

INFRASTRUCTURE LOGISTICS FOR APPLYING A JUST-IN-TIME

DEMOLITION APPROACH

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Abstract: Just-In-Time (JIT) is a mature method widely used in the manufacturing industry as well as the construction industry. It is utilised to reduce the inventory of both raw materials and final products, to shorten production cycles and improve the quality of products. The JIT philosophy has been applied to demolition projects so that the inventory of wasted materials could be eliminated and the project time could be shortened. In order to implement JIT demolition, the waste exchange process was performed before the wasted materials are generated from the project. Material owners and demanders could virtually plan for waste handling before the demolition project is physically implemented. As a result, waste materials could be sent to demanders through transportation right after they are produced from the project. Applying a JIT philosophy in demolition projects could effectively reduce the inventory of wasted materials and the amount of demolition waste to be sent to landfills. Therefore the cost and time of the project are reduced, and the quality of final delivered materials is improved. The application of JIT demolition at a regional level for the long term needs a revolution in the complex social systems to establish solid and functional infrastructure logistics. The research described in this paper aims to identify the supportive platform of infrastructure logistics to apply a JIT demolition approach in practice. In particular, the information, transportation, organisation and legislation infrastructure systems are demonstrated individually and integratively.

Key Words: Demolition waste, Infrastructure, Just-in-time, Logistics, Transportation

1. INTRODUCTION

In recent years, with increased urbanization and industrialization worldwide, the emphasis in both academic research and engineering practice is shifting from the planning, design and construction of new facilities to the maintenance, refurbishment, and demolition management of existing facilities (Langston and Ding 2001). In some cities, particularly in old industrial regions, in order to improve living quality or to meet other objectives, there are growing examples of demolishing buildings to a green land area, where demolition is independent of subsequent construction. With the increasing demands of demolition, the final lifecycle stage of a constructed facility, its methodology has gradually been moving from conventional complete destruction to more recently developed deconstruction, by which a constructed facility is dismantled fully or partially to salvage demolition materials. Demolition management, particularly deconstruction management, is becoming a novel but fertile teaching and research discipline (Liu et al. 2003). As the converse of construction, deconstruction puts forward some new management themes and adds new content even though the same issues have been faced in construction management. For example, demolished materials' disposal is rarely considered in construction management, and deconstruction planning has different characteristics from the construction planning of products, processes and built spaces.

Just-in-time (JIT), as a mature management philosophy in the manufacturing industry, has also earned ground in construction management. Its ability to minimise material inventory and enhance productivity also empowers demolition management. In a building demolition project that adopts a JIT philosophy, waste exchange happens prior to physical building demolition. Therefore, reuse and recycling of waste building material is better achieved by the satisfaction of material requirements and shortened demolition processes. JIT demolition intends to facilitate reuse and recycling of dismantled building materials. However, several important foundations need to exist in order to implement a JIT demolition project. The foundations comprise various aspects including physical requirements of building, materials and transportation, management approaches, and social background. These foundations are underpinned by hardware and software needed, and the environment within which JIT demolition occurs. After describing the concepts and models of JIT demolition in detail, this research paper brings out the concept of infrastructure logistics for a JIT building demolition project. It then identifies and analyses crucial items concerning hardware, software and environment that are necessary foundations for a JIT building demolition project.

2. EMERGENCE OF JUST-IN-TIME DEMOLITION

2.1 Building demolition situations

2.1.1 Demolition in a building lifecycle

It has been widely recognised that a lifecycle approach can play an important role in project

management by considering all lifecycle stages at the outset (Itoh and Liu 2000). However, people initially concentrated on the design and construction stages, and then involved facility operations. It might be since the 1980s that maintenance has been taken into serious consideration, and maintenance attracted much emphasis from the 1990s (Liu and Itoh 1997). Choate and Walter (1981) argued concisely that there was an infrastructure crisis in the USA due to inadequate maintenance of existing facilities. However, publishing the work did not draw society's attention immediately to the crisis, and the scope of the problem became clear in the following years while a large number of bridges in the USA suffered partial or complete collapse (Dunker and Rabbat 1993). The lessons learned from the failures and disasters led to better understanding of the importance of proper maintenance. Now national governments and local authorities in the developed world have switched their focus from new infrastructure projects requiring large capital investment to the maintenance of existing stock (Harding et al. 1996).

The emphasis on the demolition stage was also due to increasing environmental pressure, particularly in waste disposal. The demolition of building structures produces enormous amounts of materials that in most regions result in significant waste streams. The Australian construction industry, particularly in the demolition of existing facilities, is responsible for some 30-40% of the country's solid waste streams which total about 14 million tonnes annually (Australian Bureau of Statistics 2003). In recent years there have been various attempts to improve landfill disposal technologies as well as to set up advanced recycling technologies. As further improvements in processing are technically limited, future efforts will have to concentrate on improving the demolition method from destruction to deconstruction.

2.1.2 Hierarchical building demolition approaches towards waste minimisation

Buildings account for one quarter of the world's wood harvest and two-thirds of its material and energy flows (Roodman and Lenssen 1995). From the viewpoint of natural resource reservation, the construction and demolition industries need to use materials much more sustainably than they are doing now. Construction materials extracted from natural resources are typically sent to landfills after only one building life. As any natural resource is within limits after which irreversible or serious depletion and damage can occur, the resource extraction activities have to be undertaken with a view to the carrying capacity of the relevant ecosystem to absorb its varied effects (Trusty and Paehlke 1994). To be more conscious of natural resources and more innovative in building demolition, there is a desperate need to find new ways of using unwanted or no longer occupied buildings. Although the currently widely-used machine demolition may be a quick, cheap and easy to remove old buildings, other options under a systematic approach now more than ever need to be explored for the purpose of minimising construction and demolition waste. Figure 1 represents the construction-demolition chain from the raw materials extracted from the ground to landfill after one or more usages through construction and demolition activities. Building demolition alternatives decide the proportions of materials going back to construction through each of the loops from top to bottom as shown by the dashed lines.

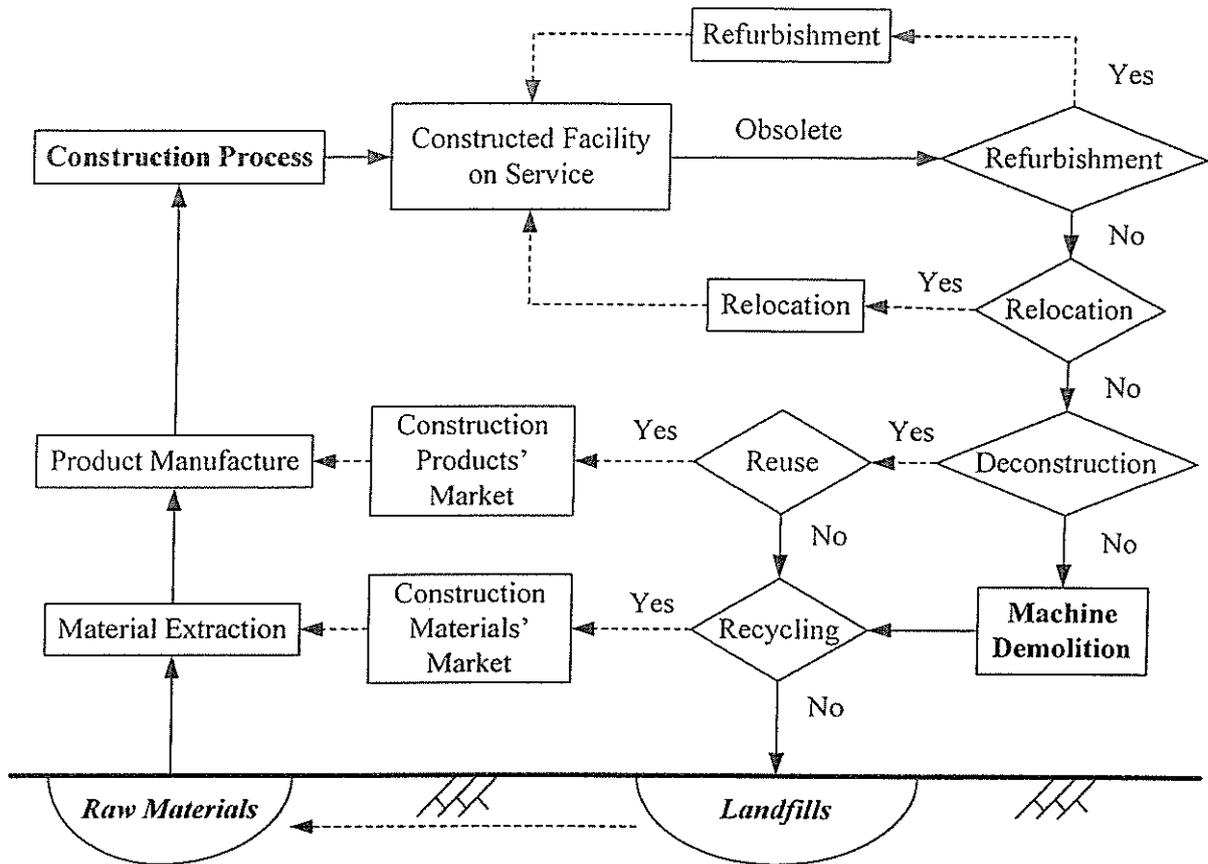


Figure 1. An Ecological Decision-Making Process on Alternatives to Building Demolition

An ideal solution for an abandoned constructed facility, which cannot be used as it is from a structural or functional standpoint, is to refurbish or relocate it. In this case the life of a building is extended, and the majority of a building is retained. For many years, renovation and rehabilitation of buildings in Australia has been developed under requirements for building heritage preservation. An example is the Geelong Waterfront Campus of Deakin University, in which the whole building originally built in the 19th century underwent extensive redesign and refurbishment in the 1990s. Relocation has widely been applied on residential houses, particularly with post and beam, weatherboard cladding and timber frame. In the Victorian region of Australia, more than one thousand buildings are relocated each year (Kibert and Chini 2000). Worldwide, successful relocation has occurred for bridges, churches, odeum and stations, and other structures. After refurbishment or relocation, as shown in Figure 1, a building may be of service again with the original or a modified function. In addition, buildings that are optimally designed with environmentally sustainable materials and with deconstruction in mind are of extreme value for reducing waste although most buildings currently being refurbished or totally demolished are not of this nature. Deconstruction is the first consideration from an ecological viewpoint if demolition has to be carried out. By deconstructing the building, the reuse of materials would provide the next best result following refurbishment or relocation in terms of waste minimization. Destruction, which represents machine-based dismantling, may still allow a major portion of the material to be recycled and reprocessed into building elements. The last process in order of preference is the

disposal of the demolished waste to landfill, which should only occur after all other options have been fully explored and investigated.

2.2 Opportunities and prospects of just-in-time in demolition projects

JIT has been widely utilised in the manufacture industry to speed up the manufacturing process and reduce inventory stock. It has also been applied in construction projects to minimise construction waste (Low and Choong 2003). The workflow and procedures of demolition projects are certainly distinct from the continual manufacturing process. Most importantly, the manufacturing process from the customer orders, raw material purchasing, producing final products, to delivery is a continuous and repeated process (Ibn-Homaid 2002). On the other hand, the demolition of a building can be done only once. Every demolition project is unique. However, demolition can still be seen as a special case of manufacturing if it is considered from a regional or national wide perspective. The building to be demolished, in this case, serves as raw materials for new construction. The waste materials generated from the demolition activity can be seen as the products of demolition. They are sent to their destination through transportation just like other manufactured products, either to the material demander or to landfill (Pun and Liu 2003). Figure 2 compares the production processes in the manufacturing, construction and demolition industries.

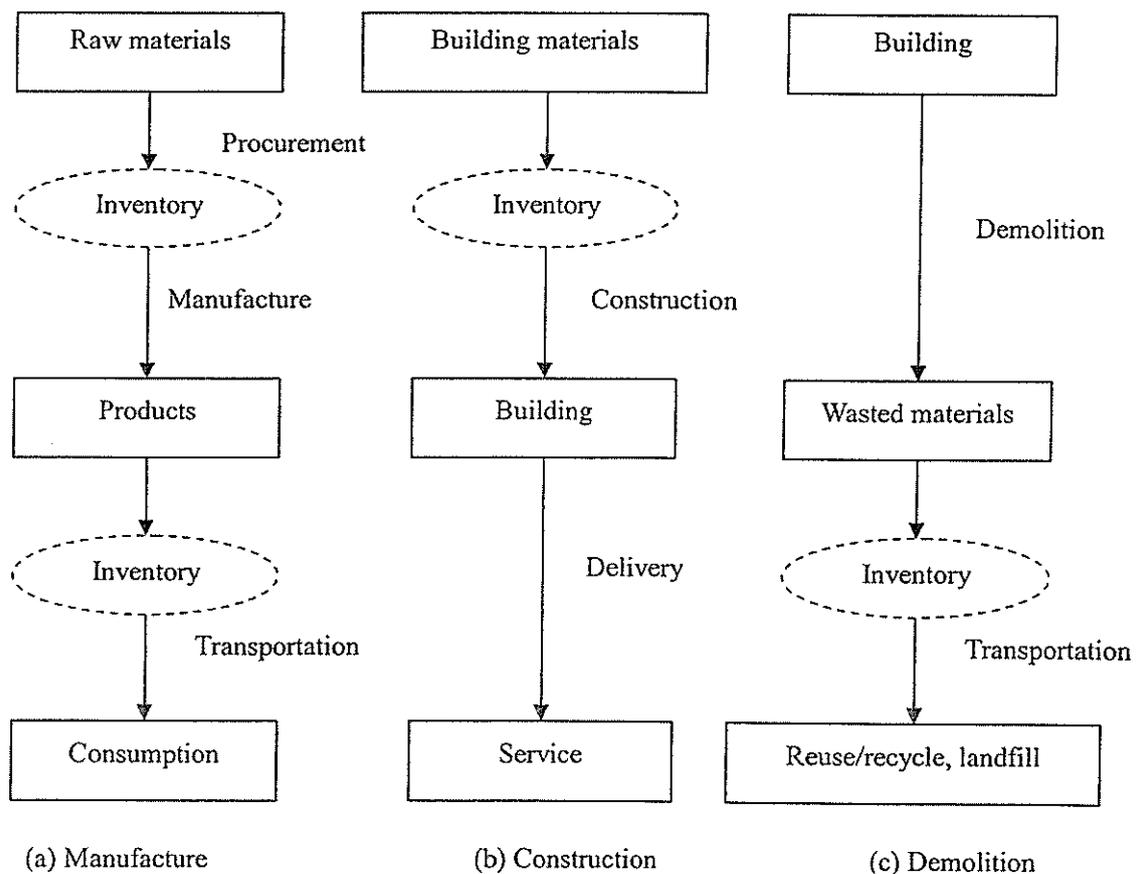
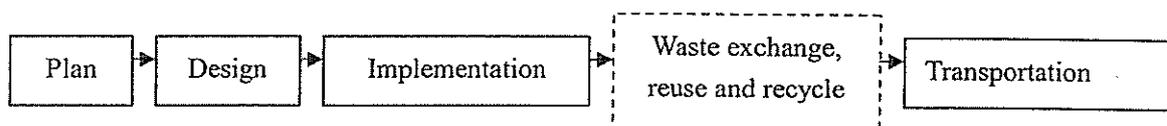


Figure 2. Production Model for Manufacture, Construction and Demolition

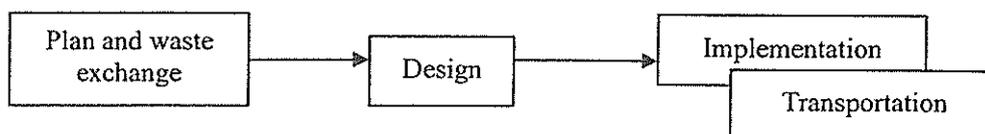
There are a few advantages of utilising a JIT philosophy in demolition projects. One of the initial objectives of a JIT philosophy is to minimise the stock of raw materials and/or final products in the manufacturing processes. In a demolition project, the dismantled building materials can be sent to material demanders without stocking. That is, the wasted materials can be directly sent to the address of the material demander after they are generated from a demolition project. In this way there is no need for the project manager or owner of the building to plan and prepare spaces for holding the waste materials. This plan and preparation could be a very complex task because safety and efficiency must both be taken into consideration. Transportation can be ordered or arranged in advance and carried out simultaneously with the demolition process. If the schedule of the demolition process is optimised and the transportation implementation is organised accordingly both can be connected. So there is no stockpile at either the demolition site or the new construction site.

2.3 A just-in-time demolition implementation model

In a typical demolition project, the waste exchange is carried out after the waste materials are generated from the demolition project. Waste exchange systems can be used to perform information exchange between wasted material holders and demanders, and finally contribute to the transactions between the two sides. Despite the media the project team choose, the generated waste materials need to be stored in the demolition site or another depository for a period of time that is taken for publishing information to enable waste exchange and finding waste demanders. This approach requires the project to be paused for the process of waste exchange before the project team can perform further processes. The whole project is therefore interrupted and the efficiency is lost. By applying the JIT philosophy to demolition projects, the delivery of demolition materials to their demanders can be carried out straight after they are produced from the demolition process. In order to achieve this, waste exchange needs to be performed before the actual demolition process. Therefore, waste materials are virtually exchanged before they are physically produced. During the demolition process, the waste materials can be delivered to the demanders directly, without stocking. This approach saves time and space to handle the waste materials. Moreover, it makes the project schedule compact and reduces unnecessary delay. Figure 3 shows both conventional demolition practice and the proposed JIT demolition model.



(a) Model of conventional demolition approach



(b) Model of JIT demolition approach

Figure 3. Applying JIT into Demolition Project

2.4 Foundations of just-in-time demolition

From the initial observation of JIT demolition, it appears to be an effective management approach for demolition projects. In particular, it facilitates waste reuse and recycling after a demolition project. However, thoroughly applying JIT into a building demolition project requires the accomplishment of a number of prerequisites. For example, the traffic condition of demolition site needs to be viable for transportation needed in a JIT demolition project. All stakeholders of a building demolition project should put efforts into satisfying those prerequisites in order to enable JIT demolition.

Infrastructure logistics of just-in-time demolition may be likened to a three-legged stool based on civil infrastructure systems, management technology and social foundation. Civil infrastructure concerns the physical building condition, suitability for deconstruction, traffic constraints of the site, and reusability of dismantled building materials. On the other hand, management technology includes communication management among project participants, an electronic demolition approach using Internet technology, and procurement and supply chain management. Finally, social infrastructure of a JIT demolition project comprises awareness of the demolition industry and the public, demolition regulation and legislation, and secondary building material market development. The three foundations of JIT demolition mutually influence each other and impose complex management themes and challenges. The following three sections describe and discuss various issues within these foundations.

3. CIVIL INFRASTRUCTURE SYSTEMS FOR JIT DEMOLITION

3.1 Building design and construction for demolition

So far, most buildings have been designed and constructed with no consideration of what will happen to them after their service life, and design for deconstruction or construction for dismantling has only been recognised for a few years by some researchers. Research and development on deconstruction technology and management have not drawn much interest from managers or engineers, and no “deconstruction code” has been published by any authoritative governments or associations (Macozoma 2001). Nevertheless, research efforts have been paid particularly by academics and industry to initiate a new direction for both the construction and demolition industry. It is generally perceived that the balance between durability and adaptability of a building results in building flexibility (Macozoma 2001). Flexibility is therefore important to reduce the generated waste while a building is modified or demolished. A number of other elements should also be considered in design for demolition, including archiving design documents, material selection with consideration of salvage, and use of connectors to link building components.

3.2 Usage cascading of salvaged materials from demolition projects

Construction and demolition waste (CDW) contributes significantly to the landfills of most

countries and regions. Because demolition wastes are usually mixed, contaminated and containing less financial value, the demolition waste problem is much more severe. Recycling building materials, in particular direct reuse, has caught the attention of the construction industry for a long period. Many types of building materials such as timber and metal appliances are totally reusable therefore contain high financial value. Reuse of those materials benefits not only the material producers but also users. Other building materials such as concrete, asphalt, glass and aluminium also contain high value and should not be disposed to landfills. These materials from demolition waste should be reprocessed and recycled. Technologies have become mature for recycling a range of building materials (Tam and Tam 2004). The reprocessed building materials are naturally of substantial value as demolition demand increases. Recycled building materials are then an ideal supply for infrastructure projects and regional construction projects.

The attitude of demolition contractors to environmental issues enforces the obvious focus of industry, where contractors have to make a profit. Furthermore, all opinions point in the same direction that the contractors have to want to be a recycler to succeed in setting up a salvage business. Popular items of salvage included timber beams, bricks, hardwood timbers, Baltic Pine timber flooring boards and older items that are popular for their antique value. Older timber will not shrink and possesses a lot more character than new, but is harder on tools and must be successfully de-nailed. Used bricks don't shrink and would be ideal for rendered walls, and used carpet underlay can be re-used as weed mats for landscaping. There is thus a fashionable culture operating in materials salvage activity, alongside a more practical "alternative use" approach.

4. MANAGEMENT TECHNOLOGY SUPPORT FOR JIT DEMOLITION

4.1 Mapping demolition management

Similar to the resource requirements for constructing a project, in order to demolish a project a diverse group of people come together, divergent materials or components change their shapes, functions and positions, and specially developed machines act in a large three-dimensional space. Demolition also contains unique management constraints due to strict environmental protection requirements, potential emergent issues, and uncertainty. The management issues during the demolition implementation stage require wider consideration, which may include demolition cost estimation, quality control, resource allocation, site layout, progress monitoring, waste handling, and so on. Figure 4 describes a demolition management map through an jigsaw puzzle. The management approaches not only seek to achieve better cost-efficiency, high productivity and quality, but also optimised environmental performance by means such as waste reuse and recycling.

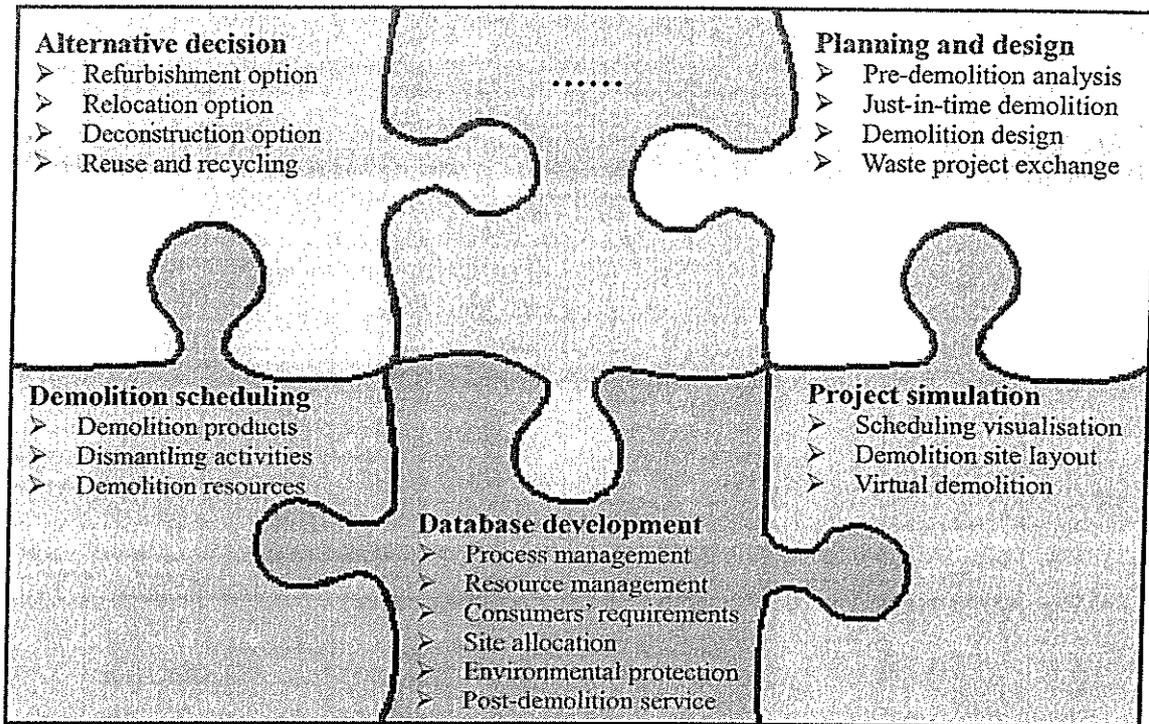


Figure 4. A Map of Building Demolition Management

4.2 Information network platform for JIT demolition

Demolition material exchange, which is fundamental to JIT demolition, is generally the information exchange process between wasted material producers and demanders. The Internet is the ideal platform to perform such information exchange. Web-based information systems can be developed to handle the waste problem from the demolition project (Liu and Pun 2003). The information system deals with waste estimation, waste information exchange, and transportation handling.

The wide understanding and acceptance of JIT demolition will benefit various sides directly and indirectly. The direct benefits accrue to demolition project clients, demolition firms, recycling companies, and second-hand materials/products demanders. Construction is not only the largest industry to consume the natural resources, but also the top contributor to the landfills. Therefore, in addition that JIT demolition may release the landfill pressure drastically. It will also conserve natural resources. Zero emission may be difficult to achieve in construction, but maximum waste utilization derived from a JIT approach will slow the rate of environmental degradation.

4.3 A reversed material supply chain for building demolition projects

While a construction project team needs to buy building materials from suppliers, a demolition project owner needs to market the dismantled building materials to demanders. The flow of building materials in a demolition project can be seen as a special supply chain

(Shakantu 2002). The idea of supply chain, since developed in the manufacturing industry, has a strong relationship with JIT production. It is therefore natural that supply chain management philosophies are involved in JIT building demolition. The building to be demolished is equivalent to raw materials in manufacturing. Accordingly, the dismantled building materials are the final products in the manufacturing process.

While a supply chain in construction is a typical “pull” chain, the chain in a demolition project is actually a “push” chain. The differences between buying and selling materials set some new contents into supply chain management. Moreover, as shown in Figure 5, the information flow of JIT demolition does not exactly match the material flow in reverse.

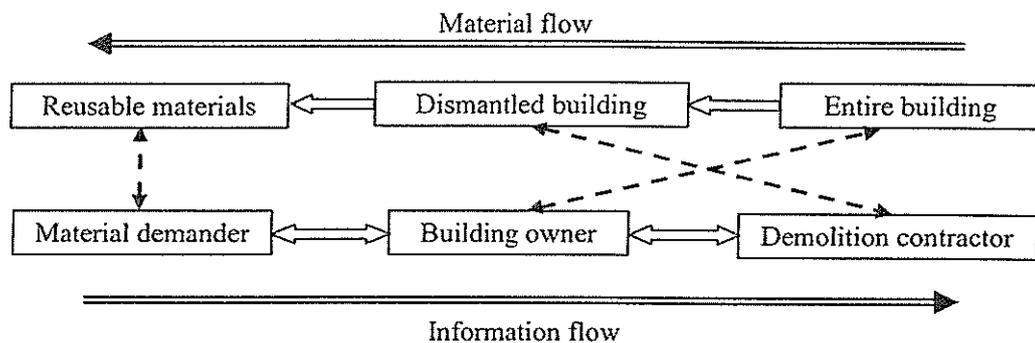


Figure 5. Material flow and information flow in the demolition material chain

The process of a demolition material supply chain starts with information flow. After a decision is made to demolish a building structure, the initial activity for the building owner involves collecting information on demands and material requirements from potential customers. This process can be seen as a virtual waste exchange. After the information collection, the building owner needs to arrange the aggregation into a specification for building demolition that describes types and amounts of waste building material to be produced and must be available to contractors who intend to submit tenders. After individual contractors submit their bids, including the demolition design that attempts to satisfy the demolition specification, the project owner, or consultant, will select a bid that best satisfies the specification. In addition, the transactions of waste materials are also confirmed after consultation and negotiation. Waste material production can also be scheduled from the demolition design and project schedule. At the level of material flow, the building is delivered to the chosen contractor as a whole raw material. The building is then dismantled into waste materials by the chosen contractor.

5. SOCIAL INFRASTRUCTURE DEVELOPMENT FOR JIT DEMOLITION

5.1 Demolition industry and companies

It is apparent that the construction and demolition of a building are opposite functions. Construction and demolition are also interactive. Frequently, the construction of a new

building requests the demolition of an old one on the site. There are also some examples in which the construction of a new structure is closely linked to the demolition of a historical one. However, the demolition industry is just a decentralised and diverse segment of the large and fragmented construction industry (Centre for Studies in Construction 1994). Only in large cities are there a few companies dedicated solely to demolition. One possible reason is that there are only a small number of independent demolition projects. In most cases, building demolition is immediately followed by new construction, and kept as brief and uncomplicated as possible. The importance of demolition is completely underestimated because the materials and energy consumed in constructing a building dominate. In fact, manufactures and supplies of building materials are only intermediate sources for construction, as the original source is nature, despite being largely invisible in the modern construction industry (Birkeland 2002).

5.2 Demolition regulations and legislation

In Australia, several demolition regulations have been documented by government departments and professional authorities such as Standards Australia (2001) and Victorian WorkCover Authority (1998). In the Geelong region of Australia, the demolition work procedure includes a demolition permit granted by a municipal building surveyor. However, compared to the construction regulations, demolition regulations are still rather separated, roughly-outlined and dated. For example, those demolition regulations given above were constituted from the occupational health and safety provisions with little concern on environment protection. There are no standards for demolition contractors. Anyone with a backhoe can bid for a demolition project (Centre for Studies in Construction 1994). Furthermore, environmental considerations need to assume more importance in the process, particularly to the building owner, designer and contractor. Research and development on building demolition have not drawn much interest from project managers or engineers, and no robust demolition code system has been published by any authoritative governments or associations. Some current legal regulations, moreover, do not even promote environmentally-friendly demolition implementation. For instance, in the Victorian landfills in Australia, the difference of disposal costs per tonne between municipal solid waste and construction and demolition waste is only one Australian dollar (Industry Research and Strategy Report 2000). The certification procedure for the quality of used building materials and components has not been well established and widely understood. Therefore, the salvaged materials and products are not easy to be approved and reused in the construction of a new project.

5.3 Demolition economics

The abovementioned small number of demolition companies also implies low economic benefits of demolition projects. Current demolition cost factors retard the boom of the demolition business (Liu et al. 2003). These factors consist of the present low acceptance of recycled and reused components and materials, high labour costs, low tipping fees of demolition waste and so on. The salvaged materials market is currently struggling due to a secure economic climate, where the average home handyman, enterprise manager and urban

developer will source new material from a hardware store rather than even considering second-hand materials. The general consensus is that further education on environmental protection is required to drastically change this behaviour in society. The economics of demolition performance also drives demolition waste disposal decision-making. Any change in hauling costs, tipping fees and virgin material prices may induce the adoption of substitutive demolition and disposal methods.

6. CONCLUSIONS AND RECOMMENDATIONS

In conclusion, building demolition produces large amounts of waste building materials. JIT philosophy, successfully applied in the manufacturing industry, is highly adoptable for demolition project management. In particular, it eliminates stocks of dismantled building materials and speeds up the demolition process. To practically implement JIT into demolition project management, there are foundations that need to be satisfied. There are civil infrastructure, management approaches and social behaviour. Civil infrastructure of JIT demolition includes building demolition techniques and related design issues, and building technologies for material reuse and recycling. Management approaches for JIT demolition concern demolition decision making, reversed supply chain of building materials, and information system application especially waste exchange. Social behaviour for JIT demolition relies on the demolition industry, economics, education and awareness. The achievement of all three foundations is necessary to support JIT demolition. The various aspects that underpin these foundations can be identified as comparing hardware, software and environment.

There are enormous efforts that should be contributed by governing bodies, the construction industry and general practitioners involved. Technically, the construction industry should work on building qualification systems and standards for secondary building materials. Moreover, the industry should pay more attention in developing new techniques of environmentally friendly demolition techniques, and new reuse and recycling applications for waste building materials from demolition projects. These developments virtually enable waste reuse and recycling. At the practitioner level, demolition contractors need to alter their management approaches to exploit the advancement of new technologies. New information technologies such as decision making support and digital communication should be utilised to enable demolition project participants to employ management mechanisms existing in logistics management and supply chain management. Finally at the public level, governments should handle the issue in two ways. First, government should create legislation that imposes compulsory environmental obligations on demolition contractors. Second, government should encourage reuse and recycling by subsidising parties who carry out the activities. The secondary material market should be further developed and regulated by authorities. Education is also necessary to improve the awareness of general public.

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