Abstract: Building demolition imposes substantial environmental impacts. In particular, large amount of demolition wastes are disposed to landfills. A solution to ease the situation is to maximally reuse and recycle waste building material. Management philosophies such as Just-in-time are applied into demolition project management in order to promote reuse and recycling of demolition wastes. Transportation logistics, widely applied in the manufacturing industry, is ideal to be adopted into demolition projects to optimise waste material production, inventorying, and transportation. In particular, it enables right types and amounts of dismantled building materials to be transferred to right location, and at right time, as required by material demanders. Consequently, waste reuse and recycling can be facilitated. Furthermore, logistics management helps the demolition project team to reduce cost, shorten project duration, and satisfy material demanders. Transportation planning concerns thorough preparation technically and managerially on the demolition site for transportation activities. Information exchange is playing a significant role in delivering and sharing information among project participants, including building owner, demolition project team, potential material demanders, and transporters. This research paper aims to identify the role of transportation logistics in a building demolition project and to analyse inventory control, transportation, and various technical aspects of logistic management for demolition wastes.

Key Words: Building demolition, waste reuse and recycling, Just-in-time, transportation planning, logistics
1. INTRODUCTION

The construction industry has been well accused for enormous environmental impacts. In particular, construction and demolition wastes generated from building and infrastructure related activities form a major stream for municipal solid wastes (Ling and Lim 2002). Among various construction activities that generate building wastes, building demolition and renovation are appeared to be most contributory (Macozoma 2001). Demolition wastes have been imposing pressure on landfills in many communities and countries. To address the concerns, demolition waste salvaging for reuse and recycling has been studied, attempted and practised in the construction industry for a long period (Kristinsson 2001; Macozoma 2001). Demolition waste management is therefore one of the top concerns of the construction industry. Substantial efforts have been paid to enable waste reuse and recycling. Technically, innovative demolition methods and novel applications of building material reuse and recycling are advancing towards the ideal situation in which demolition wastes are maximally reused and recycled (Kibert et al. 2001). Particularly, the concept of deconstruction erected as an efficient mechanism to enable building material reuse, in which a building structure is carefully dismantled to ensure that the building materials maintain their quality and are reusable. On the other hand, demolition waste reuse is not guaranteed although it is technically enabled. A number of management issues need to be addressed before demolition waste can be regarded as mature practice. There need to be tailored management approaches to facilitate demolition projects that adopt new techniques.

Recently, Just-in-time (JIT) philosophy is adopted into demolition project management in order to promote waste reuse and recycling by minimising inventory of dismantled materials during the project (Pun and Liu 2003). As a close companion of JIT, logistics management deals with moving products between suppliers and clients, which also appears in demolition waste salvage. Following the technical and managerial advances, new themes have opened for demolition project management. Among them, waste transportation logistics is playing a significant role for effective and efficient waste delivery within the reuse and recycling processes. In particular, waste inventory control, transportation planning and information exchange set intriguing content for demolition logistics.

This research paper intends to identify the role of transportation logistics for demolition projects and to analyse waste inventory control, demolition waste transportation, and several technical aspects of logistics management for demolition waste. The following section will indicate the features of building demolition and the characteristics of just-in-time demolition approach. In Section 3, the demolition waste flows and control of inventories are demonstrated through logistics management. Section 4 describes the transportation planning for just-in-time demolition implementation and its technical prerequisites. Finally, the fifth section concludes this research.

2. JUST-IN-TIME BUILDING DEMOLITION

Demolition is the last stage of building lifecycle after planning, design, construction and maintenance. After solely concerning building construction phase, the industry has been shifting attention to planning and design stages. Since the 1980s, maintenance has shared the scrutiny due to some infrastructure crisis caused by insufficient maintenance (Liu and Itoh 2001). Until recently, building demolition is placed under microscope due to increasing environmental pressures, in particular the issue of waste disposal. Prevention and reduction of
Building wastes are apparently crucial in achieving environmentally responsible building demolition project.

2.1 Building demolition and waste management

As building technology is evolving constantly, demolition keeps developing in equipments and techniques (Abdullah and Anumba 2002). Currently, major demolition techniques can be divided into three categories, namely mechanical demolition, deconstruction, and implosion. Popular mechanical and implosive demolition techniques enable rapid and relatively simple demolition projects. However, these demolition projects yield enormous amount of building wastes that are intermixed and contaminated, with most of which end up in landfills (Liu et al. 2003). To divert wastes from landfill, building deconstruction, which was the only available demolition techniques in ancient era, revived recently as a mechanism to eliminate waste disposal and promote waste reuse and recycling (CSC 1994). In a deconstruction project, a building is carefully dismantled into reusable components and materials, which are kept relatively higher quality for architectural reuse.

Waste building materials salvaging for reuse is enabled through innovative building demolition techniques, nevertheless, reuse is not explicitly achieved (Liu et al. 2004). The availability of demands, effectiveness and efficiency of information exchange, and the condition of market significantly affect outcomes of demolition waste reuse. Waste management plan plays an important role in promoting waste reuse by thoroughly arranging waste production and destinations of reutilisation. Currently, three major aspects are concerned within a waste management plan, namely waste minimisation, waste reuse and recycling, and waste disposal techniques (Mills et al. 1999). In the case of building demolition waste management, waste reuse and recycling is the most important due to difficulties and limitations of minimising demolition waste, as well as few options for disposal techniques such as incineration. As a result, waste material markets that promoting waste reuse and recycling are also crucial for eliminating negative environmental impacts of building demolition projects.

2.2 Characteristics of JIT demolition projects

Under conventional management approaches for a demolition project, it is particularly difficult to locate demands of generated waste building materials immediately after a demolition project. Furthermore, the requirements of materials from demanders are not known prior to the commencement of the demolition project, which can lead to unsatisfactory materials being salvaged (Liu et al. 2003). Assuming that the processes of building demolition design, implementation, waste building material production, transportation, waste reuse and recycling are continuous, the flow of waste material from a building demolition project forms a reverse waste material supply chain, which involves various parties including the building owner, demolition contractor, subcontractor, and the building material demander.

Keeping in mind that waste reuse is one of the most significant objectives of a building demolition project, Just-In-Time (JIT) demolition was developed as a management strategy to facilitate reuse of building materials (Pun and Liu 2003). JIT philosophy is a mature management approach nurtured in the manufacturing industry. The main concepts of JIT include reducing the inventory of raw materials and products, and speeding up the manufacturing process by decreasing the manufacturing batch size. Recently, JIT has been applied to construction projects to reduce the waste from building material management.
Waste building materials can be regarded as products manufactured from the dismantling process by the demolition project team, and then consumed in new construction projects (Pun and Liu 2003). Under the common mechanical demolition scenario, wastes are produced and sold to demanders if they are reusable. Because information on wastes materials is not available before the actual demolition project implementation, a large inventory of waste materials is likely to form before the materials are demanded. The situation leads to low efficiency in waste marketing. A solution employing JIT philosophy in building demolition projects is to perform waste production after they are actually demanded. Therefore, waste building materials are produced with specifications. In order to achieve waste information exchange ahead of actual waste production, information must be released on a waste exchange system as virtual wastes, which can be seen as an ordering process in a manufactured product transaction. The detailed work procedure for a JIT demolition planning is shown in Figure 1.

![Figure 1. Working Procedure of A JIT Demolition Project](image)

### 3. WASTE INVENTORY CONTROL

The fundamental objective of JIT demolition is to stimulate waste reuse and recycling. On the other hand, transportation logistics concerns the delivery of waste building materials to their demanders. Efficient and smooth transportation is tightly tied with waste inventory control. One of the most essential elements of JIT is to eliminate or minimise inventories during the manufacturing. Similarly in demolition, waste material inventory need to be controlled to smooth the project processes, eliminate wastage and improve the quality of waste materials.

#### 3.1 Waste flows and inventories

A piece of waste building material could take various forms and status during the process of reuse and recycling. Dismantled building materials can be temporarily stored on site until they are delivered to demanders through transportation. An illustration of waste flows and inventories is shown in Figure 2. In order to avoid costs on additional storage space, it is favourable to process and store waste material on the same site of building demolition. Due to restricted operational area of the demolition site and project schedule, dismantled building materials are to be efficiently controlled that they do not occupy too large portion of the site area for too long. Demolition project are always allocated with little or no time spared due to the fact that area redevelopment is the most common reason for demolition (The Athena Institute 2004). Costs of additional storage deter the demolition project team from the willing of reuse and recycling waste building materials. Efficient waste inventory control is therefore of significance to the success of a demolition project.
3.2 Inventory control through logistics management

Logistics management, as a close ally of JIT and supply chain management, originated from the manufacturing industry (Vrijhoef and Koskela 1999). The philosophies throughout the different management approaches are to speed up and compact production processes. Minimisation of inventory during production enables reduction of wastes thus improves the productivity. The construction industry, on the other hand, has been actively adopting management philosophies from the manufacturing industry to improve its own quality and productivity (O'Brien et al. 2002). Building demolition project management is well adoptable for logistics management especially in promoting waste material reuse and recycling. Reverse logistics is claimed to be beneficial for reducing construction logistics cost (Shakantu et al. 2000). Moreover, the nature of JIT demolition allows application of logistics management for dealing demolition wastes. In a JIT demolition project, dismantled building materials form waste inventory. Waste materials that come out of demolished building need to be transferred to demanders without delay. While waste inventory is controlled and minimised by logistics management, the demolition project team could achieve better productivity in terms of production of quality secondary waste building materials, shortened project duration, and transportation cost reduction.

4. TRANSPORTATION LOGISTICS FOR DEMOLITION WASTES

4.1 Transportation planning

In a conventional building demolition scenario, the demolition project owner needs to seek waste demands afterwards. As a consequence, transportation planning is not possibly planned
and scheduled. Waste of time and human resources are expected. Moreover, the quality of the work might be compromised. As in JIT demolition, a waste management plan is produced according to the result of waste exchange. The waste exchange occurs between the demolition project owner and secondary material users that are discovered through a waste exchange system. Information exchange carried out in the system can be and should be sufficient so that it is clear for both parties to acquire the required time, amount, types, original place and destination of demolition wastes. Therefore, transportations can be thoroughly planned as a portion of demolition waste management plan. In a construction project, good transportation logistics ensures that the right items and resources are in the right place at the right time. On the other hand, demolition refers a reverse process to construction; therefore good logistics in demolition projects naturally presents significant difference to that in construction. Particularly in demolition, good logistics, as an ideal situation, should generate right amount and type of dismantled building material, and send to right location at right time that the material demander requires.

Practically, demolition waste transportation planning has several aspects to concern despite its appeared simplicity. Firstly, the arrangement of the demolition site needs to take consideration of convenience for transportation. Normally, demolition site has adjoined building structures that should not be affected by the demolition project. Therefore, temporary storage can be only limited to on site areas. By the philosophy of JIT, building materials dismantled from the building need to be sequent to the order that they are delivered to their destinations. For example, the items that are to send at a early date should be stored on a location near the site entrance and with sufficient loading areas. As a result, there is no hassle while transportation vehicles visit and pick up demolished building materials. Moreover, labels or codes marked on building materials stock could help to explicitly describe and clarify amounts, types, delivery time and destinations of them. Secondly, the selection of transportation vehicle or service provider substantially influences the success of the delivery. The specifications of building materials for delivery including length, wide, weight and shape certainly restrict the capacity of chosen transportation vehicle. In addition, considerations need to be taken for hazardous or special materials whose handlings need to comply with environmental regulation. Vehicles with specificity such as container truck and refrigerator truck might be utilised instead of ordinary trucks. Finally, similar to manufacturing and construction, transportation planning should include time of delivery that satisfies clients. In the case of building demolition, clients are building material requesters. Frequently, building materials from demolition projects are to be reused in construction projects. Therefore, the delivery time of the building materials must satisfy the schedule of the construction projects. Apparently, information sharing, negotiation and cooperation need to be taken place before transportation logistics planning for a demolition project can be performed.

4.2 Technical prerequisites for planning material transportation

4.2.1 Requirements on building material production

If well implemented, transportation logistics management has potentials to lead the success of a demolition project, especially on the aspect of waste reuse and recycling. Yet, technical issues need to be addressed to ensure the management approaches can lay on solid ground.

From the viewpoint of demolition design, demolition wastes can be seen as products that are produced from the demolition project. To consider safety and feasibility of building demolition techniques, building components and materials need to be dismantled in a certain
order such as top-down approach. On the other hand, there could be multiple demanders that require building materials from the demolition project. Multiple requests with different type, amount and date from demanders could conflict the natural sequence of building demolition techniques. A demolition design should maximally satisfy the sequence of material demands in terms of amount and date while it should not be compromised in expenses, safety and feasibility. The task is obviously not easy to accomplish while advanced building and engineering techniques are needed.

To effectively utilise a demolition design to guild transportation design, building material generation from the demolished building need to be accurately estimated. Not only total types and amounts of building materials are to be estimated, but also building types and amounts of materials that are generated from a break-down activity need to be estimated. Further more, all activities defined in the demolition project schedule need to have associated waste material estimation. As a result, there is a virtual waste generation schedule indicating figures of waste building materials along the project (Pun and Liu 2004). Waste estimation apparently exists in conventional demolition projects yet lack of precision that is necessitated for logistics planning. It is believed that a knowledge base of secondary building materials combined with dimensional and structural characters of demolished building could help in the estimation process (Pun et al. 2003).

Apart from logistics-oriented demolition design and accurate estimation, site optimisation is also crucial to facilitate logistics management for demolition projects. Site fence, entrance, traffic lines, equipment allocation, safety, and emergency exit are all important to an effective and efficient site management. Particularly for logistics management of a demolition project, site management needs to satisfy both convenience of waste material storage and transportation.

4.2.2 Information exchange

Logistics management for a demolition project strongly depends on the fact that the demands of waste materials are acquired prior to the actually demolition project implementation. This also reflects the philosophy of JIT. To achieve the vital prerequisite, information exchange needs to be performed. In a JIT demolition project, the potential material users are invited to participate in the demolition project planning process. The collection of requirements on waste can then be organised and expressed into a production specification for the demolition project. It is possible that aggregated requirements from multiple demanders exceed the total possible volume of waste or cause conflicts. However, the disputes can be levelled through economical and environmental evaluation on various production probabilities. Negotiations can also be helpful in achieving consensus between the building owner and the material demanders. Practically, a web-based waste exchange system can serve as a portal for demolition project participants, namely building owner, contractor, transporters, and waste demanders (Chen et al. 2003). The system carries out information collection, storage and retrieval for all project participants. Information management, in particular information request and response, is crucial to the waste exchange system.

From the viewpoint of supply chain management, waste exchange, although largely dependent on information exchange, adds physical values into final building materials produced. Traditionally, a building to be demolished contains little or no value as raw material in the supply chain. The transformation from the entire building to dismantled building materials that contain financial value is strongly dependent on the effectiveness and
efficiency and result of information exchange. In addition, most of the information is released and available for all channels of the waste product chain, including profiles of the building, waste product specifications and expected environmental impact of the demolition project. The information transparency enables participants of building demolition projects to increase collaboration to achieve the project objective.

4.2.3 Preparations in the construction and demolition industry

Logistics management, combining with JIT philosophy, appears to be encouraging for building demolition projects, especially for achieving waste reuse and recycling. Nevertheless, there are obstacles within the construction and demolition industry that deters it from becoming a robust and mature measure.

Technically, the construction and demolition industry should improve several aspects to fulfil the logistics management approaches. Firstly, a classification system and a qualification system should be built to support waste building materials. Unlike manufactured products, building materials from a demolition project might have uncertain types and quality. The difficulties of identifying and describing waste building materials can cause problems in logistics management which requires substantial amount of communication. Classification and qualification systems help waste producer, buyers, and transporters to identify building materials, as well as evaluating usages. There can also be associated coding enable information technology applications that support logistics management. Secondly, demolition design should be more advanced to offer more flexibility and feasibility to waste building material logistics management. In an ideal situation, a demolition design should be composed in a way that production of waste building material exactly matches the transportation planning. Finally, and most traditionally, the environmental awareness from the communities needs to be improved. Only relatively large scale of waste building material reuse and recycling practices can provide experimental implications for logistics management in demolition projects. Apparently, government campaign and education are the effective manner to improve environmental awareness of the building industry and communities.

5. CONCLUSIONS

In conclusion, waste building material reuse and recycling is important to achieve environmentally friendly demolition projects. The JIT philosophy, which was invented for inventory minimisation and improving productivity, is ideal to merge into demolition project management. Transportation logistics, as a tight ally of the JIT philosophy, is also adoptable for demolition project management, especially in waste material inventory control. Through a proper building demolition design, waste building materials are produced in certain amount at certain time as demanders require. Transportation planning concerns selection of vehicles, arrangement of traffic, demolition site management, and time and destination of delivery. An innovative waste exchange system can be utilised to carry out communications among demolition project participants inclusive of waste material demanders. The notion of transportation logistics management for building demolition is promising; however, building technology and management need to be advanced to satisfy the requirement. In particular, lack of demolition design standard and classification system for secondary building materials are potential barriers that deter implementations of transportation logistics management in building demolition projects.
REFERENCES


