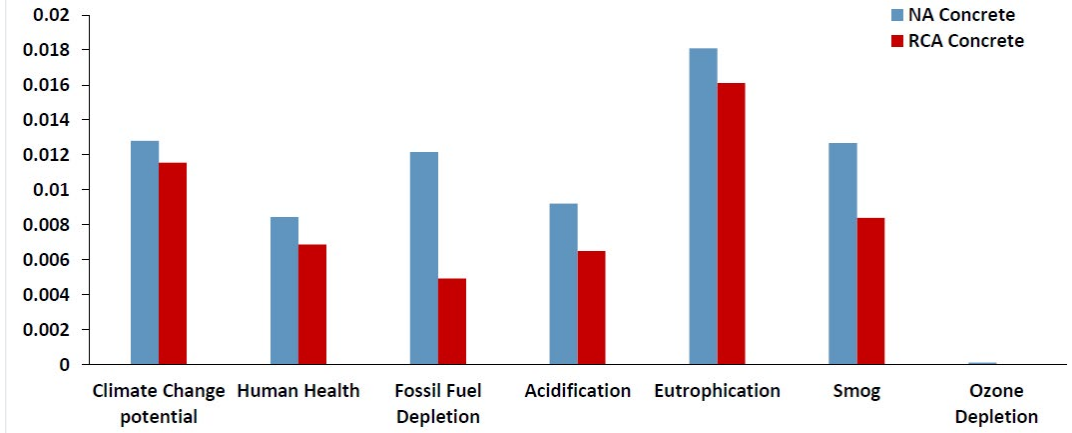
*Objective.* In the course of an internship project with CUNY/CCNY faculty, Meryl Lagouin performed a partial comparative life cycle assessment (LCA) to compare the environmental impacts of two concrete product systems—concrete with coarse natural aggregate and concrete with coarse recycled aggregate—focusing specifically on the effects of cement content, transportation distances and landfill avoidance in New York City. Since among the mostly inert construction and demolition waste materials (CDW) generated by the construction sector, concrete is a significant component, use of recycled CDW aggregate (RCA) as a replacement for natural (virgin) aggregate (NA) in concrete for new uses can increase reduction of this component of CDW in landfills, with associated transportation effects, and preserving natural resources associated with concrete production.

*Methodology.* This partial comparative LCA focused on the New York City area and considered two categories of processes—the extraction and production of raw materials and the transportation of the raw materials to concrete plants—and excluded processes assumed to be the same for both product systems, such as producing concrete in a ready-mix plant, service and demolition phases. The LCA used private aggregated data sources for lifecycle elements of the concrete production function and used data collected from the New York City

Department of Sanitation (DSNY) with respect to transfer stations, which recycle CDW, located within the City limits which DSNY regulates, to calculate the average distance between job sites and landfills and associated transportation effects, including avoided transportation due to recycling RCA. Among the LCA assumptions was an assumed 8 percent additional cement for recycled cement production; an assumption that infrastructure itself was the only parameter responsible for the beneficial environmental impact (i.e., if x% of CDW is recycled in RCA usable for new concrete, then only x% of the beneficial impacts of landfill avoidance would be allocated to the recycled concrete in the LCA); an assumption that landfilling CDW was a negative environmental impact; and, an assumption that the collected recycled products go to the nearest transfer station within New York City. The results of interim data processing permitted a further assumption that 43 percent of transfer stations located within the City are turned into RCA, which was combined with an additional assumption such as that only CDW that can be turned into RCA are sent to transfer stations, which, in turn, led to landfill avoidance metrics. The researcher used SimaPro software and ecoinvent life cycle inventory (LCI) datasets to model elements of the LCA in order to transform market and production system activities for the two waste scenarios.

*Findings.* The LCA tool permits quantification of all material flows with their associated potential environmental impacts and characterizing the effects of the different processes. The comparative LCA noted the predominance of cement production as a negative environmental

## NORMALIZED IMPACT INDICATORS



impact in the concrete production function, and found that, in absolute terms, the production of RCA and NA had similar environmental impacts. When transportation and landfill avoidance were added to the LCA model, however, a lower negative environmental impact for concrete production resulted, and, regardless of landfilling, the use of RCA in new concrete has a lower negative environmental impact than the use of NA for concrete production.

*Next Steps.* These comparative findings suggest that, with additional research, it is possible to reduce the overall negative environmental impacts of concrete production by increasing the use of RCA in new concrete within a geographic area. Project-specific LCA studies need to be performed to determine in what types of construction projects the use of recycled CDW in concrete (or other applications) has the highest environmental benefit. In addition, consequential LCA studies needs to be conducted to investigate the recycling consequences other than avoided landfilling for the environmental burden of construction.

## END NOTES

- 1 These institutions are typically not-for-profit organizations that are exempt from real property or other local taxes that fund the City's waste collection activities.
- 2 New York City Independent Budget Office (IBO), Fiscal Brief, "Ten Years After: Assessing Progress on the City's Solid Waste Management Plan", August 2017, p. 2 (<http://www.ibo.nyc.ny.us/iboreports/ten-years-after-assessing-progress-on-the-citys-solid-waste-management-plan-2017.pdf> accessed 09-20-17 @ 2:46 p.m.).
- 3 For example, the New York City Business Integrity Commission regulates the trade waste industry, among others, and their areas and markets, with respect to licensing and other authorizations to permit trade waste companies to operate within the City. Charter, Section 2101. DSNY regulates the transfer stations located within the City, including those that accept CDW. New York City Department of Design and Construction (DDC), *Construction and Demolition Waste Manual* (2003), p. 2 (<http://www1.nyc.gov/assets/ddc/downloads/Sustainable/construction-waste-manual.pdf> accessed 09-20-17 @ 2:43 p.m.).
- 4 New York City Department of Design and Construction (DDC), *Construction and Demolition Waste Manual* (2003), p. 2 (<http://www1.nyc.gov/assets/ddc/downloads/Sustainable/construction-waste-manual.pdf> accessed 09-20-17 @ 2:43 p.m.).
- 5 *Idem*
- 6 *Ibid.*, p. 3.
- 7 Meryl Lagouin, Ardavan Yazdanbakhsh and Lawrence Banks, *Replacing Natural Aggregates with Recycled Aggregates for Concrete Making in NYC—An Environmental Impact Assessment Study* (2016).
- 8 DDC, *op. cit.*, inside front cover.
- 9 *Idem* See also Clare Mifflin, Juliette Spertus, Benjamin Miller and Christina Grace, authors; [AIA New York Center for Architecture, Kiss + Cathcart Architects, ClosedLoops](#) and [Foodprint Group](#), as collaborating organizations with support from The Rockefeller Foundation, *Zero Waste Design Guidelines*, p. 129, on the general strategy and utility of leadership by city agencies in helping to promote change through practices in their new buildings," and p. 131, on waste management planning strategies on site. ([http://www.zerowastedesign.org/wp-content/uploads/2017/10/ZeroWasteDesignGuidelines2017\\_Web.pdf](http://www.zerowastedesign.org/wp-content/uploads/2017/10/ZeroWasteDesignGuidelines2017_Web.pdf) accessed 11-09-17 @ 4:20 p.m.)
- 10 *Ibid.*, p. 2.
- 11 *Idem*
- 12 DSNY 16 RCNY Sections 1-10. See Mifflin *et al.*, *op. cit.*, p. 124.
- 13 *Ibid.*, p. 3.
- 14 *Idem*
- 15 *Idem*
- 16 *Idem*
- 17 *Idem*
- 18 *Idem*
- 19 *Idem*
- 20 *Ibid.*, pp. 12, 14-17. The *Manual's* guidelines were incorporated in the DDC Standard General Conditions to the City's Standard Contract (Section 01 74 39 Construction Waste Management and Disposal), so that specification standards "require the contractors to recycle C&D waste." *Ibid.*, p. 14. See also Mifflin *et al.*, *op. cit.*, p. 129, identifying the demolition permit process as a "window of opportunity to salvage furniture and finish materials—carpet for one—before the demo process starts."



21 *Idem*

22 *Ibid.*, p. 13; pp. 15-16; see also, pp. 18-21.

23 LEED projects have additional specifications required by the LEED program in addition to what is required by the DDC specification discussed above. See also, Mifflin *et al.*, *op. cit.*, pp. 124 and 127. LEED no longer considers use of recycled gypsum wallboard and ceiling tiles in alternative daily cover on a landfill as meeting its recycling requirements.

24 City Charter, Section 20; see also Local Law 66/2014 with respect to the 80 x 50 requirement.

25 *New York City's Roadmap to 80 x 50*, p. 98. The four sectors are energy, buildings, transportation and waste, with the waste sector contributing four percent of Citywide GHG emissions. ([http://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/New%20York%20City's%20Roadmap%20to%2080%20x%2050\\_Final.pdf](http://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/New%20York%20City's%20Roadmap%20to%2080%20x%2050_Final.pdf) accessed 09/21/17 @ 2:28 p.m.).

26 *Ibid.*, pp. 99-100.

27 Though not clear from the cited material, this metric most likely focuses on emissions from landfills within City borders. See also, Mifflin *et al.*, *op. cit.*, footnote 2, p. 17.

28 *Ibid.*, p. 98.

29 *Ibid.*, p. 99.

30 Most of those emissions are caused by the production of portland cement (an ingredient of concrete). This is caused mostly by decomposition of limestone in kiln ( $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$ ), and also by combustion of the fuel used for heating the kiln in cement plants. Producing a metric ton (1,000 kg) of cement can result in the release of around 800 kg of CO<sub>2</sub> in the US. European plants are a bit more efficient, as some of them avoid using coal.

31 DDC, *op. cit.*, p. 8.

32 See abstracts of "Experimental and Numerical Evaluation of CIPP Lining Systems for High Temperature Applications in Sewer Pipes" and "Madison Avenue Watermain Rehabilitation Trenchless Technology Assessment" in *Building Ideas*, Vol. 2, pp. 52-55. (<http://www1.nyc.gov/assets/ddc/downloads/town-and-gown/building-ideas-2.pdf>).

33 Comparative analysis conducted by Julio Davalos, Ph.D., and Marija Krstic, doctoral student, CUNY/City College of New York, Department of Civil Engineering.

34 From <https://en.wikipedia.org/wiki/Pozzolan> (accessed 11/13/17 @ 4:31 p.m.).

35 NYS DEC press release dated September 20, 2017 <http://www.dec.ny.gov/press/111459.html>, accessed 11-09-17 @ 12:15 p.m. For regulations, see also <http://www.dec.ny.gov/regulations/81768.html>.

36 *Idem*

37 Section 360.2 (b)(101) (Definitions).

38 Section 360.19(k)(2)(1).

39 Subpart 361 generally; Section 361-5.4(b).

40 Section 361-5-5(a) and 361-5.6. Though ultimately subject to further regulations, this tracking document includes, at a minimum, information about the C+D debris handling and recovery facility generating the waste or material transported, information about the transporter and the intended destination of the material. See Section 361-5-6(a)(1)-(3). See also Subpart 364-5 generally.

41 Section 360.12(a)(1).

42 Section 360.12(c)(3), (i), (vii)-(xi); see also Section 360.12(b) for

other beneficial uses such as wood pallets and sand and gravel from street sweepings and water system catch basin materials.

43 Subpart 366-2 generally; Section 366-2.2(a)(2). New York City's Solid Waste Management Plan, adopted in 2006, is in effect until October 2025. IBO, *op. cit.*, pp. 1-2.

44 Section 366-2.5.

45 Section 366.2-5(a), (5), (7), (9), (10) and (12).

46 Section 366.2-5(b), (1)(iii) and (2).

47 Mifflin *et al.*, *op. cit.*

48 *Ibid.*, pp. 6, 125.

49 *Ibid.*, pp. 132-133.

50 Matthew P. Adams, Tengfei Fu, Adal Guerra Cabrera, Monica Morales, Jason H. Ideker, O. Burkan Isgor, "Cracking Susceptibility of Concrete Made with Coarse Recycled Concrete Aggregates," *Journal of Construction and Building Materials*, Vol. 102 Part 1, January, 2016, pp. 802-810.

51 Jason H. Ideker, Matthew P. Adams, Jennifer Tanner, Angela Jones, "Durability Assessment of Recycled Concrete Aggregates for Concrete: Phase II Final Report," *Oregon Transportation Research and Education Consortium*, OTREC RR-13-01, June 2014, Portland OR.

52 The conservative nature of the public works environment can be exacerbated by the fact that completed public works projects, which are long-lived assets, are expected to operate for a long period of time in a continuing context of public capital needs typically out-stripping public capital funding resources. Further, "state of good repair" activities must continually compete with new and expansion project needs within the envelope of constrained public capital resources.

53 See <http://www1.nyc.gov/site/ddc/resources/publications.page>.

54 See above under **CDW and the City** for a summary of the City's academically-supported comparative experimentation with glass pozzolan on sidewalk elements of a roadway reconstruction project.

55 M.S. Winfield, A. Taylor, "Replacing the Load: The Need for an Aggregates Conservation Strategy for Ontario", Pembina Institute for Appropriate Development, 2005.

56 Within the City's jurisdiction, there are 21 transfer stations, 16 of which have crushers.

57 Mifflin *et al.*, *op. cit.*, p. 128.

58 *Idem*

59 *Idem*

60 F.H. (Bud) Griffis and John V. Farr, *Construction Planning for Engineers*, (New York, 2000) (McGraw-Hill Custom Publishing Textbook), p. 171 (listed material directly quoted).

61 *Ibid.*, p. 172 (listed material directly quoted).

62 Glenn Ballard and Greg Howell, "What Kind of Production Is Construction?", Proceedings IGLC '98 Guarujá, Brazil, pp. 2, 4, 6. See also, Ophir Rozenfeld, Rafael Sacks, Yeheil Rosenfeld and Hadassa Baum, "Construction Job Safety Analysis", *Safety Science*, 48 (2010), p. 491.

63 Gerald Finkel, *The Economics of the Construction Industry* (Armonk, New York, 1997), p. 83.

64 Ballard and Howell, *op. cit.*, pp. 2, 4.

65 Iris Tommelein, David Riley, Greg Howell, "Parade Game: Impact of Workforce Variability on Trade Performance", *Journal of Construction Engineering and Management*, Sept/Oct 1999, p. 304.

66 *Ibid.*, p. 305.

67 Sven Bertelsen, "Lean Construction: Where Are We and How to Proceed?", *Lean Construction Journal*, Vol. 1, October 2004, p. 56.

68 *Ibid.*, p. 52.

69 Ballard and Howell, *op. cit.*, p. 5.

70 *Idem*

71 Bertelsen, *op. cit.*, p. 58.

72 *Idem*

73 Bertelsen, *op. cit.*, p. 59.

74 *Ibid.*, p. 60.

75 *Idem*

76 *Ibid.*, pp. 61, 63; see also Martin Marosszeky, Khalid Karim, Steven Davis, Nitin Naik, "Lessons Learnt in Developing Effective Performance Measures for Construction Safety Management," from proceedings of 12<sup>th</sup> Annual Conference of the International Group for Lean Construction, 2004.

77 Rozenfeld, *op. cit.*, pp. 492, 497.

78 Public owners of construction that are units of government perform several roles, including regulation of built environment participants and processes, as well as the built artifacts, simultaneously.

79 See Robert R. Eccles, "The Quasifirm in the Construction Industry," *Journal of Economic Behavior and Organization*, Vol. 2 (1981), pp. 335-357. See also Contract, Chapter IV (Article 17).

80 Which likely shares aspects with the private construction context.

81 As an example, see Chapter II, Article 4 of DDC's standard general conditions to the City's standard construction contract contain (Section 2.1.22).

82 New York State General Municipal Law, Section 103; New York State Finance Law, Section 163.

83 Other procurement process/service delivery methods include design-build and construction-management-at-risk, which the City is not authorized to use under current law.

84 New York General Municipal Law, Section 101, for municipal government public works.

85 Fred F. Kotler, *Project Labor Agreements in New York State: In the Public Interest*. Ithaca, NY: Cornell University, School of Industrial and Labor Relations — Extension Division, Construction Industry Program (2009), p. 2. [http://digitalcommons.ilr.cornell.edu/cgi/viewcontent.cgi?article=1021&context=reports&sei-redir=1&referer=http%3A%2F%2Fscholar.google.com%2Fscholar%3Fhl%3Den%26q%3Dkotler%2B%2Bproject%2Blabor%2Bagreements%2Bin%2Bnew%2Byork%2Bstate%26btnG%3D%26as\\_sdt%3D1%252C33%26as\\_sdt%3D#search=%22kotler%20f%20project%20labor%20agreements%20new%20york%20state%22](http://digitalcommons.ilr.cornell.edu/cgi/viewcontent.cgi?article=1021&context=reports&sei-redir=1&referer=http%3A%2F%2Fscholar.google.com%2Fscholar%3Fhl%3Den%26q%3Dkotler%2B%2Bproject%2Blabor%2Bagreements%2Bin%2Bnew%2Byork%2Bstate%26btnG%3D%26as_sdt%3D1%252C33%26as_sdt%3D#search=%22kotler%20f%20project%20labor%20agreements%20new%20york%20state%22) Accessed 09-01-17 @ 12:39 p.m.