Information processing for end-of-life coordination: a multiple-case study

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Abstract

Purpose – The purpose of this study is to explore how demolition contractors coordinate project activities for buildings at their end-of-life. The organizations are thereby conceptualized as information processing systems facing uncertainty.

Design/methodology/approach – A multiple-case study methodology was selected to gain in-depth insights from three projects with different end-of-life strategies: a faculty building (material recycling), a nursing home (component reuse) and a psychiatric hospital (element reuse). Using a theory elaboration approach, the authors sought to explain how and why demolition contractors process information for end-of-life coordination.

Findings – End-of-life strategies differ in the degree of building, workflow and environmental uncertainty posed to the demolition contractor. Whether or not a strategy is effective depends on the (mis)match between the specific levels of uncertainty and the adopted coordination mechanisms.

Research limitations/implications – The explanatory account on end-of-life coordination refines information processing theory for the context of (selective) demolition projects.

Practical implications – The detailed case descriptions and information processing perspective enable practitioners to select, implement and reflect on coordination mechanisms for demolition/deconstruction projects at hand.

Originality/value – Reflecting its dual conceptual-empirical and inductive-deductive focus, this study contributes with new opportunities to explain building end-of-life coordination with a refined theory.

Keywords Building, Information systems/management, Materials, Circular economy, Demolition, Whole life cycle

Paper type Research paper

Introduction

To cope with increasing socio-environmental pressures, the construction industry urgently needs theoretically grounded and empirically validated insights for building end-of-life coordination. It is estimated that the construction industry generates around 35% of all solid waste around the world (Llatas, 2011) and that it is simultaneously responsible for more than half of the total amount of virgin resources consumed annually (Iacovidou and Purnell, 2016; Ness *et al.*, 2015). Most of the waste originates from demolition (Schultmann and Sunke, 2007; Akanbi *et al.*, 2018; Cheshire, 2016; Chen and Lu, 2017), the fate of almost every obsolete building that has not received a monumental or cultural heritage status (Wassenberg, 2011). The end-of-life phase of a building is typically marked by the complete elimination of all parts of a building (Thomsen *et al.*, 2011). Demolition contractors have thereby relied on crushing force (bulldozers, wrecking balls, explosives, etc.) and landfilling to dispose of obsolete buildings (Akinade *et al.*, 2017; Chini, 2007). Awareness of the detrimental impacts of such traditional practices nevertheless calls for more scientific

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insights into alternative strategies, or reverse logistics methods (Chinda and Ammarapala, 2016), that enable the reuse and/or recycling of building resources.

To effectively divert waste from landfills, demolition contractors must manage uncertainties related to reuse or recycling end-of-life strategies. Such strategies comprise a range of interdependent demolition activities, such as collecting, inspecting, sorting and further processing of (building) parts (Agrawal *et al.*, 2015) that need to be coordinated by a demolition firm. Coordination, defined as managing the dependencies between activities (Malone and Crowston, 1994), involves the gathering, interpreting and synthesizing of information to initiate and control material flows. Recent ethnographic insights by Van den Berg *et al.* (2020) demonstrate that this is particularly challenging for more complex building end-of-life strategies that attempt to close material loops. Demolition contractors must, for example, acquire information about the context of a building component and interpret how it is assembled and exposed to wear to determine whether that component still has lifetime potential (Koutamanis *et al.*, 2018). Subsequent recovering, sorting and transporting activities are also often underdeveloped in construction (Mahpour, 2018) and their interdependencies make material flows vulnerable for unexpected changes (Chang, 2001; Chang and Tien, 2006). Reuse and recycling also seem limited because of a lack of interest from clients, consumer taste and attitudes and limited support from rules and regulations (Park and Tucker, 2017; Hosseini *et al.*, 2015b). Such barriers are mostly of systemic nature (Densley Tingley *et al.*, 2017) and linked to a lack of information (Hosseini *et al.*, 2015a), which illustrates that uncertainty is inherent in coordinating end-of-life activities.

A fruitful perspective to better understand end-of-life coordination is, consequently, offered by information processing theory (IPT). This theory views uncertainty, defined as a lack of information required to take a decision, as the driver behind organizational activities and decision-making (Winch, 2010). The purpose of information, referred to as "data which are relevant, accurate, timely and concise" (Tushman and Nadler, 1978), is thus to reduce or remove uncertainty. The theory posits that the uncertainty arising from a firm's business environment creates information processing needs to which the firm must respond adequately (Tushman and Nadler, 1978; Galbraith, 1974; Galbraith, 1973). In other words, demolition contractors can be seen as organizations that face uncertainty in coordinating end-of-life activities. The uncertainty forces a demolition contractor to process information with which the firm can initiate and control material flows. The extent to which uncertainties and a demolition contractor's organizational responses match determines the effectiveness of the firm's coordination efforts. However, the uncertainties associated with different end-of-life strategies, demolition contractors' organizational responses *and* their (mis)matches are still poorly understood. End-of-life coordination has not been viewed from an information processing perspective yet. The goal of this research is therefore to explore how demolition contractors coordinate end-of-life strategies by elaborating IPT.

This paper is structured as follows. It starts with a background on empirical knowledge about end-of-life coordination and on theoretical knowledge about information processing, which stress a need for a dual inductive-deductive *theory elaboration* research approach. The research design section, accordingly, presents procedures for collecting and analyzing data in three case study projects: a faculty building, a nursing home and a psychiatric hospital. The results section presents how the corresponding demolition contractors processed information in these projects. The (mis)matches between coordination mechanisms and the specific levels of uncertainty are, subsequently, discussed with an information processing model. The paper concludes with a conceptualization of demolition contractors as information processing systems and empirical characterizations of the firms' coordination activities.

Background

Based on a literature review of empirical and theoretical work, the authors point to two knowledge gaps. Empirical studies, on the one hand, lack a sound theoretical perspective that helps to explain how demolition contractors manage uncertainty. Theoretical studies, on the other hand, are deficient in demonstrating end-of-life coordination with data from real-world projects.

Empirical knowledge on end-of-life coordination

The end-of-life phase of a building is characterized by intensive decision-making and organizational activities concerning the building's future (Akbarnezhad *et al.*, 2014; Chinda, 2016). Buildings are designed for a specified working life, which generally does not exceed 50–60 years (Laefer and Manke, 2008). The end-of-life phase follows after a linear sequence of initiative, design, construction and operation/maintenance of life cycle phases. It involves a variant between conventional demolition, the deliberate man-made destruction of a building and its parts, and selective demolition (also called deconstruction), the careful dismantling of a building to maximize recovery value (Kourmpanis *et al.*, 2008). Selective demolition typically requires more labor involvement and longer project durations in comparison with conventional demolition activities but could also yield profits because of reuse benefits (Pun *et al.*, 2006). A building's end-of-life phase may start when a building no longer meets the programmatic needs of its occupants. Other decisive motives for demolition include obsolescence, physical decay, oversupply of similar buildings, quality-of-life (liveability) problems or socio-political processes (Wassenberg, 2011; Thomsen and Van der Flier, 2011). When this is deemed necessary, strategies are determined to either recapture value or dispose of the building's components, elements and materials.

Possible end-of-life strategies include landfilling, recycling and reusing. These strategies particularly differ in the extent to which the original value of the component, element or material is recovered after its primary life (Allwood *et al.*, 2011). The traditional landfilling strategy involves discarding the building resources in landfills without any attempts to recover value, causing space concerns in densely populated areas and potentially contaminating surrounding watercourses with toxic chemicals used in buildings (Cooper and Gutowski, 2015). A main strategy in construction is recycling, in which discarded building parts are reprocessed into raw materials for new products (Iacovidou and Purnell, 2016). Recycling is often seen as good environmental practice (Coelho and De Brito, 2013; Wang *et al.*, 2018), as it reduces the demand for new resources and reduces the cost and energy use incurred by landfilling. However, a major problem is that the recycled materials are often used in a lower grade application compared to the initial application and, consequently, that a great proportion of the initially invested energy is lost (Akbarnezhad *et al.*, 2014; Allwood, 2014). Secondary materials may also not be used to substitute virgin materials but instead drive the production of new low-price products (Haas *et al.*, 2015). Recycled concrete aggregate, for example, can be used as a sub-base material but cannot completely substitute aggregate in new concrete (yet) (Kibert, 2016). As recycling typically reduces the raw material's quality, the potential for future uses and economic value, it is also referred to as "down-cycling" (Chini, 2007). More environmental benefits can be gained through reuse, in which discarded parts are recirculated and used for the same function while the invested embodied energy is preserved (Kibert *et al.*, 2001). The waste hierarchy hence prioritizes reuse over recycling (and recycling over landfilling) in terms of material efficiency (Lansink, 2017).

Effective end-of-life coordination seems challenging because of peculiar project uncertainties. Demolition contractors are principally responsible for planning, implementing and controlling the flow of products from a salvaged building to a point of further processing (Hosseini *et al.*, 2015b, Rogers and Tibben-Lembke, 1999), like a new construction site. These reverse logistics processes have yet to become common practice in construction because of barriers at industry, organization and project levels (Chileshe *et al.*, 2016b). Jayasinghe *et al.* (2019, p. 705) relate those barriers to a lack of information and collaboration and suggest that "a sound information flow" is key in end-of-life coordination. Demolition contractors consequently need to deal with uncertainty to capture the benefits of (more) sustainable end-of-life strategies. Pun *et al.* (2006), for example, argued that demolition techniques aimed at recovery (rather than destruction) are associated with increased risk and complexity. Rules and regulations regarding recycling/reuse of building products vary locally and require appropriate organizational responses (Chini and Goyal, 2011). A demolition contractor also needs to be dedicated and engaged as well as to collaborate with stakeholders (Udawatta *et al.*, 2015), both upstream and downstream its supply chain. Effective reuse, for example, requires that designers of new projects are provided with extra information about any reclaimed products (Gorgolewski, 2008). Uncertainties related to barriers for reuse and recycling strategies – such as tight scheduling and budgeting, liability risks for using recovered products, building code incompliance and a lack of guidelines (Hosseini *et al.*, 2015b, Iacovidou and Purnell, 2016; Van den Berg *et al.*, 2019) – similarly affect demolition contractors' selection and deployment of coordination mechanisms. Although managing uncertainty thus seems a relevant and lasting challenge in end-of-life coordination, this has not been investigated empirically. As the responses of an organization to uncertainty (and the suitability thereof) are information processing problems (Winch, 2015), an information processing framework is considered most appropriate to guide such systematic reflections.

Previous empirical studies have thus identified end-of-life phase activities and some associated challenges but lack a sound theoretical framework that helps to explain how demolition contractors coordinate those activities.

Theoretical knowledge on information processing

IPT provides a "predominant framework" to understand and analyze organizational (re-) design (Levitt *et al.*, 1999, p.1482). The theory could be adopted to develop recommendations for the implementation of (digital) information systems but is particularly suitable to explain effective organizational designs under uncertainty (Haußmann *et al.*, 2012). It essentially views firms, like demolition contractors, as information processing systems facing uncertainty. The theory stems from the work by Galbraith (1974, 1973, 1977) and other organization theorists (cf. Tushman and Nadler, 1978), who related the structural design of an organization to its information processing needs. A central idea is that organizations must process information to reduce uncertainty but have limited capacity to do so. Information processing is generally defined as the gathering of data, the transformation of data into information and the communication and storage of information in the organization (Egelhoff, 1991). This is a prerequisite to accomplish internal tasks, interpret the external environment and coordinate diverse activities (Daft and Lengel, 1986). According to Galbraith (1974), organizations must create information processing capacity according to the amount and type of uncertainty that the organization experiences. While an organization can be over- or under-designed in its capacity to process information, the theory predicts that organizational activities – like end-of-life coordination – are most effective when the information processing needs match (or fit) with the available information processing capacity.

IPT puts forward a number of mechanisms to plan and design an organization. These mechanisms reflect how an organization structures roles, processes and reporting relationships around the completion of a main task. Galbraith (1974) started outlining three mechanisms that provide an organization with increasing ability to handle uncertainty:

"rules and procedures," "hierarchy" and "targets or goals." Rules and procedures are sufficient when tasks are routine and predictable. When exceptions to those rules occur, they are resolved by referring the exception to the next hierarchical level. Instead of specifying specific activities, an organization may also set targets or goals to be achieved so that employees can select appropriate behaviors themselves. With increasing uncertainty, the hierarchy becomes overwhelmed and organizations have two options: either reducing information processing needs through creating "slack resources" and/or "self-contained tasks" or increasing information processing capacity through investing in "vertical information systems" and/or creating "lateral relations" (Galbraith, 1974; Galbraith, 1977). The first two mechanisms reduce the need to process information because exceptions are less likely to occur and fewer factors need to be considered when an exception occurs. The other two mechanisms adapt an organization so as to process new information during task performance. Many organizational scientists have further developed Galbraith's seminal work through refining types of uncertainty and suggesting different coordination mechanisms. Tushman and Nadler (1978), for example, extended the view of organizations as information processing systems with a model for organizational design and structure. Daft and Lengel (1986) suggested that organizations do not only process information to reduce uncertainty but also to reduce equivocality, the existence of multiple and conflicting interpretations about an organizational situation (Weick, 1979). Bensaou and Venkatraman (1995) shifted the focus of IPT from the intra-organizational to an interorganizational level of analysis so they could relate three types of uncertainty (i.e., task, partnership and environmental) with structural, process and information technology-mediated coordination mechanisms. Such works led to modifications of the original theory.

IPT, with its different modifications, has been used to explain organizational behavior in various contexts. For example, Thomas and Trevino (1993) used a multiple-case study with an IPT lens to demonstrate how organizations process information during strategic alliance building in the healthcare industry and how that is linked to alliance success. Many other examples originate from the manufacturing industries and include works on buyer–supplier relationships (Bensaou, 1999), supply chain coordination under varying rates of innovation (Meijboom *et al.*, 2007), cross-functional strategic consensus-building (Feger, 2014), sustainable supply chain management practices (Busse *et al.*, 2016; Foerstl *et al.*, 2018), relational uncertainty in service dyads (Kreye, 2017) and the impact of manufacturing complexity on sustainability (Wiengarten *et al.*, 2017). IPT studies that deal with construction-related topics are scarcer but include attempts to quantify uncertainty and equivocality in projects (Chang and Tien, 2006), to demonstrate how client organizations consider specific industrialized construction alternatives (Levander *et al.*, 2011) and to study inertia in client decision-making (Engeström and Hedgren, 2012). The influential work of Winch (2010) furthermore views a construction project as a process of reduction of uncertainty through time and illustrates this with case examples. However, previous studies have not viewed end-of-life coordination from an information processing perspective. This makes it unclear what sources of uncertainty, mechanisms and relationships are applicable in this context to explain demolition contractors' organizational activities.

Previous studies that adopted an information processing perspective have thus systematically explained different types of organizational behavior but lack empirical delineations of end-of-life coordination.

Research design

This research aims to explore how demolition contractors coordinate end-of-life strategies through elaborating IPT. Theory elaboration is an approach that modifies the logic of a general theory to reconcile it with contextual idiosyncrasies. This approach is the preferred case research design when a potent general theory exists – such as IPT – that only partially explains a phenomenon of interest (Fisher and Aguinis, 2017). Theory elaboration is positioned in between theory building and theory testing approaches. As such, it has a dual conceptual-empirical as well as inductive-deductive focus. In other words, a theory elaboration approach makes it possible to explain empirical phenomena with a refined theory (Figure 1).

Methodology

Given the paucity of research on end-of-life coordination, the authors selected a multiple-case study methodology. This qualitative research methodology enables to gain in-depth insights about the complexity and richness of real-world phenomena over which researchers have little or no control (Eisenhardt, 1989). The case studies were planned to answer *how* and *why* demolition contractors process information for end-of-life coordination. Case studies are the preferred methodology to explore such questions (Yin, 2009). A theoretical replication logic was followed to purposefully select three case study projects that dealt with different end-of-life strategies: a faculty building, a nursing home and a psychiatric hospital (Table 1). These cases were similar in important respects: the buildings were all at the end of their useful life, located in the same country (The Netherlands) and being demolished around the same time (hence subject to the same rules and regulations). The relevant demolition contractors had nevertheless been provided with different specifications on how to handle these buildings: enabling material recycling (Case 1), component reuse (Case 2) and element reuse (Case 3). As the first end-of-life strategy is common practice for buildings at the end of their useful life (Tam and Tam, 2006; Del Río Merino *et al.*, 2010), this is a "typical" case in terms of Yin (2009); the second and third cases are "unique," as those end-of-life strategies are unconventional. The three cases thus provide intriguing opportunities to illustrate how dissimilar end-of-life strategies can result in different information processing needs, capabilities and (mis)matches and begin to suggest some factors which may be important in the successful coordination of demolition projects.

Data collection

Data was collected from a wide variety of sources to enable data triangulation and was organized in a case study database (Table 2), which is in line with recommended case study principles (Miles and Huberman, 1994). An essential source of case study information stems from 13 interviews with key project participants. To enable informants explaining about processing information in their own terms, a semi-structured interview method was chosen. That method balances a structured list of questions to allow comparisons across interviews with the flexibility to modify the order and details of how topics are covered (Bernard and Ryan, 2010). Some key informants were identified during initial discussions with contact persons that led to agreements for collaboration in this research; others were referred to during an interview (snowballing). The researchers specifically sought to interview project participants with *first-hand* experience in coordinating end-of-life activities such as collecting, inspecting, sorting and further processing. Interviewees were therefore not only selected from the focal demolition contractors: they also included managers and other decision-makers of firms with which the contractor interacted with. The interviews covered information processing needs and capabilities questions in the distinct projects, divided over four parts: project characteristics (e.g. building details and end-of-life strategies); uncertainties and information needs (e.g. reverse logistics activities and associated risks and

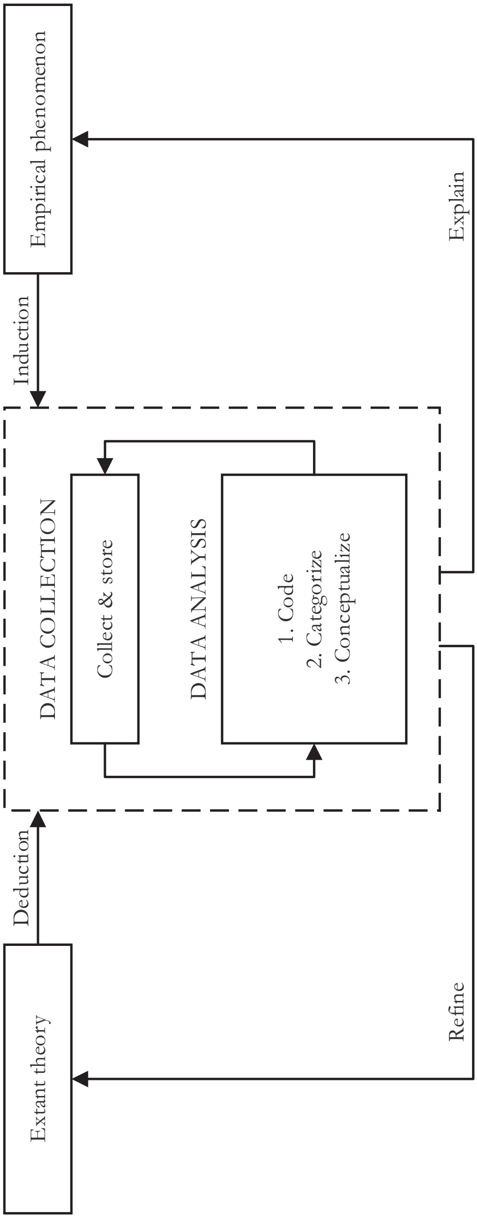


Figure 1.
Theory elaboration approach

challenges); coordination mechanisms and information capacity [e.g. project organization, communication and information and communications technology (ICT) usage] and (mis) matches (e.g. success factors and possibilities for improvement). The interviews lasted between 60 and 100 min each and were all audio-recorded and transcribed verbatim. A summary of the transcriptions was sent back to the interviewees for verification purposes.

The case studies were also informed by project documentation, site visits and (secondary) reports (Bernard and Ryan, 2010). Project participants shared relevant project documents after the researchers promised "special care and sensitivity" (Yin, 2009, p.73) regarding the confidential nature of some business documents. The collected documents include, among others, construction drawings (revealing technical building details), schedules (activities and their interdependencies) and tender/contract documents (project and market conditions). In case 3, access was also obtained to a new, online database with recovered building elements and the first author was informed about the database's workings during a project meeting with an architect and ICT manager. Furthermore, the (first and second) authors conducted multiple visits to the salvaged buildings (and a logistics centre) while demolition was going on. Guided by the site supervisors, the

Table 1. Characteristics of selected demolition (case study) projects

Characteristic	1: Faculty building	2: Nursing home	3: Psychiatric hospital
Focal end-of-life strategy	Material recycling	Component reuse	Element reuse
Exemplary products	Bricks, steel and plastics	Floor, wall, and façade parts	Doors, handrails and sinks
Key (chronological) activities	Asbestos abatement, soft stripping and sorting materials	Soft stripping, disassembling components and moving components	Asbestos abatement, disassembling elements and selling elements
Gross floor area	25,000 m^2	4,500 m^2	15,000 m^2
Location	Netherlands (East)	Netherlands (West)	Netherlands (South)
Construction–demolition	1967–2017	2012–2017	1973–2017
(Planned) duration	22 weeks	18 weeks	39 weeks

Table 2. Overview of data collected per case (DC, demolition contractor; GC, general contractor; C, client/principal agent and T, trader)

Data source	1: Material recycling	2: Component reuse	3: Element reuse
Interviews	Site supervisor (DC) Project leader (GC) Project manager (C1) Project manager (C2)	Site supervisor (DC) Project leader 1 (GC) Project leader 2 (GC) Expedition leader (GC) designer (GC)	Site supervisor (DC) Project leader (DC) Project leader (C) Commercial advisor (T)
Project documentation	Project schedules, construction drawings and artist impressions	Project schedules, construction drawings, tender and contract documents, cost estimations and e-mail correspondence	Project schedule, construction drawings, exemplary project log book and access to database with recovered building elements
Site visits	Direct observations, pictures, unstructured conversations and notes (two site visits)	Direct observations, pictures, unstructured conversations and notes (one site visit and two visits to logistics centre)	Direct observations, pictures, unstructured conversations and notes (two site visits)
Other	News articles, videos and student project report	–	Project meeting, web shop, news articles, videos and student project report

researchers closely observed, photographed and wrote down how laborers organized the flow of building products away from the site. During these visits, they had many unstructured conversations with on-site personnel (including the foremen in Cases 1 and 2), who augmented their understanding of practical issues in end-of-life coordination. Afterwards, the first author summarized and digitalized the lessons learnt from these observations in site visit reports. Finally, some secondary data was collected in Cases 1 and 3: online news articles and short videos on the projects' progress made by third parties and two student project reports on decision-making in reverse logistics.

Data analysis

Data analysis consisted of systematically coding, categorizing and conceptualizing the raw data to transform it into an interpretive explanation of building end-of-life coordination. Even though data collection and analysis are presented as two sections here, because they represent subsequent stages in a research process, chronologically the two activities partly overlapped.

The analysis started with coding the transcripts, project documentation, site visit notes and the (secondary) reports collected. Coding is the first step in making analytic interpretations of such qualitative data. It involves segmenting the data into meaningful parts and attributing a label (or code) that depicts the core topic of a segment (Saldaña, 2016). Whereas these codes typically come from either an extant theory (in a theory-testing approach) or from an observed phenomenon (in a theory building approach), they were here derived from both sources, as the authors had opted for theory elaboration. The first author initially assigned codes derived from IPT – in particular, concerning uncertainties, organizational responses and (mis)matches – to segments of data (reflecting the deductive character of this research). Special attention was paid to evidence that did not seem to fit the theory, which is "a general analytic strategy" for case study research (Yin, 2009, p. 126). For example, some of the demolition contractors' information processing efforts clearly related to characteristics of the salvaged buildings and could not be explained with concepts derived from IPT. This then led to new codes derived from the data (reflecting the inductive character of this research). The resulting "coding scheme" hence contained codes that originated from IPT literature (e.g. "slack resources") as well as from the data itself (e.g. "drawings") – which is in line with a sound theory elaboration approach (Fisher and Aguinis, 2017). Revisions of this coding scheme were discussed among the authors – as a recommended tactic for "improving accuracy of the coding process as well as avoiding bias" (Boeije, 2009, p.178) – and those discussions stimulated recoding parts of the data until sufficient regularities emerged (Miles and Huberman, 1994).

This step subsequently permitted categorizing the data. The first researcher looked for similarities and differences between the coded data to "delineate categories [and] increase the level of conceptual abstraction" (Boeije, 2009, p.114). For the deductive part of this research, (coded) data segments were categorized according to concepts that originated from IPT studies. For example, fragments of the interview transcripts that indicated how site supervisors were involved in solving any issues on-site were coded with the label "hierarchy" that originates from Galbraith (1974, p. 29) and these fragments were, accordingly, grouped together. For the inductive part of this research, the general guideline of constant comparison was followed as deciding with "which dimensions to measure information processing along requirements requires some judgement" (Egelhoff, 1991, p.349). This involves making systematic comparisons across coded data segments to isolate and refine key categories until those can be clearly described and distinguished (Bernard and Ryan, 2010). Data that was initially coded as "building materials information," "unexpected constructions" and "asbestos locations" was, for example, categorized under the major heading "as-is conditions," as they each dealt with (a lack of) information about the existing building conditions. Categories closely related to each other were once again grouped into aggregated concepts, which is illustrated in Table 3 for the "building uncertainty" concept. Following these two approaches, a hierarchical scheme started to emerge with information processing needs on the one hand and mechanisms providing information processing capacity on the other hand.

The analysis ended with conceptualizing the connections between the distinguished core concepts. Having established consistent coding and categorizations, the concepts that accounted for a large portion of the data and occurred frequently across the different cases pointed to the central attributes for theoretical explanations of the empirical data. The researchers, accordingly, arranged the collected data in three case-by-attribute matrices (Bernard and Ryan, 2010). In other words, they structured the data along the same sources of uncertainty, organizational responses and (mis)matches for each case separately. As suggested by Yin (2009), the specific degrees of information processing needs and the (mis-)matches between needs and capabilities were thereby interpreted by triangulating different data sources. For example, interview transcripts were compared with project drawings and site observation notes to infer whether a demolition contractor faced "low," "medium" or "high" information processing needs regarding "as-is conditions." Such interpretations were furthermore discussed among all authors until consensus was reached and validated during a workshop with three experts (a director and a site supervisor of a demolition contractor and a project manager of a general contractor). The latter "member checks" (Boeije, 2009, p.177) confirmed that the conceptualized information processing relationships accounted for the empirical data. As suggested by Yin (2009), the explanatory accounts were substantiated with detailed, contextually rich case descriptions of demolition contractors' actual information processing efforts. Finally, a cross-case analysis was conducted to identify major sources of uncertainty in demolition projects and common coordination mechanisms.

Results

Demolition contractors faced three major sources of uncertainty in coordinating end-of-life strategies:

(1) building;

(2) workflow; and

(3) environmental uncertainty.

These three types of uncertainty were identified in each of the three case study projects examined (though in varying degrees). Building uncertainty originated from (a lack of) information about the existing situation of the asset (as-is conditions) and the extent to which ease of demolition had been a design concern (disassemble-ability). Workflow uncertainty stemmed from the demolition contractor's possibilities to assign skilled personnel with the necessary tools and equipment to specific tasks (task capability) and the number of dependencies between those tasks (task interdependencies). Environmental uncertainty arose from a demolition contractor's investments specific to the relation with its client that have significantly lower value in other projects (relational specificity) and the general characteristics of the market for salvaged building resources (market conditions).

Table 3. Coding and categorizing of qualitative data (here covering an inductive part of theory elaboration)

Representative quotes and observations (translated from Dutch)	Code	Category	Aggregated concept
"We had some inspections to check what materials are actually in the building. And then we made some estimations. But the exact number of materials is and remains an educated guess." (site supervisor case 1, p.5)	Building materials information	As-is conditions	Building uncertainty
"You always encounter some constructions that you are not aware of in advance. [Based on original drawings] we have an idea about how the building has been adapted over the years . . . Only when you start demolishing and soft stripping, then you can see whether that is actually true." (project leader case 1, p.3)	Unexpected constructions	As-is conditions	Building uncertainty
"I always ask for a complete package [of drawings]: which foundation was used, which footplate? That is important for the transportation. Because sometimes you think that small footplates are used, but then it turns out that big footplates were used. Then I need to double the number of transportations." (site supervisor case 2, p.5)	Unexpected constructions	As-is conditions	Building uncertainty
"It is always a surprise where asbestos is located. . . . You typically come across asbestos during the demolition process, when you start opening up things." (site supervisor case 3, p.2)	Asbestos locations	As-is conditions	Building uncertainty
"We made an inventory: what materials are actually in the building, that is always the basic step, step one. You need to know what you are talking about. We put that in a digital system that is accessible to everyone. You can find there what materials are available and what those are composed of." (project leader C case 3, p.1)	Building materials information	As-is conditions	Building uncertainty
"One can walk through a building endlessly, but I cannot see how solid the masonry is." (site supervisor case 1, p.14)	Solidity of constructions	Disassemble-ability	Building uncertainty
Some of the interior walls are already demolished. They leave the load-bearing structure behind. Bolted joints are used to connect the separate roofs to the steel columns and to connect the steel columns to the separate floor slabs. (site visit observations case 2)	Reversible connections	Disassemble-ability	Building uncertainty
"We made a foundation roster that can be deconstructed. You can disassemble it, because no chemical bonding has been applied. It is attached to foundation piles with a kind of screw connection. . . . It is actually made in such a way that it can be disassembled fairly easily." (designer case 2, p.2)	Reversible connections	Disassemble-ability	Building uncertainty
"All components that are used, like the foundation, concrete floors, steel structure, roof components, façade components. . . all of those are – in principle – reusable. And interchangeable. [Our system] is like a Lego box: everything fits well and that makes it easy to reuse." (expedition leader case 2, p.1)	Lego-like system	Disassemble-ability	Building uncertainty
The entire building has window sills made out of marble. When we walk through the (partly demolished) building, the site supervisor pointed to them and explained: they "are stuck" because a "strong type of glue" had been used to assemble them. Disassembling is now impossible, which the site supervisors seems to regret as he says: "a pity, because they still have economic value." (site visit observations case 3)	Irreversible connections	Disassemble-ability	Building uncertainty

In the three subsections below, the authors interpret the specific levels of building, workflow and environmental uncertainty for each of the case study projects separately and explain how the focal demolition contractors attempted to adopt coordination mechanisms that matched those levels of uncertainty. Each section starts with a brief project introduction.

Case 1: material recycling (faculty building)

The first case dealt with recycling (demolition) materials from the transformation of a large faculty building into 445 (student) studios and a hotel with conference facilities (Table 4). The demolition contractor involved was selected by a general contractor, based on the lowest bid, for asbestos abatement and soft stripping. The general contractor, in turn, was selected by a developer that would sell the transformed building to two clients after project delivery: one managing the studios and the other, the hotel. The demolition contractor's works only leave the load-bearing, concrete structure intact (for subsequent construction) and thereby generated bulky demolition waste, most of which is sent to waste processing firms for recycling. This debris included bricks/cementitious materials, steel, iron, aluminium, plastics, timber and other materials.

Building uncertainties arose from the exact type and amount of (recyclable) materials. There was no accurate material inventory available for the demolition contractor. The firm responded to that by collecting and analyzing construction drawings and making inspection rounds prior to the start of the project. The general contractor provided the firm with the original construction drawings, dating back from the early 1960s but still available. Drawings from later renovations had nevertheless got lost over the years. Some control measurements were therefore taken by the general contractor to verify whether the actual grid sizes, lengths and heights correspond with the (original) drawings. The project leader explained:

Source of uncertainty	Dimension	Information processing needs	Organizational response (providing information processing capacity)	Fit
1. Building	As-is conditions	High	Collection of drawings (limited available) Regular on-site inspections	Insufficient
	Disassemble-ability	Medium	Goals (for material separation) Hierarchy (to solve on-site issues)	Match
2. Workflow	Task capability	Low	Rules (for routine tasks)	Match
	Task interdependencies	Medium	Self-contained tasks (stripping and asbestos removal) Direct contact (between teams) Limited slack resources (on-site storage)	Match
3. Environmental	Relational specificity	Low	Formal meetings (to report progress) Few formal information systems	Match
	Market conditions	Low	Prolongation of buyer collaboration (through annual contracts with waste processors)	Match

Table 4. Match between uncertainties and organizational responses for material recycling (Case 1)

> It used to be a building from the Central Government Real Estate Agency. These buildings have the reputation of having a higher dimensional accuracy [than other buildings from that era]. That also turned out to be the case here.

The demolition contractor's site supervisor nevertheless stated that "the exact number of materials is and remains an educated guess" based on rules of thumb. During one of the site observations, the aforementioned project leader also showed a brick wall in one of the many rooms that was not depicted on any drawing but had "surprisingly shown up" during soft stripping. The poor accessibility and disassemble-ability of building elements suggest that the building was not designed for easy disassembly. The firm therefore aimed to separate the building's infill from the load-bearing structure through conducting soft stripping activities (and to separate the resulting demolition waste per material type) under the supervision of a foreman. Information about some building characteristics is only obtained during these activities and sometimes requires adaptation of the ongoing work.

That workflow posed low uncertainties. The demolition contractor aimed to establish a fast and cost-efficient indoor waste stream. That started with clearing the four elevator shafts so that these could be used as construction chutes. Soft stripping laborers, working from the upper floor downwards to the ground floor, collected and sorted the demolition waste per material type and then threw it through these shafts. On the ground floor, a skid-steer loader was used to push these materials out of the building for temporary storage at the (spacious) site. According to the site supervisor, this "very quick waste stream" is quite predictable, as the soft stripping works are well-understood and comparable for all (nine) floors. Uncertainty is increased because of the interdependence of these tasks with the removal of asbestos-containing ductwork, which needs to be done by specialized laborers with their own equipment. The soft stripping crew needed to skim all easy-to-remove objects before those laborers could do their job. After the asbestos is removed, the first crew returns and completes the soft stripping. A foreman coordinated these interdependencies through facilitating daily (informal) discussions between the two crews.

Environmental uncertainties for recycling materials were low. The general contractor needed to hand over the student studios within the transformed building before the start of the academic year (and the hotel with conference facilities slightly later). This firm decided to postpone the reconstruction tasks until the building would be completely stripped, for which it closely monitored the demolition contractor's progress with weekly meetings and (almost) daily inspections. Their collaboration is fairly traditional with little electronic data exchange and low levels of mutual trust. On the other end of the supply chain, the demolition contractor had a number of fixed waste processing/recycling firms (specialized per material type) to which it brought the extracted and sorted materials from the building. Concrete and other cementitious materials were crushed on-site and transported to new road construction projects (to serve as sub-base material). Annual contracts between the demolition contractor and the different waste processing firms guaranteed fixed prices to dispose of the different types of (sorted) waste materials. The waste processing firms ultimately reprocessed these materials into raw materials for new products.

Case 2: component reuse (nursing home)

The second case dealt with the reuse of components generated during selective demolition of a nursing home (Table 5). That was originally built by a general contractor specialized in prefabricated and modularized buildings with a temporary or semipermanent function. The building components that this firm works with include foundation, floor, wall, façade and roof components. The general contractor hired a demolition contractor, based on a long-term

Table 5.
Match between uncertainties and organizational responses for component reuse (Case 2)

Source of uncertainty	Dimension	Information processing needs	Organizational response (providing information processing capacity)	Fit
1. Building	As-is conditions	Low	Collection of drawings (all available) Regular on-site inspections	Match
	Disassemble-ability	Low	Rules (per type, for disassembly and transport) Hierarchy (to solve on-site issues)	Match
2. Workflow	Task capability	Low	Rules (for routine tasks)	Match
	Task interdependencies	Medium	Self-contained tasks (outsourcing of transport) Slack resources (GC's logistics centre)	Match
3. Environmental	Relational specificity	Medium	Prolongation of supplier collaboration Direct contact (to solve problems)	Match
	Market conditions	Low	Prolongation of supplier collaboration Prolongation of buyer collaboration	Match

partnership, to disassemble the components it had once assembled. The general contractor, subsequently, reused the disassembled components in a new school building.

The demolition contractor faced low building uncertainty. A lot of information was available about the nursing home, which was designed to be disassembled after five to seven years. Interviews suggested that mechanical connections were used to ease both construction and selective demolition of the components. Bolted joints were indeed observed during the first researcher's site visit: they connected the separate roofs to the steel columns and the steel columns to the separate floor slabs. Collected contract documents between the building owner (care provider) and the general contractor included stipulations about the demolition, such as removal costs and the option for the general contractor to repurchase the building. One of the general contractor's project leaders argued that they therefore keep an "excellent archive" with construction drawings and other documentation of the completed project(s) so that they can "make a good prediction" about the current situation of the building. The firm shared such information with the demolition contractor to which it outsourced the demolition tasks. The site supervisor of that contractor confirmed he received all relevant information, such as "which foundation was used, which footplate? That is important [to know] for the transportation." The information is complemented with visual inspections of the building, which he referred to as "doing your homework." The disassemble-ability and the availability of accurate information about the building lower information processing needs.

Workflow uncertainty was slightly higher though. Demolition consisted of a number of interdependent tasks that enable the reuse of components. The demolition contractor started with stripping out all infill to make the components accessible. The reusable components were then labelled according to a deconstruction drawing from the general contractor. Analysis of this document (and confirmed by a project leader) suggested that this is an original construction drawing that the contractor had marked to indicate which components were planned to be reused – and where. One designer explained that the deconstruction drawing tells the demolition contractor that, for example, "the ones marked blue need to be moved to one construction site and the red ones to another." For a new construction project, "you have a drawing with components from the old building. The blue label from the old building is [then] put on the new drawing" (project leader). Based on that drawing, the demolition contractor disassembles the components and organizes their transportation. Laborers thereby follow specific handling instructions for disassembling the components and putting them on a truck, such as "five footplates on one pile" (expedition leader). The demolition contractor's site supervisor argued that the actual transportation tasks were outsourced to a specialized firm "because of busy times." The firm nevertheless remained responsible for moving components that could not be reused in a new project directly to a logistics centre near the general contractor's main office. The components are there stored until such a new project is found.

These tasks took place in an environment that requires some information processing from the demolition contractor. To disassemble the modular components without damaging them, knowledge about those components and – particularly – their connections is necessary. Several interviewees suggested that the demolition contractor has the above-mentioned knowledge. For more than five years, the firm has been the only party that the general contractor works with for the selective demolition of its buildings. "He knows our buildings now. He knows how we think, we know how he thinks. That works well," argued one of the project leaders. Exemplary for the close collaboration is the technical solution that the demolition contractor proposed for disassembling timber façade components affected by some rot. As illustrated by the site supervisor after a site visit:

> At the top and at the bottom, there are three bolts. [If it rots], you cannot remove those bolts. We proposed to use a drill pipe to drill over it [. . .] so that we do not need a crowbar on the inner side with the risk that [. . .] you get damage.

While the demolition contractor discussed exceptions like this with the general contractor, the two parties had prolonged their collaboration over the years which reduced the need to process information.

Case 3: element reuse (psychiatric hospital)

The third case dealt with the reuse of elements (such as doors, handrails, sinks, light armatures and ceiling plates) from the selective demolition of a psychiatric hospital (Table 6). In this project, the principal agent, a consultancy firm acting on behalf of the building owner, selected a demolition contractor based on a best value (i.e. most social and sustainable) bid. With its bid, the focal firm had committed itself to train and work with temporary workers at a distance to the labor market (e.g. dropouts, offenders and people with mental disorders) and to demolish the building in a way that disassembled building elements could be reused. To that end, the principal agent had already developed a database coupled with an online marketplace through which the demolition contractor tried to sell reusable elements. Because of this innovative approach, the works were seen as a "flagship project" and have received quite some media coverage.

Building uncertainty primarily originated from the poor disassemble ability of the asset. The demolition contractor faced medium information processing needs regarding the as-is conditions. To map those, the principal agent had deployed a number of techniques. Pictures were taken during several inspections and all kinds of details of the infill of rooms were written down. This included, for example, the current quality, disassemble-ability, sizes and color of elements such as radiators, doors, lighting, ceiling panels and so on. These stocktaking efforts took place for each unique room and were then, based on the available construction drawings, multiplied by the total number of rooms. "You then get quite a

Table 6.
Mismatch between uncertainties and organizational responses for element reuse (Case 3)

Source of uncertainty	Dimension	Information processing needs	Organizational response (providing information processing capacity)	Fit
1. Building	As-is conditions	Medium	Collection of drawings Regular on-site inspections Detailed stocktaking report (principal agent)	Match
	Disassemble-ability	High	(Quality and quantity) targets Hierarchy (to solve on-site issues)	Match
2. Workflow	Task capability	High	Rules (for routine tasks, not selling) Hierarchy (supervising job creation program)	Insufficient
	Task interdependencies	Medium	Self-contained tasks (stripping vs asbestos removal) Limited slack resources (on-site storage)	Match
3. Environmental	Relational specificity	Medium	Information system (principal agent's web shop) Formal meetings (to report progress) Direct contact (to solve problems)	Insufficient
	Market conditions	High	Prolongation of buyer collaboration	Insufficient

plausible idea," explained the firm's project leader. All that information was later entered in an information system (database) to which the selected demolition contractor was granted access (and the researchers later as well). Based on such stocktaking information, the site supervisor argued that disassemble ability "had originally not been a design concern." The researchers also observed this on site: a strong type of glue had been used for the (marble) window sills that made it impossible to disassemble them without causing damage. "A pity, because they still have economic value," commented the site supervisor.

That factor also contributed to significant workflow uncertainties. The contractor had committed itself to disassemble the entire building and to sell the building elements for future reuse. It was decided to start with soft stripping and disassembly of these elements before the removal of the asbestos containing façade. That made it possible to store the reusable elements indoors, protected from the weather. In different rooms of the salvaged building, the researchers observed piles of disassembled elements, sorted per type and waiting to be sold. The sale of those elements was nevertheless associated with many uncertainties as it was difficult to predict market demand. On forehand, very few potential buyers had been identified. It was also the first time that an online marketplace (web shop), developed by the principal agent, was used to offer elements to the market. The actual demand turned out to be very limited: "everything was disassembled by hand, which takes much more time [. . .]. I hoped to earn that back with the sales, but that was unsuccessful" said the demolition contractor's project leader. Eventually, the demolition contractor did not see any other option than to (pay and) dispose of almost all of the – already disassembled – elements.

Environmental uncertainty also created significant information processing needs for the demolition contractor. The construction industry "is not ready yet" to reuse recovered building elements, suggested the firm's project leader. After a telephonic invitation, one trader in (new and recovered) building elements bought just a few elements from the demolition contractor: timber beams, door dredges, hinges, handrails and a couple of doors. The commercial advisor of that firm argued that "general contractors still prefer new products." The elements that this firm bought were "almost certainly" resold to the private market. The demolition contractor's site supervisor argued that the lack of certifications and warrantees on (particularly) installations also significantly limited sales:

> [. . .] a ventilation device [as observed on the roof] is still working perfectly. It is already in use for so many years though that no company or project developer will reuse something like that, because insurance companies will never insure it.

Uncertainties also originated from changing building codes, as recovered elements may not meet today's requirements any longer. The principal agent finally speculated that widespread reuse is only possible if there is a large and continuous supply of high-quality recovered elements.

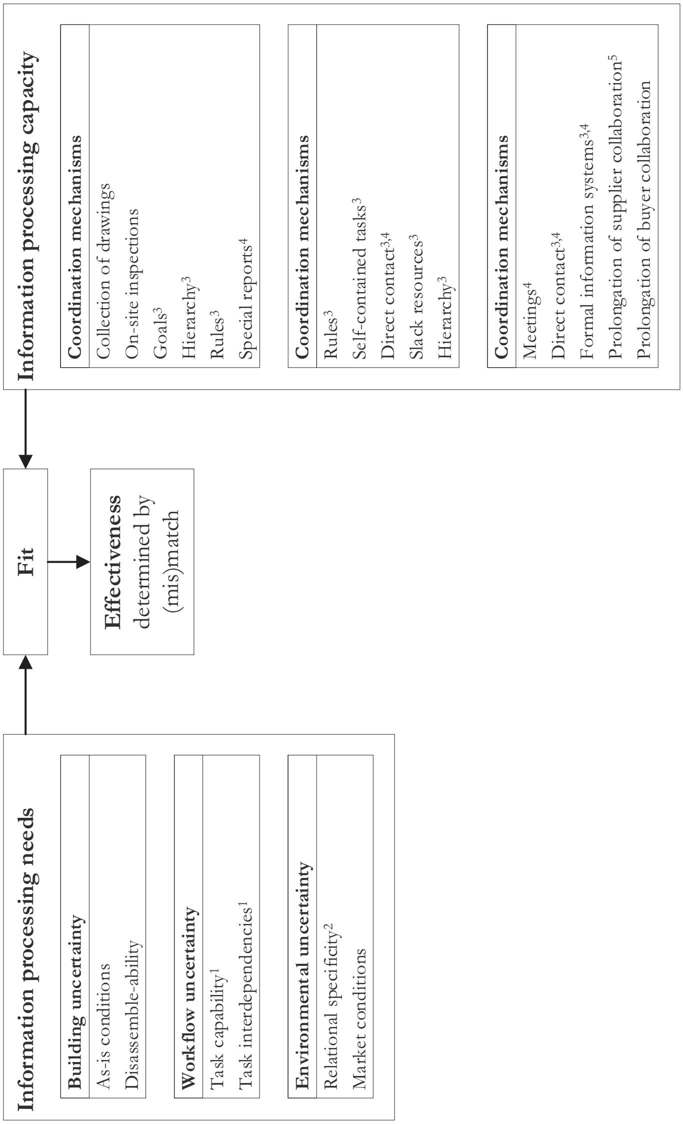
Discussion

This multiple-case study has adopted a conceptual information processing perspective to explain end-of-life coordination with empirical data from three demolition projects. This section discusses how the resulting insights contribute to the body of empirical knowledge about end-of-life coordination and to theoretical knowledge of information processing. The authors also address the limitations of this work and derive suggestions for future research.

Contributions: explanatory accounts for building end-of-life coordination

This research has elaborated an information processing model for building end-of-life coordination (Figure 2). Given recent calls to close material loops (Adams *et al.*, 2017; Pomponi and Moncaster, 2017; Heeren and Hellweg, 2019), the multiple-case study contributes with insights into increasingly important activities and may provide a basis to develop new (digital) information systems that could support demolition works on site. It is explained that demolition contractors deploy coordination mechanisms in response of building, workflow and environmental uncertainty. Depending on the focal end-of-life strategy, different degrees of information processing needs stem from these three sources of uncertainty. A building owner or developer typically mandates ensuring reuse, recycling or landfilling of a salvaged building (or parts of it) based on criteria such as demolition cost, project duration and/or energy use (Cha *et al.*, 2011; Coelho and De Brito, 2013). Depending on the selected strategy, a demolition contractor then faces more or less uncertainty of each one of the three identified sources. For example, building uncertainty is low in the second case (because existing conditions of the building were well known and standardized, prefabricated building components had been used), but this type of uncertainty is higher in the third case (particularly because that building had not been built for easy disassembly). With more uncertainty, the need for increased amounts of information grows and, hence, the need for increasing information processing capacity. The three explanatory accounts that this paper offers suggest that demolition contractors respond differently to the specific uncertainty levels they face.

In the first case, the demolition contractor – characterized here as a *separator* – coordinated material recycling through adopting mechanisms that matched with the experienced information processing needs. For example, formal progress reporting to the general contractor and annual contracts with a number of waste processing firms were sufficient to cope with low environmental uncertainties. As another match, the firm set goals to achieve efficient waste streams that are sorted per material type and employed a foreman to solve any related on-site issues (hierarchy) as organizational responses to the building's poor disassemble ability. These tasks require basic skills and knowledge (i.e. low task capability) but need to be performed before and after removal of asbestos (two self-contained tasks). To deal with uncertainties from those interdependencies, the demolition contractor adequately facilitated daily contact between



Notes: [1]Chang and Tien (2006); [2]Bensaou and Venkatraman (1995); [3]Galbraith (1974); [4]Daft and Lengel (1986); [5]Busse *et al.* (2016)

Figure 2.
Information processing model elaborated for building end-of-life coordination – based on data and theories

the two teams responsible for soft stripping and asbestos abatement and used the possibility to temporarily store materials on-site (slack resources). A mismatch was nevertheless found for the information processing needs and capacity associated with the as-is building conditions. The demolition contractor acquired the original construction drawings (as the drawings from later renovations got lost) and inspected the building to assess as-is conditions, but these mechanisms were insufficient and could not prevent some adaptations to the workflow (e.g. delays) when unexpected building parts were found.

In the second case, the demolition contractor – characterized as a *mover* – coordinated component reuse by adopting mechanisms that matched with the information processing needs it faced. Building uncertainties were low, as the nursing home had been designed and constructed by a general contractor specialized in temporary and semi-permanent buildings with industrialized and modular components – ensuring high disassemble-ability and the abundant availability of construction drawings. Simple mechanisms, such as collecting these drawings and inspecting the building, were therefore sufficient. Specific handling instructions (rules) for correctly disassembling the reusable façade, floor and other building components were also sufficient to deal with most workflow-related uncertainties. The actual transport is (as a self-contained task) outsourced to a specialized firm, which enables the demolition contractors to cope with slightly higher uncertainties from task interdependencies. Recovered components are being moved to a new construction site (for direct reuse), but if that is not possible, they are moved to and stored at a logistics centre (slack resources) of the general contractor. Market conditions pose little information processing needs, as the general contractor (that hired the demolition contractor) can easily reuse those components in new projects. Slightly higher uncertainty stems from the demolition contractor's efforts to learn about the general contractor's specific modular system, to which it adequately responded by prolonging the collaboration with fixed contracts.

In the third case, the demolition contractor – characterized as a *salesman* – coordinated element reuse through adopting mechanisms that did not completely match with the experienced information processing needs. The demolition contractor could adequately cope with building uncertainty through mechanisms such as collecting construction drawings and a stocktaking report and through setting targets for disassembling reusable elements. The firm's information processing capacity was nevertheless insufficient to deal with environmental uncertainty. The firm lacked information about the actual demand for recovered building elements. Changes in building codes, problems with recertifying and reinsuring the elements and end-customer's preference for new products limited the reuse potential of the disassembled building elements – and all contributed to high information processing needs. The demolition contractor's response was to experiment with a new online marketplace (web shop) and to prolong its collaboration with a trader in building elements, but these mechanisms were insufficient to cope with high levels of environmental uncertainty. Similarly, the firm's organizational responses to the information processing needs originating from task capability were insufficient: laborers with specialized resources were only deployed for disassembly and asbestos abatement (both self-contained tasks), yet not for sales tasks. On-site storage of disassembled elements (slack resources) was furthermore limited to the project duration. As a result of these mismatches, most elements could not be sold and eventually had to be disposed of as demolition waste.

Scientific and practical implications

This paper offers new opportunities to understand and explain demolition contractors' organizational design choices in the context of end-of-life coordination. As such, it has a number of theoretical and empirical implications. First, the study advances previous research that identified (self-reported) barriers for reuse and recycling strategies (Iacovidou and Purnell, 2016; Chileshe *et al.*, 2016a; Hosseini *et al.*, 2015b) with (actual) insights on *how* demolition contractors cope with such barriers. Second, it advances research on selecting a specific end-of-life strategy (Akbarnezhad *et al.*, 2014; Chinda, 2016) by demonstrating *why* those strategies are only effective with the adoption of an appropriate combination of coordination mechanisms. This implies that the information processing perspective of this study introduced can help to explain coordination activities that are happening in the real world. But at the same time, the empirical analyses suggested some modifications to the (classical) IPT. That is, third, the study adds three major sources of uncertainty for the context of end-of-life coordination to IPT literature (Galbraith, 1973; Tushman and Nadler, 1978; Busse *et al.*, 2016): building, workflow and environmental uncertainty. Fourth, it advances literature with relevant, context-specific organizational responses that provide information processing capacity. Three of those responses had not been identified heretofore, but the first two ("collection of drawings" and "on-site inspections") resemble with the "special reports" mechanism proposed by Daft and Lengel (1986) and the third ("prolongation of buyer collaboration") mirrors the "prolongation of supplier collaboration" mechanism of Busse *et al.* (2016).

Practically, this work can inform demolition contractors, and their upstream and downstream supply chain partners, about adopting coordination mechanisms that match with present information processing needs. The fresh, theoretical look at end-of-life coordination "might be a source of inspiration and an invitation [. . .] to think about [. . .] the meaning of the findings" (Boeije, 2009, p.118). Practitioners may, accordingly, learn from the detailed case descriptions and demolition contractor characterizations but could also find guidance in selecting, implementing and reflecting on coordination mechanisms for demolition projects. For example, relevant mechanisms can be derived with which the latter *salesman* demolition contractor could increase information processing capacity: inviting architects/designers to buy elements before they are disassembled to avoid unnecessary work (direct contact); establishing relationships with general contractors willing to reuse elements (long-term contracts); deploying a storage facility for disassembled products to extend possible sale times (slack resources) and developing specialized sales teams with specific knowledge and skills about reusable elements (self-contained tasks). Rethinking coordination as information processing activities can thus help practitioners in finding mechanisms with which they can effectively respond to uncertainties at hand.

Limitations and future research

This theory elaboration study helped in explaining significant decision-making and organizational activities for three different demolition projects but is subject to several limitations pertaining to the approach. For that reason, several opportunities for validating, refining and complementing this study exist. First, this study is limited to qualitative interpretations of uncertainty dimensions and organizational responses in demolition projects. The authors tried to provide contextually rich and detailed case descriptions of these projects, which is preferable when little is known about a certain phenomenon (Yin, 2013; Flyvbjerg, 2006) but acknowledge that some of the identified concepts are not fully formalized and operationalized yet. The selected cases thereby only deal with (non-residential) buildings, which limits the explanatory power of the information processing concepts and relationships this paper put forward. To improve the external validity, it is thus necessary to extend the analyses to other types of demolition activities in urban areas (e.g. infrastructures, dwellings or parks) and to support these with quantitative measurements of the identified key concepts. Follow-up studies along the lines of, for example, Premkumar *et al.* (2005) – who explicitly examined the IPT concept of "fit" – could thus help to further validate the developed theory. Second, this study may have downplayed the existence of multiple and conflicting interpretations of information (see e.g. Adriaanse and Voordijk, 2005). Throughout this paper, the authors have argued that demolition contractors process information to reduce uncertainty, which is in line with most of the organizational literature. However, as noted earlier, Daft and Lengel (1986) pointed out that there is a second reason why (such) firms process information: to reduce equivocality or ambiguity. Future research should explicitly distinguish between these two types of information processing needs with more micro-oriented examinations to refine how and why relevant coordination mechanisms are deployed. Third, the focus on information as a critical organizational contingency may have abstracted the materiality away. The paper viewed a demolition contractor as an information processing system, emphasizing managerial activities aimed at processing information. However, a demolition project is (also) characterized by physical production. Following the critique of Koskela and Ballard (2006), "it is a materials processing system too." Future research can, therefore, complement the present work by adopting different theoretical perspectives, such as based on production management, transaction cost economics or agency theory, to acquire a more holistic view on end-of-life coordination.

Conclusions

This conceptual-empirical study contributes an explanatory account on end-of-life coordination through elaborating information processing theory. A demolition contractor is conceptualized as an information processing system facing uncertainty. Such a firm faces three major sources of uncertainty in coordinating end-of-life activities: building, workflow and environmental uncertainty. End-of-life strategies differ in the uncertainties posed to the demolition contractor. Depending on the specific levels of uncertainty, the firm responds with adopting a set of organizational measures that provide information processing capacity. Coordination is more effective when the information processing capacity matches with the experienced information processing needs: the *separator* demolition contractor in the first case was effective in coordinating material recycling; the *mover* demolition contractor in the second case effectively coordinated component reuse; but the *salesman* demolition contractor in the third case was ineffective in coordinating element reuse. As such, this multiple-case study answers how and why demolition contractors process information for end-of-life coordination. This implies that rethinking demolition works as information (processing) problems can help those firms in selecting, implementing and reflecting on appropriate coordination mechanisms. Despite limitations pertaining to qualitative interpretations of building end-of-life activities, a one-sided view on the role of information and the use of a single theoretical perspective, it is hoped that this study's insights help in explaining how effectively coordinating activities during the end-of-life phase may enable the start of completely new life cycle phases.

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