Pushing the Recycling Envelope: Construction and Demolition Waste.3
ACS Manhattan Room
@150 William Street, 19th Floor
August 1, 2019, 9:00 a.m. to 11:30 a.m.

AGENDA

9:00—9:15 a.m.	Registration, Introduction and Welcome
9:15—10:15 a.m.	Life Cycle Cost Benefit Analysis Modeling Professor Ardavan Yazdanbakhsh, CUNY/CCNY
10:15—10:30 a.m.	DOT Pilot Project Professor Matthew Adams, NJIT Kate Mikuliak, NYC DOT
10:30—11:30	Discussion

Introduction. This is the third Town+Gown: NYC symposium event focusing on advancing the recycling envelope for construction and demolition waste (CDW). The first event, on November 30, 2017 (CDW.1), was a general exploration of the State of Academic Research and Practical Considerations and Impediments and Ideas for Future Research to Advance the Recycling. (See Appendix A) Considerations of recycling waste in the City depend on the nature of the waste that is being considered, and CDW, "managed almost exclusively in NYC by private transfer stations and processors," is distinct from the MSW stream.[1] 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.)."[2] CDW can also contain hazardous wastes such as "asbestos, lead paint and mercury from florescent lamps."[3]

Practitioners and academics interested in advancing the CDW recycling envelope joined material loop working groups and attended a follow-up event on October 30, 2018 (CDW.2), with brief academic framing presentations and a knowledge co-creation session with simultaneous breakout table sessions for concrete, gypsum, carpet and soil material loops. (See Appendix B) Follow-up working group meetings[4] generated several potential research projects listed below to pursue in the next academic year.

Concrete Loop

- *Pilot Casting Project Aimed at Closing a Concrete Loop within City Operations.*
- *Targeted Life Cycle Cost Analysis of Closing Concrete Material Loop within City (and template for other material loops).*
- *Data Mapping Project Applied to Concrete.*
- *Leveraging LEED and ENVISION to Increase CDW Recycling at Facilities*

Soil Loop

- *Data Mapping Project.*
- *Waste Measurement Technology during Transfer Process Project.*
- *Waste Generation Measurement at Sites Technology Project.*
- *IT and Capital Planning/Construction Process Solutions to Closing the Soil Loop on City Projects.*
- *Using What We Have for What We Need.*
    - *City-wide Survey*
- *"Mildly Dirty" Soil Analysis.*
    - *Manufacturing Clean Soil*

Gypsum Loop

- *Testing Project for Gypsum from City Project Demolition*
- *Leveraging LEED and ENVISION to Increase CDW Recycling at Facilities.*

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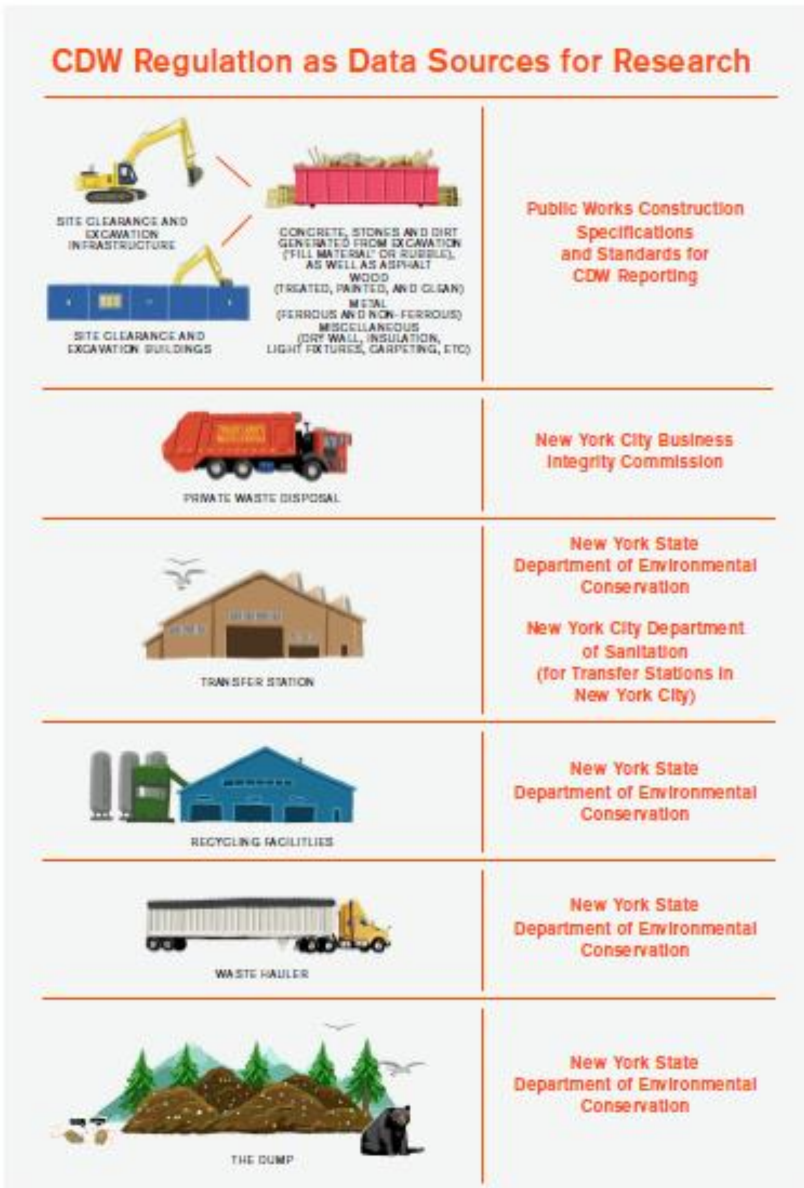
[1] New York City Department of Design and Construction (DDC), *Construction and Demolition Waste Manual* (2003), p. 2 (http://www1.nyc.gov/assets/ddc/downloads/Sustainable/construction-waste-manual.pdf accessed 09-20-17 @ 2:43 p.m.).
[2] *Idem*
[3] *Ibid*., p. 3.
[4] Concrete on 03/01/19, Soil on 03-08-19, and, Gypsum on 03-15-19.

- *Data Mapping Project Applied to Gypsum.*
    - *City-wide Survey*

At this event, CDW.3, there will be a presentation from Professor Ardavan Yazdanbakhsh of CUNY/CCNY-Grove on the details about life cycle cost benefit analysis (LCCBA) modeling applied to recycled concrete aggregate, which can provide all material loops with a LCCBA model template. LCCBA modeling is critical for the innovation policy design effort that the CDW working group is engaged in and in applying transaction costs economics principles to such policy design effort, as described in greater detail below. Professor Matt Adams of NJIT and Kate Mikuliak of NYC DOT will also provide an update of the upcoming pilot RCA casting project.



Opportunities Presented by the Regulatory Environment. *New York City's Roadmap to 80 x 50*,[5] the City's most recent articulated long-term sustainability plan required by the Charter, makes no specific references to CDW's presence in the City's waste stream or its contribution to the circular economy.[6] The *Roadmap's* focus on organic waste is likely due to its significance as a generator of greenhouse gases among all waste categories, analyzed from the perspective of the waste itself and not from the larger perspective of the creation and transportation of new construction materials themselves, which has been the subject of Professor Yazdanbakhsh research, which included a project within Town+Gown.[7]

Rules of the City's Department of Sanitation (DSNY) designate elements of CDW as recyclable and further require that CDW recyclables be "source separated from other waste streams."[8] 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."[9] 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."[10] 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".[11] 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."[12]

The 2003 *Construction and Demolition Waste Manual* from the New York Department of Design and Construction (DDC)[13] was intended to function as "an introduction and resource handbook for construction and demolition (C&D) waste reduction, reuse and recycling on New York City Projects"[14] and "prevent construction waste and divert from landfills the C&D waste that is generated."[15] This *Manual* was largely eclipsed when local law enacted in 2006 mandated application of the LEED program for construction and renovation of the City's public building portfolio, including LEED certification standards and reporting of diversion rates for CDW. ENVISION,[16] a rating and certification system similar

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[5] *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
accessed 09/21/17 @ 2:28 p.m.).

[6] *Ibid.,* pp. 99-100.

[7] Appendix A, CDW.1 precis, to this document, p. 11.

[8] DSNY 16 RCNY Sections 1-10. For the following material, see Appendix A, CDW.1 precis, in this document, p. 10.

[9] *Ibid.*, p. 3.

[10] *Idem*

[11] *Idem*

[12] *Idem*

[13] 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.).

[14] DDC *Manual*, *op. cit.,* inside front cover.

[15] *Idem*

[16] See https://research.gsd.harvard.edu/zofnass/menu/envision/ accessed 07-23-19 @ 2:49 p.m.

to LEED, for infrastructure projects, is not, however, mandated by local law for the City's infrastructure program.

The last time the City conducted a city-wide analysis of all waste produced in the City, in 1989-1990, the analysis included CDW as a component of commercial waste, which has a mixed regulatory pattern. DSNY regulates, pursuant to state law, and is responsible for collecting most putrescible waste[17] generated by residential and institutional[18] buildings, including hospitals, colleges and universities, located within the City. Private carters are responsible for collecting commercially-generated putrescible and CDW generated from new construction or renovation and rehabilitation of buildings and infrastructure, which the NYS DEC regulates in its entirety. The publicly- and privately-carted putrescible waste streams are considered, as a whole, to be the municipal solid waste (MSW) stream, and CDW is distinct from the MSW stream.

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.[19] Under market conditions at the time the *Manual* was released, "[s]ource separation generally yields the highest recycling rate and the best price for materials", and the construction site provides opportunities for source separation.[20] 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."[21] 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 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. While LEED no longer considers use of recycled gypsum wallboard and ceiling tiles in alternative daily cover on a landfill as meeting its recycling requirements, discussions among the CDW working group members has revealed 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.

The purpose or objective emerging from these three CDW events is ***closing material loops by increasing CDW recycling and re-use of recycled CDW products and using the City's capital program as the locus to support innovation in the wider construction industry***, which, at present, has not been the subject of any major explicit New York City government policy effort. The state of the regulatory environment discussed above suggests that a meaningful opportunity exists to conduct an innovation policy design effort to advance CDW recycling by providing the results of some of the activities below as resources for

[17] The term "putrescible waste" is intended to include all waste material that is likely to rot or decompose.
[18] 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.
[19] DDC *Manual*, *op. cit.,* inside front cover.
[20] *Idem*
[21] *Idem*

the State, which regulates the CDW field through NYS DEC,[22] and the City, through its agencies, when it turns to aspects of CDW recycling using its jurisdictional powers.   Regulations recently promulgated by NYS DEC (see Appendix A—CDW.1), and an Enforcement Discretion Letter, dated January 25, 2019, which may result in a rulemaking to adjust C&D Processing and Fill Material regulations, evince an intent to create and/or expand markets for re-use of recycled CDW through the use of pre-determined beneficial uses, which cease to be considered a solid waste when the material meets requirements for intended use. Additional state-level interest in addressing CDW re-use and recycling has emerged. State legislation (A 3203 and S 1587) was in the last session to impose a requirement for contractors working in New York City[23] to recycle the waste generated on construction and demolition sites for buildings, not infrastructure, starting at 25 percent in the first year and growing to 50 percent in subsequent years.

***Innovation Policy Design*.** It turns out that, with these three events focusing on advancing the CDW recycling envelope, the working group within Town+Gown: NYC is engaging in a form of **innovation policy design.** The purpose of a **system of innovation** or **SI** "is to pursue innovation processes [or] develop and diffuse innovations", and SI activities "are the determinants of the development and diffusion of innovations." [24] Innovation policy design, which aims at solving or mitigating policy problems created by an under-performing system, is conducted within a **system of innovation** that depends on a set of **activities**[25] to "identify [systemic] problems to be solved before designing a policy."[26]

"Since innovation policy consists of actions by public organizations that influence innovation policy, policy is a part of all of [these] activities."[27] Governmental organizations, when participating in a system of innovation, tend not to "influence the innovation processes directly but influence (change, reinforce, improve) the **context** in which the innovating firms operate."[28] But the activities of Innovation policy design are shared by private and public organizations, and there is a **division of labor** between them "with regard to who performs each of the activities," which can vary over time.[29]

"As a basis for the design of innovation policy, the **problems** in the system [which can be national, regional or sectoral] must be **identified.**"[30] The scale of the system "depends, to a large extent, on the

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22 See Appendix A, CDW.1 precis, to this document, pp. 13-16.

23 The legislation referred to "cities having a population of one million or more", which only includes New York City, to make this general legislation in order to avoid the State Constitution's home rule provisions.

24 *Idem*

25 In contrast to "functions". Charles Edquist, *Innovation Policy Design: Identification of Systemic Problems*, Centre for Innovation, Research and Competence in the Learning Economy, Lund University, Paper No. 2011/06, p. 7; https://www.researchgate.net/profile/Charles_Edquist/publication/269630710_Design_of_innovation_policy_through_diagnostic_analysis_Identification_of_systemic_problems_or_failures/links/548177b80cf22525dcb6166e/Design-of-innovation-policy-through-diagnostic-analysis-Identification-of-systemic-problems-or-failures.pdf , accessed 7/23/19 @ 1:37 p.m.   "**Innovations** are [defined as] new creations of economic and/or societal significance, mainly carried out by firms (private or public) [that take the form of] new products or new processes . . . [that] firms produce (and sell) . . . by means of technological or organizational processes." At p. 5.

26 *Ibid.*, pp. 3, 22.

27 *Ibid*., p. 19.

28 *Idem.*

29 *Idem.*

30 *Ibid.,* pp. 19-20*.*

questions one wants to ask."[31] The state of the regulatory environment discussed above suggests that the system involves both the State and the City, the largest local government in the State, as conjoined stakeholders, with the City presenting a locus for innovation policy research and incubation activities. Public economics holds that "public policy intervention in a market economy" is appropriate when the private sector is unwilling or unable to achieve societal goals, which generates the *problem,* and the public entity has "the *ability* to solve or mitigate the problem."[32]

Once problem identification under the necessary conditions above "for pursuing an innovation policy" exist, it is necessary to conduct a "detailed **analysis of the causes** of the problem" to indicate "*where* and *when* intervention is called for" and "*how* it should be pursued."[33] A governmental entity engaged in innovation policy can use 'diagnostic analysis', which first requires an assessment of the performance of the innovation system, identifying, in particular, "the kinds of innovations with which the system is performing badly" and thus defining the *problem*. The second step, which should "be carried out in terms of the ten activities in systems of innovation" listed below, involves an analysis to identify the causes of the previously identified problem.[34] The first part of the analysis involves assessing the current division of labor between public and private sectors "influencing (a low) performance with regard to a certain category of innovations" and then asking "[w]hat **should** the division of labor be?" The second part involves assessing the "characteristics of the part of the activities performed by public organizations" and then asking "[h]ow **should** the characteristics of the public intervention be changed?"[35]

An innovation policy design effort involves ten multi-causal **activities** listed below**.**[36] Town+Gown: NYC, a city-wide action research program in the built environment, is suited to facilitate several of these activities for this innovation policy design effort.

I. Provision of knowledge inputs to the innovation process

1. Provision of research results creates new knowledge

Research and development activities become the "means of developing economically relevant knowledge that can provide the basis for innovations, or the *financing* of the commercialization of such knowledge, i.e., its transformation into innovations."[37]

Research includes basic research, applied research and experimental research. Applied research, which Town+Gown facilitates and supports, is "original investigation in order

[31] *Ibid., p. 20.*
[32] *Idem.*
[33] *Ibid.,* p. 27.
[34] Ibid., p. 29.
[35] *Idem.*
[36] *Ibid,* pp. 6-8. The following list is directly from pp. 6-7.
[37] *Ibid.,* pp. 5-6.

to acquire new knowledge . . . directed mainly toward a specific practical aim or objective"[38]

2. Competence building in the context of organizational learning

"Competence building includes processes and activities related to the capacity to create, absorb, and exploit knowledge for . . . organizations [and] includes formal learning as well as informal learning," which Town+Gown performs with its clearinghouse of research results and working group methodology.[39]

II. Demand-side activities

3. Formation of new product markets

Government intervention "in the market on the demand side" may be necessary when "the market for certain goods and services might not exist or the users of goods and services might not be sophisticated enough to provide the required feedback to the producers with regards to new needs." "Another example of public support to market creation is the creation and introduction of standards." "In some cases, the instrument of public procurement for innovation has been important for market formation. In other words, a market emerged because the public sector demanded products and systems that did not exist before the public procurement for innovation."[40]

The City's capital program is extensive and varied, but fragmented, generating a significant amount of CDW, and its magnitude can function as a market maker. The CDW working group structure could, along with applied research results, provide necessary feedback to support market creation or expansion, creation or revision of standards and procurement including innovative processes.

4. Articulation of new product quality requirements emanating from the demand side

"The provision of new markets is often linked to the articulation of product quality requirements, which may be regarded as another activity of the SI. * * * Much of this activity is performed spontaneously by demanding customers in most SIs, enhancing innovation and steering processes of innovation in certain directions. * * * However, product quality requirements may also be a consequence of public action, for example, regulation in the fields of health, safety and the environment, or the development of technical standards. Public procurement for innovation normally includes a function specification of the product or system wanted, and this certainly means demand articulation that influences product development significantly."[41]

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38 *Ibid.,* p. 10.
39 *Ibid.,* p. 11.
40 *Ibid.*, pp. 12-13.
41 *Ibid.*, p. 13.

III. Provision of constituents for this system of innovation

5. Creating and changing organizations need for developing new fields of innovation

Since "organizations are considered key components in systems of organization[, e]ntry and exit of organizations, as well as change of incumbent organizations, are therefore important activities contributing to the change of systems of innovation. Organizations include not only firms, but also universities, research institutes, financing bodies, and so on. * * * [P]ublic action can facilitate such private activities . . . New R&D organizations (research organizations, universities) and innovation policy organizations can also be created through political decisions."[42]

Town+Gown works with universities and colleges, on behalf of public agencies, through its experiential learning component and its faculty-directed research component *via* its Master Academic Consortium Contract.

6. Networking through markets and other mechanisms

This includes "interactive learning among different organizations . . . involved in the innovation process; implies integrating new knowledge elements developed in different spheres of this system of innovation and outside with elements already available in the innovating firms."[43]

"The relations between universities and public research institutes, on the one hand, and firms on the other, are coordinated only to a limited degree by markets. *** This means that the public sector might create organizations to facilitate innovation."[44]

Town+Gown is a city-wide university-community partnership program that brings academics and practitioners together to create actionable knowledge in the built environment. It is also an open platform research program that uses experiential learning and faculty-directed research to facilitate partnerships between academics and practitioners on applied built environment research projects through the collaborative inquiry model of systemic action research. The CDW working group is comprised of both built environment academics and practitioners, and Town+Gown can develop additional symposium events as the working group continues.

7. Creating and changing institutions

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[42] *Ibid*., pp. 13-14.
[43] *Ibid.*, pp. 6-7.
[44] *Ibid.* p. 15.

This includes focus on "various laws and regulations, R+D investment routines and cultural norms that influence this system of innovation by providing incentives for and removing obstacles for innovation."[45]

The working group efforts reflected in the research projects identified above reflect all these issues.

IV. Support services for innovating firms, which include both private and public firms[46]

8. Incubation activities

This includes "providing access to facilities and administrative support for innovating efforts."[47]

Town+Gown works across the academic and practitioner divide to develop and support research activities that can lead to incubation activities using city agencies as sites for pilot projects as a form of incubation.

9. Financing of innovation processes and other activities

This is aimed at facilitating "commercialization of knowledge and its adoption;"[48] the Master Academic Consortium Contract contains intellectual property provisions that support this on faculty-directed research conducted under it.

10. Provision of consultancy services relevant for innovation processes

This can include "services related to the transfer of technology, commercial information and legal questions, *** [but] there are cases . . . where public authorities also provide consultancy services, either directly or by acting as a broker between firms and service providers."[49]

Policy problems can be analyzed through the lens of performance because the "**performance** of an innovation system is the same as the output of the system" [which] is – simply – innovations."[50] Innovation policy objectives formulated in terms of intensities of various kinds of innovation permit participants "to achieve more precision in innovation policy-making."[51] Intensity formulations are expressed as comparisons:

- "development of innovations or the diffusion or absorption of innovations"
- "[r]adical or incremental innovations"

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45 *Ibid.,* p. 7.
46 *Ibid.,* p. 5.
47 *Ibid.*, p. 7.
48 *Idem*
49 *Ibid.,* pp. 17-18.
50 *Idem.*
51 *Idem.*

- “[h]igh-tech products or low-tech products”
- “[p]roduct innovation or process innovations”
- “[i]nnovations related to specific sectors of production”
- “[i]nnovations related to certain – general – objectives of innovation policy”, which includes environmental[52]

A policy problem may have different categories or taxonomies of innovation with related *indicators* of innovation and “[*t*]*axonomies and indicators are crucial as a basis for the design and implementation of innovation policy*” to enable the governmental policy entity to balance the direction of categories described above within its resource constraints.[53] Formulating innovation policy objectives in terms of intensities also permits the governmental policy entity “to know the consequences of innovations for . . . environmental balance.”[54]

Impediments to Use of Recycled CDW. CDW.1 identified some impediments to the re-use of recycled CDW—or closing the construction material loops—which contributes to its continued use as ADC, as discussed above, and retards mitigating the environmental costs incurred in original production and transportation of construction materials.[55] Significant consumption of construction materials occurs in major urban centers, subject to economic and business cycles. Continued construction activity creates demand to produce more materials to support that construction, which is a significant sector in the local economy. High quality aggregates for concrete, for example, are becoming scarcer close to the urban areas that demand concrete, thus increasing the transportation of aggregates from further and further away.[56] The transportation of material into urban environments has high negative environmental and economic impacts. Providing for and standardizing the use of CDW would 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 natural resources.

While a significant amount of research has been completed on recycling CDW for use in new construction, some materials, such as steel and aluminum, have always found a willing and profitable market, but other materials have not fared so well despite academic research indicating that they would produce acceptable new materials. 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.[57] The construction industry operates in a conservative, risk-adverse environment,[58] and many engineers will not use a material unless specifically allowed or directed by the

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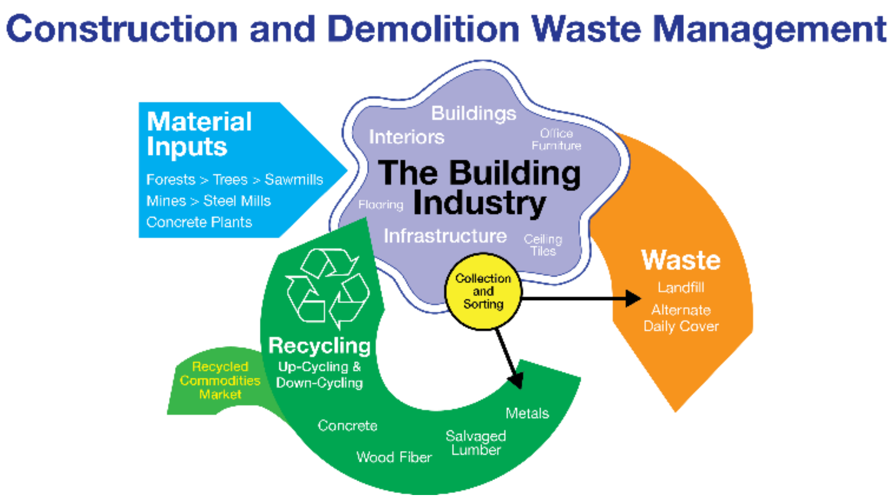
52 *Ibid., p. 21.*
53 *Ibid., pp. 21-23, 25-26.*
54 *Ibid. p. 26*.
55 See Appendix A—CDW.1—to this document.
56 M.S. Winfield, A. Taylor, Replacing the Load: The Need for an Aggregates Conservation Strategy for Ontario, Pembina Institute for Appropriate Development, 2005.
57 Jason H. Ideker, Matthew 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.
58 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

government standards and specifications.[59] 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.[60]

In addition, increasing CDW waste recycling raises additional issues with respect to the performance of CDW recycling and processing centers.[61] 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.

TCE Elements. The first infographic below shows the larger system in which this policy design effort takes place.



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.

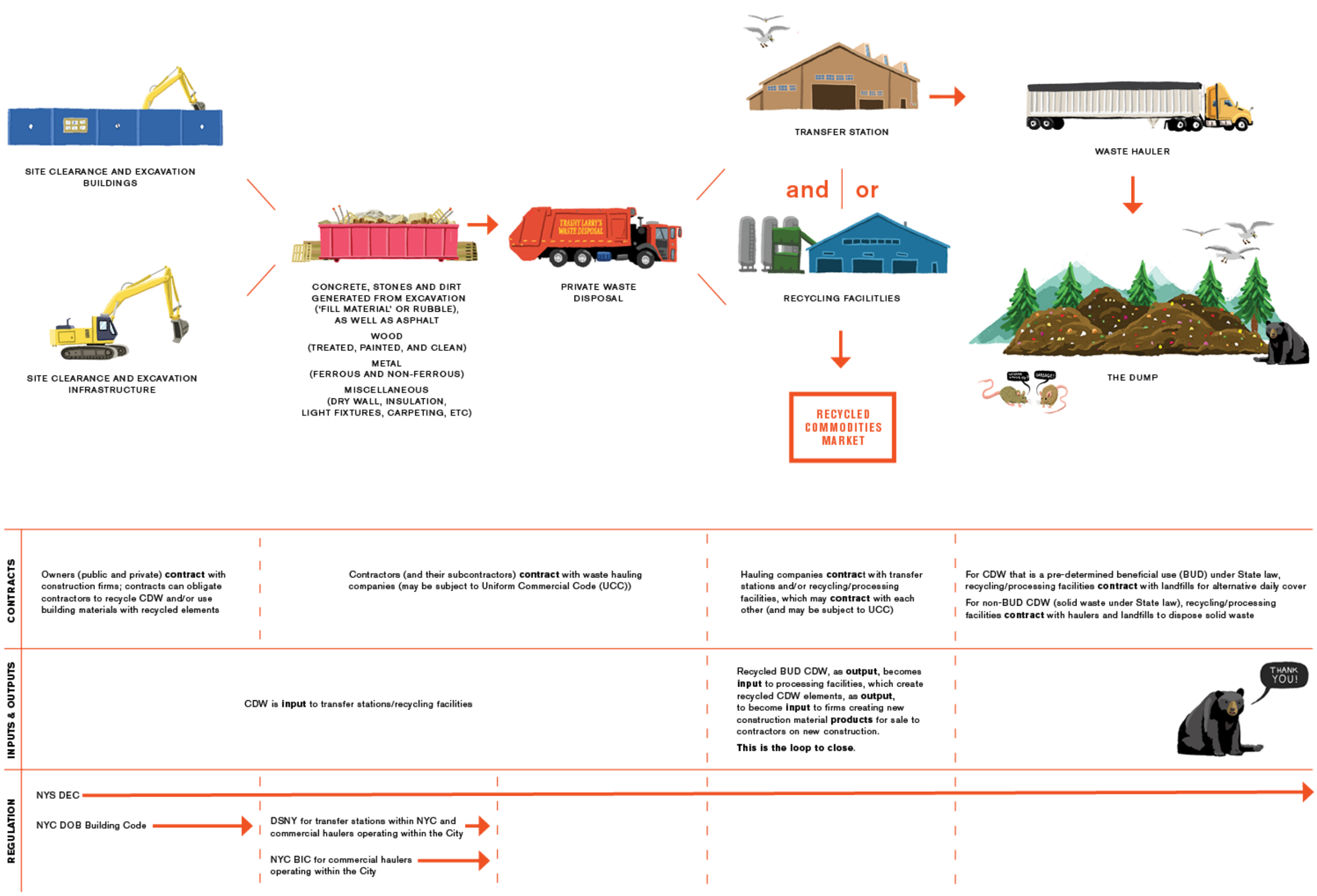
59 As an example, with respect to concrete specifications within the New York City context, there are two separate processes--one for roadway infrastructure projects and another for public building projects. On the roadway infrastructure side of the built environment, DDC maintains the material specifications and standards for both the New York City Department of Transportation and the New York City Department of Environmental Protection, two of DDC's client agencies on their roadway reconstruction projects. See http://www1.nyc.gov/site/ddc/resources/publications.page. 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.

60 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.

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

The second infographic below breaks down the larger system and brings in some of the TCE elements consisting of contracts, inputs and outputs, and regulatory authority.

Construction and Demolition Waste System: TCE Elements



LCCBA and Transaction Costs Economics. When it is difficult to "model cause and effect, . . . problem definition . . . change[s] over time, and there [is] not be consensus about the policy goal," there Is what is known as *a "wicked" problem.*[62] Environmental policies related to climate change exhibit "wicked" problem characteristics, and the working group's efforts to increase re-use of recycled CDW on building and infrastructure projects—to close the material loops—is no exception. The good news, however, is that "[f]or wicked problems, improving the situation rather than coming up with an optimal solution, is what is realistic."[63] But that does not mean policy design should ignore transaction costs, which is the focus of transaction cost economics (TCE).

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62 Laura McCann, "Transaction Costs and Environmental Policy Design," *Ecological Economics,* 88 (2013) 253-262, p. 253.
63 *Idem.*

As noted above under ***Innovation Policy Design***, "[w]hen the market fails to supply a good to the level that is socially desirable, market failure is said to have occurred [and i]t is at this point that intervention by government or non-government organisations to ensure the supply of public goods may be justified."[64] Among the types of market intervention policy instruments are market-based programs, regulation, and a "combination which also draws on partnerships and social networks [each of which] provides a different level, mix and distribution of benefits and costs which occur over varying spatial and temporal scales."[65] When, however there is a market failure and "government intervention may be justified, "[g]overnment intervention is only justifiable on efficiency grounds when the benefits of the intervention are greater than the costs (including the transaction costs)."[66] A policy measure will have transaction costs for the affected private parties, but "the development, implementation and administration of the policy also generates transaction costs to both the pubic policy maker and to the private parties affected by the policy."[67] The public economics efficiency justification for governmental intervention thus makes the development of a rigorous and usable LCCBA of first importance.

> *TCE in a Nutshell.* TCE is a complicated (for Town+Gown at least) economic theory initially developed by Oliver Williamson in the 1980s primarily to address "the governance of markets transactions for private goods in a developed country institutional context."[68] TCE "highlights the importance of transaction costs when considering the governance structure of a firm as a means of coordinating production related transactions compared to the neo-classical emphasis of the firm as a production unit."[69] When the theoretical conditions of asset specificity, transaction frequency and timing, uncertainty surrounding the transaction, bounded rationality, opportunism, current institutions, and additional characteristics of the transactors are considered under TCE,[70] TCE, as a normative application, permits identification of "the 'best' governance structure [that] minimizes the transaction costs of creating and enforcing contracts" for the private contracting parties.[71] It is important to remember that the innovative policy design effort envisioned by the CDW working group will involve private firms producing goods and services and government and private firms purchasing them within the context of public and private construction in New York City.

Thus, the TCE framework permits an evaluation of transaction costs not only among private parties to a private transaction, but also to the governmental entity and the affected private parties when a governmental policy is developed, which governmental policy is subject to the efficiency criterion. With respect to the governmental entity, the "transaction costs are categorized into research and information collection and analysis, policy enactment (development of legislation), policy design and implantation and administration of the policy [which] also generates transaction costs to the public policy maker and

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64 Anthea Coggan, Stuart Whitten and Jeff Bennett, "Influences of Transaction Costs in Environmental Policy," *Ecological Economics,* 69 (2010) 1777-1784, p. 1777.
65 *Idem.*
66 *Ibid.*, p. 1779.
67 *Idem.*
68 McCann, *op. cit.*, p 254.
69 Coggan *et al, op. cit.*, p. 1780.
70 *Ibid.,* pp. 1780-1782.
71 *Ibid.*, p. 1780.

to the private parties affected by the policy."[72] When applied to public policy development, "[m]aximizing net benefits, rather than minimizing transactions costs, is the goal, although the empirical work often uses a cost-effectiveness framework", which underscores the need for a rigorous and usable LCCBA model.[73]

"[W]hile institutions that are more efficient may arise spontaneously . . . in general they should be the focus of design, especially in the case of environmental and natural resource policy issues."[74] [I]ncorporating transaction costs . . . into the design of institutions and policy instruments . . . enables the analyst to bring in practical issues that are normally ignored" and provides an analytical framework to make "progress on wicked problems" and avoid "unintended consequences of policies."[75] TCE analysis during policy design permits "policy choice and policy design needs to be matched to the specific physical and institutional characteristics of the problem [and] accommodate "heterogenous and changing situations" as well as the "dynamic effects of policy choices on both technological change and institutions."[76] TCE analysis during policy design also permits consideration of "sequencing of policies, rather than just choice of policies"; permits consideration of policies short of optimal solutions by use of comparative policy analysis to identify a policy design hierarchy that tries and evaluates "easier solutions first and then [makes] more fundamental changes in policy, technology, or even the institutional environment if needed or when the amount of change required is large"; and, permits consideration of when "win-win alternatives, education and extension activities and media campaigns may be effective."[77] "Making impacts observable to the agents causing the problem may be helpful in a positive transaction world [and] may limit conflict and lobbying and thus lower transaction costs."[78]

While "prices reflect 'the laws of nature and the laws of man, [f]undamental physical, biological and technical factors will also affect . . . transaction costs [of environmental-related policies] and thus should affect the choice of environmental policy instrument, and the design of the policy."[79] "[D]ifferent types of market failures which arise from non-excludabliity, rivalry, etc., are typically addressed by using different types of policy instruments [that can also take account of t]he local vs global nature of an issue, the amounts of change needed, time lags, heterogeneity, internal vs external effects, measurability, economies of scale, uncertainty, asset specificity, and technology."[80] In environmental policy design, using the TCE model, it is important to focus on ***physical factors (the rules of nature)*** affecting transaction costs and on ***cultural and institutional environment factors*** affecting transaction costs.[81] Each set of factors can be ranked on a spectrum ranging from factors that are least amenable to change, those that are somewhat amenable to change and those that are amenable to change (the proverbial

72 *Ibid.,* p. 1779; see also McCann, *op. cit.,* p. 254.
73 McCann, *op. cit.,* p. 254.
74 *Ibid.,* p. 260.
75 *Idem.*
76 *Idem.*
77 *Idem.*
78 *Idem.*
79 *Ibid.*, pp. 254-255.
80 *Ibid.*, p. 255.
81 *Ibid.,* pp. 254-255; see pp. 254-257 for physical factors and pp. 257-260 for cultural and institutional factors.

"low hanging fruit"), which may be a good starting point for policy design and from which to ratcheting up over time.[82]

Among *physical factors* that are *least amenable to change* are the fundamental laws of nature, and, while these factors "cannot be fruitfully be the object of design," policy design must address and design around them.[83] The re-use of CDW recycled materials as input for materials for use in new construction depends on the physical attributes of the new construction materials and are the subject of governmental and professional standards. In addition, physical factors relate to the local vs global issue, which would "affect the optimal design of policies."[84] A local focus on increasing re-use of recycled CDW products in new construction "could thus encourage least cost [options] regardless of location . . . and have lower enactment costs [than efforts aimed at wider-scale CO2 emission]."[85] "[T]he smaller the scale of the resource issues, the more likely that collective action will be effective (all else equal)."[86]

When the scale of an intervention for "an environmental problem crosses political boundaries, more coordination will be required "and thus higher transaction costs than would be necessary if location did not matter."[87] Transfer and processing of New York City-generated CDW can take place outside city limits, but the impact of state-wide regulation can mitigate this issue of scale for local policy design. Since the environmental impacts of the current state of CDW involves original product creation outside the City and transportation outside the City, "[t]he time lag from emission to noticeable increases in ambient pollution/damages[88] makes causality harder to establish and raise public support for policies."[89] This time lag also explains the relative lack of focused local policy interest in the re-use of recycled CDW materials in new construction as a way to reduce CO2 emissions.

Moving on to *physical factors* that are *somewhat amenable to change*, "the amount of change needed to address a problem" directly affects transaction costs.[90] The extent to which a policy requires "new equipment or even fundamental changes in the production systems of a firm "may increase transaction costs as the policy is implemented."[91] When, however, "small change is needed, and where private and social impacts are aligned, education may be sufficient, [but] the higher the potential losses to firms, the higher the level of lobbing to prevent a new environmental policy, thus increasing transaction costs."[92] Issues of heterogeneity, "which is less important for manufactured items . . . make the situation harder to model, exacerbates problems of asymmetric information, increases transaction costs involved in developing and implementing targeted policies to change behavior and increases the need for creativity

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82 *Ibid.,* p. 260.
83 *Ibid.*, p. 255.
84 *Idem.*
85 *Idem.*
86 *Idem.*
87 *Idem.*
88 And the reverse, which is the time lag between reductions in emission to noticeable decreases in ambient pollution/damages.
89 McCann, *op. cit.,* p. 255.
90 *Idem.*
91 *Idem.*
92 *Idem.*

in policy design."[93] Natural material variability can be overcome by specification standards, but differences among firm sizes and production methods and technologies used by firms cannot.

Commodities, such as recycled CDW—separated or not—and products made from recycled CDW are excludable goods, "one for which it is . . . possible to exclude an additional user . . . at reasonable costs" which makes contractual exchange and markets possible, and "enforcement of those rights would imply very high transaction costs." [94] But these types of transaction costs between private parties are covered by the standard commercial transaction process, which, with the Uniform Commercial Code, have been mitigated within the legal enforcement process. "Technological externalities are transmitted through some physical medium, and enter the utility function or production function of another agent directly (physically), rather than directly through prices."[95] "Reducing a pollutant at its source is generally recognized as more efficient than removing it once that pollutant is dispersed in the environment,"[96] suggesting a parallel to re-use of recycled CDW materials in new construction. "Who can physically reduce the effect of least cost, and which arrangement has lower transaction costs, should affect the assignment of property rights," but in this case, it is the recycling market and a policy to encourage recycling of job-site source separated CDW materials and re-use of those recycled materials in new construction that reduces the larger externalities generated by future production of construction materials outside the city.[97] "The extent to which external effects are also felt by the individual taking an action may affect transaction costs involved with solving environmental and natural resource problems. *** When private effects (negative or positive) are small and public effects are large, intervention using incentive mechanisms (either polluter-pays or beneficiary-pays) may be warranted. The costs to compensate the agent for abatement, as well as the transaction costs of implementing programs, are expected to be lower when private costs are low."[98]

"Measurability and observability have effects on transaction costs incurred by public agencies, and thus affect what policies are feasible."[99] Measuring local emission reductions from a local recycled CDW product re-use policy would not only be beside the point, since the most of the potential reduction would be outside the City but would also "entail very high monitoring costs," which makes the search for suitable proxies for measurement.[100] A policy that borrows from LEED and ENVISION, to measure percentages of recycling of CDW to include percentages of use of recycled CDW products in the construction might be a feasible approach to measurability/observability. Policies that take advantage of economies of scale "would tend to be more efficient," though economies of scale are "a function of technology and industry structure as well as the magnitude of the change required."[101] "All else equal, total transaction costs will increase with the number of agents involved [but] if there are many similar

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[93] *Idem.*
[94] *Ibid.,* p. 256; see also discussion of asset specificity on p. 257.
[95] *Idem.*
[96] *Idem.*
[97] *Idem.*
[98] *Idem.*
[99] *Idem.*
[100] *Idem.*
[101] *Idem.*

entities, average transaction costs may decreasing," subject to heterogeneity among agents, with the possible overall mitigation by higher transaction frequency.[102]

Public policy design takes place within an environment of uncertainty with respect to "[t]ime lags, natural variability in space and time, ... heterogeneity of agents, measurement difficulties" as discussed above.[103] "[E]nvironmental laws cannot be written to take account of all contingencies [which pose transaction costs implications], "so decision-makers will typically have to act in a state of imperfect knowledge" in the absence of "improving information by new research" which is also costly.[104]

Finally, technical change emerges as the single *physical factor* that *is amenable to change*. Public policy design must take into account not only the "current state of technology, for production, abatement and monitoring, but also the *potential* for technological change."[105]

Turning to *cultural and institutional factors affecting transaction costs*, like physical factors, they begin with "deep institutional factors that are least amenable to change, and thus must be designed around, and [end with those amenable to change], which are the most likely objects of design."[106] Among the *institutional factors* that are *least amenable to change*, culture impacts transaction costs, which are "lower in high trust societies," with social capital helping to "diffuse environmental practices [and] also decrease transaction costs of making and enforcing new policies."[107] The existence of wicked problem characteristics, however, "often involve conflicting values and goals," which can increase transaction costs.[108] Certain aspects of the "formal institutional environment consist[ing] of constitutions, legal systems, laws and policies *** will serve to enable the design of effective and efficient environmental policy instruments, while others will preclude some policy instruments" in the absence of change to laws, which are changeable, subject to constitutional constraints and politics, but which increases transaction costs.[109]

Institutional factors that are *somewhat amendable to change* include physical vs administrative boundaries, lobbying, property rights, market structure and existing laws and policies.[110] "Administrative boundaries that do not coincide with environmental areas of interest . . . make cooperation more difficult and increase transaction costs [and] multiple agencies with responsibilities for solving a problem will also increase coordination costs."[111] The mixed regulatory scheme in New York includes City agencies regulating aspects of CDW within the City jurisdictional boundaries, but City regulation takes place within superior New York State laws that apply to all municipal governments in the State, which should serve to mitigate this issue. "[C]reating boundary organizations that mediate between scientists, resource managers, and stakeholders may be useful for wicked problems[; w]hile

[102] *Ibid.,* p. 257
[103] *Idem.*
[104] *Idem.*
[105] *Idem.*
[106] *Idem.*
[107] *Ibid., p. 258.*
[108] *Idem.*
[109] *Idem.*
[110] *Ibid., pp. 258-259.*
[111] *Ibid., p. 258.*

entailing transaction costs to create and operate, they may ultimately reduce transaction costs, especially in situations of conflict."[112] A City-wide policy design to close material loops within the City's capital program may provide a case-study model for the State to apply state-wide once results of the local policy are evident. "[T]ransaction costs[, however,] at the enactment stage, such as lobbying over a policy at both the legislative and agency (bureaucratic) levels, may be higher than the transaction costs to implement a policy," which argues for policy design efforts to include as many stakeholders as possible at the beginning.[113]

Property rights are "fundamentally important both for distributional impacts but also for efficiency."[114] While "the efficient outcome assumes a particular system of property rights . . . one cannot determine an efficient outcome independent of the property rights assignment *** [and s]ome parties may be able to make changes at lower costs to solve a problem."[115] It might be useful to assess in policy design whether some "parties [are] able to make changes at a lower cost of regulating and [whether] the transaction costs of regulating some groups may be lower than regulating others."[116] In this context, policy design should also consider "which party has better information or is better able to use information."[117] A market where a single buyer is able to seek the product or service of multiple sellers—a monopsony—"may facilitate bargaining" and thus reduce transaction costs.[118] Policy design to close loops by leveraging the City's capital program may have aspects of a monopsony structure. Finally, [it is . . . necessary to recognize that previous policy decisions [elsewhere in the regulatory environment] can either enable or constrain the design of efficient and effective policies."[119] While New York State pre-empts the regulatory field with respect to its component local governments, there are superior federal laws, under which the states enact their environmental laws, such as the federal Clean Air Act and the Clean Water Act, which also interact with each other, that will effect "what policy instruments can be used, how they can be implemented and the transaction costs of making changes."[120] It will be necessary to evaluate "possible interactions between existing policies, or between existing policies and new policies [and identify whether] they are at cross purposes or complementary [or] whether existing legislation can be used for new purposes."[121]

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112 *Idem.*
113 *Ibid., p. 259.*
114 *Idem.*
115 *Idem.*
116 *Idem.*
117 *Idem.*
118 *Idem.*
119 *Idem.*
120 *Idem.*
121 *Idem.*

Sequencing and timing, behavioral economics and intermediaries are *institutional factors* that are *amendable to change*, which are objects of design and not factors to be designed around.[122] "Sequencing of policy matters" with "less restrictive, more popular policies, such as education efforts [that] have not been tried previously" having lower transaction costs than more "draconian" policies.[123] Not only are sequencing and timing decisions within the policy designer's control, but also the ability to choose the proverbial "low hanging fruit" options, with lower transaction costs, is within the policy designer's control.[124] The presence of "lead time" and the ability to gradually ratchet up implementation of various environmental policy options decrease transaction costs.[125] Policy designers' use of behavioral economic theory choice architecture, such as "[r]estructuring the decision to take advantage of defaults . . . or changing the decision environment in other ways . . . can promote choices with both private and public benefits" and thus reduce transaction costs.[126] Finally, the "[u]se of intermediaries (e.g., brokers) may reduce transaction costs, especially for infrequent transactions that require specialized knowledge" to enhance economies of scale issues.[127]

122 *Ibid., pp. 259-260.*
123 *Ibid. p. 259.*
124 *Ibid.,* p. 260.
125 *Idem.*
126 *Idem.*
127 *Idem.*

Appendix A

Pushing the Recycling Envelope: Construction and Demolition Waste
ACS Manhattan Room
@150 William Street, 19th 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[128] 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," [129] leaving the remainder of the City's putrescible waste stream for private carters, which are regulated, in part, by the City.[130] 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.[131] 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.)."[132] CDW can also contain hazardous wastes such as "asbestos, lead paint and mercury from florescent lamps."[133] A research project in Town+Gown: NYC, 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.[134]

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."[135] 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."[136] 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."[137] The percentage represented by CDW in the City's solid waste stream is considered to be "at

128 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.
129 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.)
130 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.
131 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.).
132 *Idem*
133 *Ibid*., p. 3.
134 Meryl Lagouin, Ardavan Yazdanbakhsh and Lawrence Banks, *Replacing Natural Aggregates with Recycled Aggregates for Concrete Making in NYC—An Environmental Impact Assessment Study* (2016).
135 DDC, *op. cit.,* inside front cover
136 *Idem* See also Clare Miflin, 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 accessed 11-09-17 @ 4:20 p.m.)
137 *Ibid.,* p. 2.

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."[138]

DSNY Rules designate elements of CDW as recyclable and further require that CDW recyclables be "source separated from other waste streams."[139] 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."[140] 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."[141] 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".[142] 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."[143]

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.[144] 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.[145] 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."[146] 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.[147] With the C&D Waste specification in place for the project during the construction phase, a project manager would work

138 *Idem*
139 DSNY 16 RCNY Sections 1-10. See Miflin *et al., op. cit.,* p. 124.
140 *Ibid.*, p. 3
141 *Idem*
142 *Idem*
143 *Idem*
144 *Idem*
145 *Idem*
146 *Idem*

147 *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 Miflin *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."

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."[148] Beginning with a "walkthrough 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.[149]

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. [150]

While *New York City's Roadmap to 80 x 50*, the City's most recent articulated long-term sustainability plan required by the Charter,[151] focuses on waste, which is "the smallest contributor" among "the four sectors that contribute to GHG emissions in NYC,"[152] there are no specific references to CDW's presence in the City's waste stream or its contribution to the circular economy.[153] Within the waste sector, 78 percent of total GHG emissions comes from methane released from New York City's landfilled waste,[154] and 22 percent comes methane released from the wastewater treatment process.[155] "[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.[156]

In contrast to organic waste, concrete waste does not decompose or contribute to GHG—concrete carbonates and *absorbs* CO2 from the environment. It is the creation of concrete,[157] 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.[158] Life cycle cost-benefit modeling, within a mixed market economy, is one tool that can help provide government, as regulator, with

148 *Idem*
149 *Ibid.,* p. 13; pp. 15-16; see also, pp. 18-21.
150 LEED projects have additional specifications required by the LEED program in addition to what is required by the DDC specification discussed above. See also, Miflin *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.
151 City Charter, Section 20; see also Local Law 66/2014 with respect to the 80 x 50 requirement.
152 *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 accessed 09/21/17 @ 2:28 p.m.).
153 *Ibid.,* pp. 99-100.
154 Though not clear from the cited material, this metric most likely focuses on emissions from landfills within City borders. See also, Miflin et al., op. cit., footnote 2, p. 17.
155 *Ibid*., p. 98.
156 *Ibid*., p. 99.
157 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 (CaCo3->CaO+CO2), 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 CO2 in the US. European plants are a bit more efficient, as some of them avoid using coal.
158 DDC, *op. cit.,* p. 8.

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.[159] One recent field test, in 2016, related to use of a particular recycled CDW element—glass pozzolan—on a sidewalk reconstruction project in Queens.[160] Pozzolan is a by-product of recycling glass recycling, which, when finely ground and mixed with specific chemicals and water, can act like cement.[161] 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."[162] They also "limit the exempt disposal of C+D debris and provide expanded allowance for the reuse of fill materials in environmentally protective situations."[163]

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"[164] 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."[165] 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."[166] 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 regulation.[167] These new reporting requirements will, over time, not only create data for research purposes, but also create data at the

159 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)

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

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

162 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.

163 *Idem*

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

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

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

167 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.

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]."[168] 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 gas scrubbing 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[169]

Finally, C+D debris is an enumerated waste stream that local solid waste management plans (LSWMPs) must include.[170] 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."[171] 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,

[168] Section 360.12(a)(1).
[169] 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.
[170] 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.
[171] Section 366-2.5.

including deconstruction, reuse and recovery programs."[172] 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.[173]

In addition, a collaborative group recently released *Zero Waste Design Guidelines* (ZWDG), focusing specifically on CDW associated with buildings, not horizontal infrastructure.[174] While this collaboration followed an overall interdisciplinary methodology used by the 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.[175] 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 lifespan 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."[176]

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.

[172] Section 366.2-5(a), (5), (7), (9), (10) and (12).
[173] Section 366.2-5(b), (1)(iii) and (2).
[174] Miflin et al., *op. cit.*
[175] *Ibid.*, pp., 6, 125.
[176] *Ibid.,* p. 132-133.

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.[177] 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.[178] The construction industry operates in a conservative, risk-adverse environment,[179] 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 and the New York City Department of Environmental Protection, two of DDC's client agencies on their roadway reconstruction projects.[180] 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.[181]

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177 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.

178 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.

179 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.

180 See http://www1.nyc.gov/site/ddc/resources/publications.page.

181 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.

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.[182] 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.[183] 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 C&D debris 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,"[184] and transportation of construction materials and CDW in and out of the City is impacted by the New York City Department of Transportation'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.[185] The split incentives between owners and tenants and between initial construction costs and ongoing operations and

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

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

[184] Miflin *et al., op. cit.*, p. 128.

[185] *Idem*

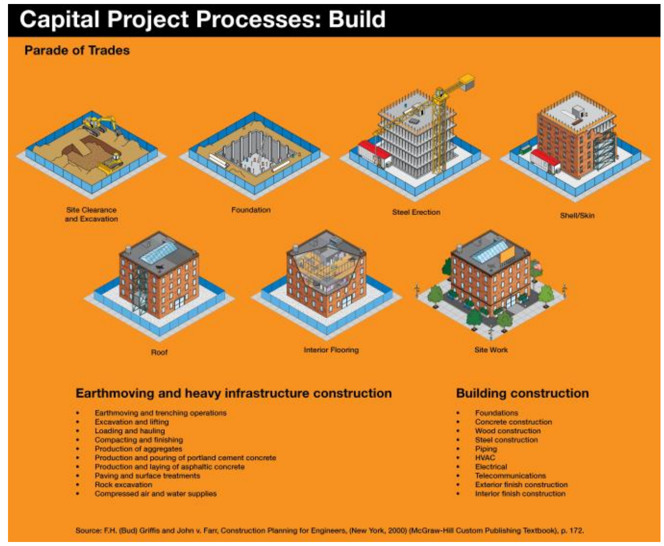
maintenance that apply in the sustainable energy area also apply to the area of recycling CDW.[186]

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[187]

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[188]



While horizontal infrastructure construction differs from building structure construction in many ways, it is possible 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.[189] 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."[190]

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]".[191] This "parade of trades" process on a vertical building project (and to a lesser extent on a horizontal infrastructure project) also "involves a large

186 *Idem*
187 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).
188 *Ibid*, p. 172 (listed material directly quoted).
189 Glenn Ballard and Greg Howell, "What Kind of Production Is Construction?", Proceedings IGLC '98 Guaruja, 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.
190 Gerald Finkel, *The Economics of the Construction Industry* (Armonk, New York, 1997), p. 83.
191 Ballard and Howell, *op. cit.,* pp. 2, 4.

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."[192] The concentration of work at the site will vary by trade and "the different parades [will] move through a building in different directions."[193] 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."[194]

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."[195] 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.[196] The construction projection 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)."[197] 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."[198] 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" [199] 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"[200] and "flows of crew [shared with other construction projects] and equipment in a highly dynamic system"[201] requires both "managing bottom up and not top down only . . . while focusing the middle management's own resources on managing the logistics . . .". [202] 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."[203] 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.[204]

This "parade of trades" montage described above, however, takes place within the complex context of contractual relationships. The relationships among the owner[205] of construction and the *constructor network of firms*, is a contractual one. The

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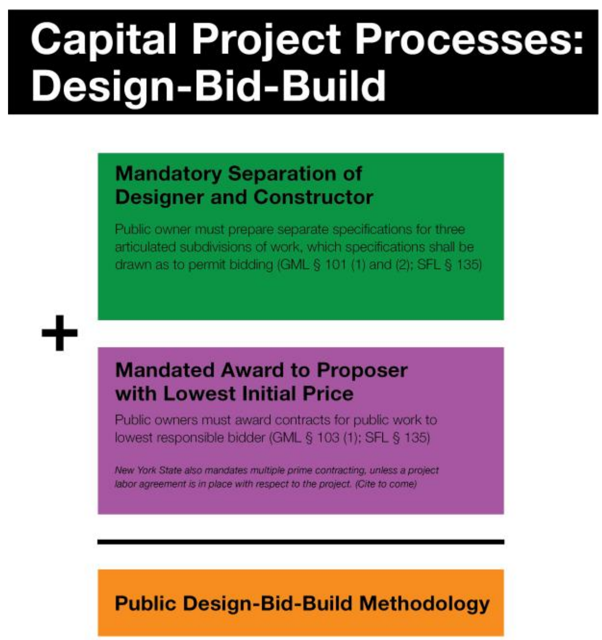
[192] Iris Tommelein, David Riley, Greg Howell, "Parade Game: Impact of Workforce Variability on Trade Performance", *Journal of Construction Engineering and Management*, Sept/Oct 1999, p. 304.
[193] *Ibid.*, p. 305.
[194] Sven Bertelsen, "Lean Construction: Where Are We and How to Proceed?", *Lean Construction Journal*, Vol. 1, October 2004, p. 56.
[195] *Ibid.,* p. 52.
[196] Ballard and Howell, *op. cit.,* p. 5.
[197] *Idem*
[198] Bertelsen, *op. cit.*, p. 58.
[199] *Idem*
[200] Bertelsen, *op. cit.*, p. 59.
[201] *Ibid.,* p. 60
[202] *Idem*
[203] *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 12th Annual Conference of the International Group for Lean Construction, 2004.
[204] Rozenfeld, *op. cit.,* pp. 492, 497.
[205] 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.

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).[206] 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,[207] 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.[208] One of the devils of increasing CDW recycling may be at this level of detail.

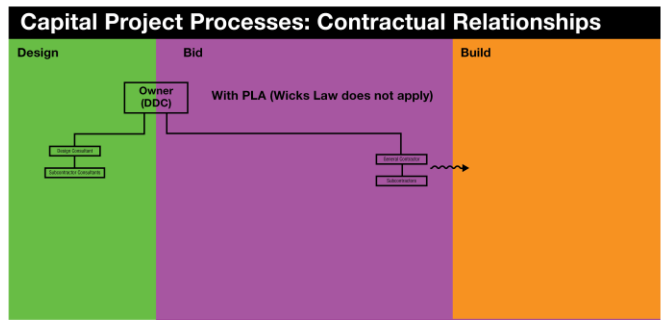
A few words on Design-Bid-Build and Multiple Prime Contracting. Owners of public works in the State, which includes the City, are limited in the way they can deliver their projects due to the required procurement and contracting methods.[209] The way City construction agencies enter into contracts with 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.[210] 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.

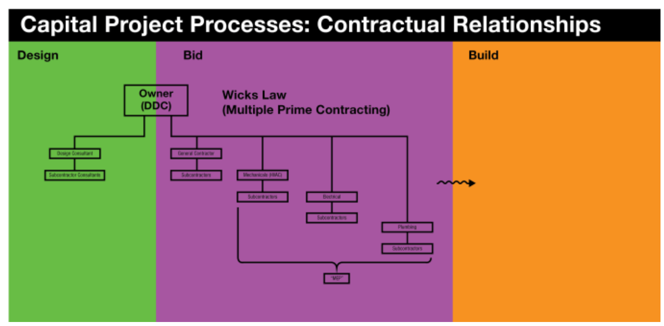


[206] See Robert R. Eccles, "The Quasifirm in the Construction Industry, *Journal of Economic Behavior and Organization,* Vol. 2 (1981), pp. 335-357. See also Contract, Chapter IV (Article 17).
[207] Which likely shares aspects with the private construction context.
[208] As an example, see Chapter II, Article 4 of DDC's standard general conditions to the City's standard construction contract contain (Section 2.1.22).
[209] New York State General Municipal Law, Section 103; New York State Finance Law, Section 163.
[210] 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.

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.[211] 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."[212] A PLA binds all bidders on capital projects subject to the PLA to the terms of the PLA.





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

212 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%2Bf%2Bproject%2Blabor%2Bagreements%2Bin%2Bnew%2Byork%2Bstate%26btnG%3D%26as_sdt%3D1%252C33%26as_sdtp%3D#search=%22kotler%20f%20project%20labor%20agreements%20new%20york%20state%22 Accessed 09-01-17 @ 12:39 p.m.

Pushing the Recycling Envelope:
Construction and Demolition Waste.2
ACS Manhattan Room
@150 William Street, 19th Floor
October 30, 2018, 8:30 a.m. to Noon

AGENDA

8:45 a.m. – 9:40 a.m. **Academic Framing Presentations**

- Introduction and Overview of Event: Terri Matthews, Director of Town+Gown: NYC
- Material Loops—Concrete as Case Study: Matthew Adams, Assistant Professor, Department of Civil and Environmental Engineering, New Jersey Institute of Technology
- Where's the Data?: David Nadler, Assistant Professor, New York Institute of Technology
- Construction Logistics 101: Ronald Pennella, Adjunct Professor, NYU/Tandon School of Engineering, and Edward Lydon, Pavarini McGovern

9:40 a.m. – 9:50 a.m. **Break**

9:50 a.m. – 10:50 a.m. **Knowledge Co-Creation—Simultaneous breakout working group table sessions by material**

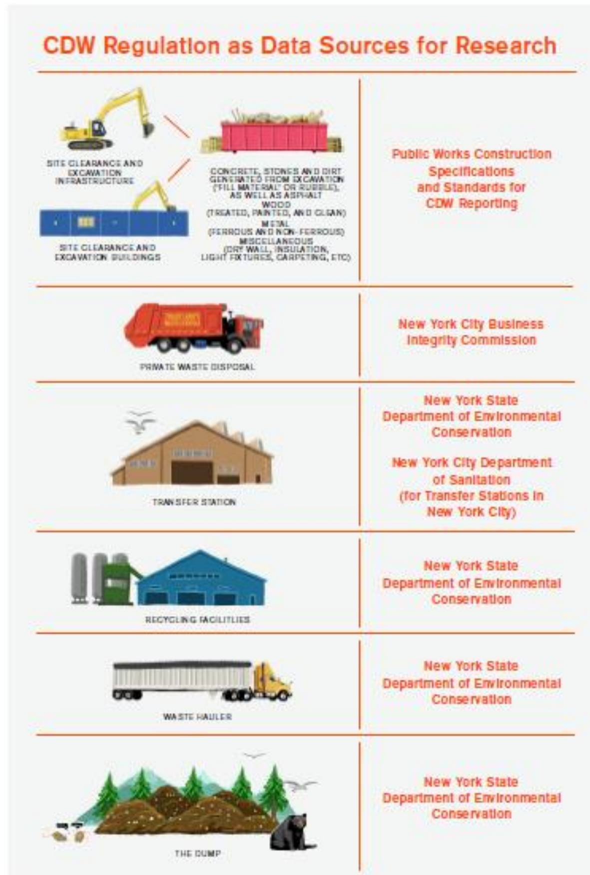
- Concrete
- Gypsum wallboard and ceiling tile
- Glass
- Carpet
- Soil

10:50 a.m. – 11:00 a.m. **Break**

11:00 a.m. – 11:30 a.m. **Reconvening: Reporting Back and Closing Remarks**

CDW.1 Background. Last year's symposium event, _*Pushing the Recycling Envelope: Construction and Demolition Waste*_ (see https://www1.nyc.gov/assets/ddc/downloads/town-and-gown/Precis_Final.pdf) (CDW.1) was intended as an initial exploration of issues associated with the expansion of construction and demolition waste (CDW) recycling in the city. Presentations on academic research related to concrete recycling were intended to create a knowledge base to understand the absence of specific references to CDW's presence in the City's waste stream and its contribution to the circular economy[213] in *New York City's Roadmap to 80 x 50*, the City's most recent articulated long-term sustainability plan required by the Charter.[214] In contrast to organic waste, concrete waste does not decompose or contribute to GHG, but the creation of concrete,[215] the transportation of the raw materials to create concrete, and the transportation of concrete CDW for processing, recycling and disposal do contributes to GHG emissions, pointing to recycling concrete as a way to reduce concrete's contribution to GHGs in the circular economy. Academic presentations of life cycle cost-benefit modeling were intended to serve as one tool that could help provide government, as regulator, with sufficient information to help determine options for potential intervention to increase recycling of CDW.

Concrete's GHG profile, unfortunately, does not align well with the City's span of regulatory control, which directly impacts the nature of available data. CDW is not part of the solid waste stream over which the City exerts significant regulatory control because New York State exerts significant regulatory control over CDW, which not only directly impacts the nature of available data but also impacts the market for recycled CDW.[216]



The precis document for CDW.1 summarized DDC's 2003 *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,"[217] and the final regulations, released by New York State Department of Environmental Conservation (DEC), effective on November 4, 2017, that significantly revised the

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

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

215 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 (CaCo3->CaO+CO2), 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 CO2 in the US. European plants are a bit more efficient, as some of them avoid using coal.

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

217 DDC, *op. cit.,* inside front cover

State's Solid Waste Management Regulations. At CDW.1, we learned that the city's adoption of LEED standards for public buildings substituted for the 2003 guidelines and further that the last time the city explicitly focused on CDW was in its 1989-90 Waste Composition Study, which together with the data issues related to regulatory control, suggested that a follow-up event to identify research gaps—what we don't know and need to know to advance CDW recycling—that academics within Gown can help us address was the most appropriate way to follow-up from CDW.1.

Over the summer and fall, Town+Gown: NYC collected feedback from agency practitioners within of Town, which is summarized in Appendix A.

New Background Information for CDW.2. During the planning for this event, we learned of planned changes to LEED, which covers sustainable design and construction practices for buildings. See https://www.usgbc.org/node/4717858?return=/pilotcredits/New-Construction/v4 [LEED v4: CHANGES ARE COMING TO CONSTRUCTION & DEMOLITION RECYCLING – RCI – Recycling Certification Institute, Recycling Facility Certification Program.]()

We also learned about Envision, which covers sustainable design and construction practices for infrastructure. See https://research.gsd.harvard.edu/zofnass/files/2015/06/Envision-Manual_2015_red.pdf, in particular, RA1.3 to RA1.7.

Finally, we were reminded of recent local law changes (LL 152/2018) that will govern transfer stations located within the city. See file:///C:/Users/matthewte/Downloads/Local%20Law%20152%20(2).pdf.

Piloting Knowledge Co-Creation Sessions at CDW.2. With CDW.2, Town+Gown: NYC is piloting a new format for its symposium events aimed at "real time" co-creation of knowledge to identify what we know, what we don't know and need/want to know to make changes in practice and policy based on research so that Town+Gown: NYC can accelerate the action research cycle by:

- Moving Town+Gown: NYC research projects (see Appendix B for abstracts of completed projects) to the "thought leader" stage and toward a more systemic form of decision-making, using Town+Gown: NYC projects and related symposium events as a point of departure
- Increasing academic synthesis and translation of current work in various areas as research resources

By identifying research gaps that the Gown community knows are important to the city, Town+Gown: NYC can work with Gown to focus future targeted research to address those gaps, which constitutes "action" within Town+Gown: NYC's action research paradigm. It is also possible, however, that this knowledge co-creation can identify insights to support "action" without additional research.

Soon after CDW.2 concludes, Town+Gown: NYC will synthesize the work from the working groups as an addendum to the event precis and make it available to those who participated, post it to the Town+Gown: NYC website Archives, and create follow-up events, all with a view to developing future targeted identified research projects.

Protocol for Working Group/Table Sessions.

General Group Objectives:

- Practitioners and Academics share knowledge of what they are doing/would like to do/where known data is (*what we know)*
- Practitioners share knowledge of impediments (city-wide process/organizational issues and regulatory issues) (*what we need to know*)
- Identification of targeted research ideas in the presence of participating academics for future

research projects/events in T+G to support practitioners and for researchers to use back at their schools to show areas that need work

- Also, identification of insights to support “action” without additional research
- All keeping in mind:
  - Role of city/city agencies as owner
  - Role of city/city agencies as regulator within its jurisdiction of its own buildings/infrastructure, privately-owned buildings, industry participants, and markets
  - Role of designers (architects and engineers) and builders
  - Role of communities

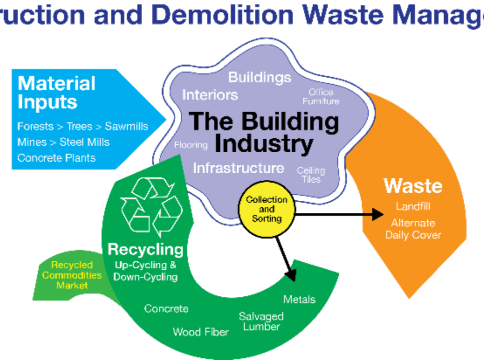
<u>Protocol:</u>

Those attending CDW.2 will break into groups by material loop:

- Concrete
- Gypsum wallboard, ceiling tile and wallboard
- Glass
- Carpet
- Soil

Each material loop group will outline a proto CDW Management Plan, as a prompt, that could be a collection of the layered diagrams as described below. A simple graphic prepared for event will work for the whole process in abstract but is really a collection of many layers for each product and material that is used in buildings and infrastructure. These layers sometimes can also cross materials, say from glass (as a curtain wall) to aggregate in concrete.

Construction and Demolition Waste Management



Each group can use the graphic to ask some questions about each material. Using concrete as an example, we already have a lot of questions at many stages of the process for concrete, which could be used by other material loop groups:

- At the raw material stage regarding a possible shortage of aggregates
- At the collection stage, site sorting etc.
- At the reuse stage, how do we use the material? Strength characteristics, etc.
- At the end stage, is alternate daily cover a beneficial use that would otherwise not be available (if we divert too much concrete?)
- We also have data gaps all around to begin to tackle the magnitude of the problems (and frame the solutions.)
- Market conditions and generation issues.

Each working group’s end-product is a proto CDW Management Plan to illustrate puzzle elements we need to find and/or create through research to expand the market for the material loop.

With the materials made available at each table, the working group will explore ideas in the topic area in some capturable form and present them at the end of the session, with suggestions for next steps for Town+Gown: NYC and the working groups.

Each working group can use whatever process they feel will work for it, but should consider assigning members to the following roles:

- sticky note maker + placer on white paper (familiar to those who have been through VE/VA engagements)
- picture taker
- summarizer and/or presenter to reconvened group

Appendix A

Practitioner Comments after CDW.1: Prelude to What We Need to Know

DSNY	Products to explore: • ceiling tile • gypsum wallboard • recycled glass aggregate Policies to explore: • Requiring a recycling plan and deposit be made before initiation of a construction project • Requiring a recycling rate for C&D • Allowing time for deconstruction prior to demolition • Extended Producer Responsibility for C&D products
DDC	Given the logistical complexity of reusing demo'd material as aggregate on site, I wondered if it was worth thinking about a banking or credits system? Did also wonder about identification of appropriate product fabrication w/reused aggregate: e.g., Jersey barriers, parking stops etc., for which qualitative control might not be so critical (or at least articulating this, though it didn't seem to resonate too well with the general sense of the meeting).
DEP	Creating policy drivers to incentivize the recycling market Review of the DEC Pat 360 regulations an applicability to City infrastructure Discussion on recycling rates of waste transfer stations.
DEP	Calculating the true recycling rate for mixed construction demolition waste, not all recycling facilities in NYC recycle 100% of the material they receive. How can we specify specific recycling locations in the specs and contracts without sole-sourcing Creating a platform to coordinate for soil transfer from active construction sites across different agency projects.
DDC	We can see if we can gather information on how this can be used to help us achieve better sustainable goals, and credits with the Envision Rating System.

DDC	Using recycled concrete aggregate (RCA) in asphalt without additional research poses risks such as
	• RCA will have a higher void ratio (Gsb vs Gsm) due to the entrained air in the cement paste, which will drive up the asphaltic cement demand.
	    o Is the carbon savings by recycling aggregate greater than the carbon sink from using more petroleum in the asphalt mix?
	    o The higher asphalt levels will possibly lead to more rutting, and this is solved by modifying the aggregate gradation, which makes the concern in 1.c below even worse.
	• RCA will have a lower friction resistance capacity – concrete gets the friction capacity due to the aggregate at the surface, but the RCA will have a mix of aggregate and cement paste at the surface. The wearing of the cement paste will lead to the surface possibly polishing and becoming too smooth, and allowing the surface aggregates to pop and start raveling of the asphalt surface.
	• Asphalt is generally mixed using a bunch of well graded piles of material (a stockpile of 3/8", ½", 5/8", etc.) that are blended to make a very precise gradation – much more scientific than how concrete aggregates are graded. If most RCA is just a low-effort mill and crush that might make a well-graded C33 mix, would it require additional processing and handling to be ready for incorporation into asphalt? This additional processing would need to be taken into account for any value calculations.
	• Products where RCA might be used: Parking stops seem like a good idea, but, in that context, it is necessary to consider a jersey barrier as *structural*.

Appendix B

Abstracts of Completed Town+Gown: NYC Projects

2017-2018

Analyzing Construction and Demolition Waste Flows within New York City

Town: NYC EDC
Gown: Carnegie/Heinz
Researchers: Christian Bergland, Taimur Ahmed Farooq, Alvaro Gonzalez, Jafar Haider, Yui Xu

Objective. The research team was tasked with developing a framework to permit greater value capture, within the construction and demolition sector, of low-value recyclable construction and demolition waste, which includes gypsum wallboard, carpet and ceiling tiles generated in building construction.

Methodology. Using gypsum as the case study material, the research team intended to identify the market value and materials flows of gypsum waste generated by construction sector activities within the city by conducting a stock and flow analysis of gypsum, in the broader conceptual context of a “cradle-to-cradle” version of the circular economy model. As part of the stock and flow analysis of gypsum, the research team also reviewed the city’s current reporting system for construction and demolition waste (CDW) generally and the LEED system program with respect to CDW, and conducted case study analysis of gypsum recycling outside the U.S.

Findings. The team, however, encountered significant data issues that impeded the ability to conduct a stock and flow analysis at the city-level. A database with elements necessary for a stock and flow analysis covered the mid-Atlantic states that aggregated New York City data with data from other localities in the New York State. A New York State-wide database, however, was found to be highly aggregated. In view of the lack of New York City-specific systems data, the team developed a two-pronged approach one of which involved actions that NYC EDC could undertake on its own, such as creating an informational campaign to raise awareness and promote CDW recycling at job sites, and the other of which focused on systemic actions to provide incentives for recycling as a route to creation/expansion of markets for recycling and to improve stakeholder data production capacity as a foundation for future efforts.

Next Steps. Since the researchers had identified the absence of system-level data as a foundational roadblock to increasing CDW diversion, the team suggested that efforts to solve the data issue would be necessary for the city to begin to act on many of the other recommendations, especially those based on the international case studies.

2015-2016

Replacing Natural Aggregates with Recycled Aggregates for Concrete Making in NYC—An Environmental Impact Assessment Study

Town: See note below*

Gown: CUNY/CCNY-Grove
Researcher: Meryl Lagouin

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 demotion 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 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.

** Past volumes of Building Ideas have abstracted projects that originated outside Town+Gown: NYC, but nonetheless relate to the Built Environment or existing research questions. Since projects like this can provide the foundation for future research projects within Town+Gown: NYC, they are captured in Building Ideas.*

2013-2014

Life Cycle Cost Analysis and Green Infrastructure in New York City Life Cycle Cost Analysis and Green Infrastructure in New York City

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

Objective. Earlier Town+Gown: NYC 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.

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.

2011-2012

Gypsum Recycling in PlaNYC 2030: Spaces for Government Intervention

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.

Research 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.